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JUN 05 2006

STATE OF NEW YORK
DEPARTMENT OF AGRICULTURE AND MARKETS
10B Airline Drive
Albany, New York 12235

Division of Agricultural Protection and Development Services
518-457-7076
Fax. 518-457-2716

June 2, 2006

Daniel Spitzer, Esq.
Hodgson Russ LLP
One M & T Plaza, Suite 2000
Buffalo, New York 14203

Re: Marble River LLC Wind Energy Draft Environmental Impact Statement

Dear Mr. Spitzer:

I have completed a review of the Draft Environmental Impact Statement (DEIS) for the Marble River Wind Energy project in the Towns of Clinton and Ellenburg. The Department is providing the following comments for consideration.

1 1. On pages 19 and 20 the DEIS indicates that the minimum burial depth of the cables will be 36 inches. To prevent interference with agricultural land improvement activities, the Department recommends a minimum burial depth of 48 inches in agricultural areas.

2 2. On pages 19 and 20 of the DEIS discusses the installation of buried cables in agricultural areas and the restoration of the fields following construction. The DEIS does not include any information concerning subsoil decompaction. The discussion of the cable installation should include subsoil decompaction to a depth of 18 inches below the disturbed soil surface in agricultural areas. Where topsoil has been temporarily removed, the subsoil should be decompacted prior to topsoil replacement.

Thank you for consideration of the Department's comments.

Sincerely,

Matthew J. Brower
Agricultural Resource Specialist

cc: Anntonette Alberti, Horizon Wind Energy
Andy Davis, NYS Dept. of Public Service
Jack Nasca, NYS DEC

STATE OF NEW YORK DEPARTMENT OF PUBLIC SERVICE

THREE EMPIRE STATE PLAZA, ALBANY, NY 12223-1350

Internet Address: http://www.dps.state.ny.us

June 5, 2006

Mr. Daniel Spitzer
For Town of Clinton
One M&T Plaza
Suite 2000
Buffalo, New York 14203-2391

Mr. James McNeil, Town Supervisor
Town of Ellenburg
P.O. Box 22
Ellenburg Center, NY 12934

Mr. Michael Filion
Supervisor, Town of Clinton
23 Smith Road
Churubusco, NY 12923

Re: Comments on the Marble River Wind Power Project
Draft Environmental Impact Statement (DEIS)

Dear Messrs Spitzer, Filion, and McNeil:

The Staff of the Department of Public Service (DPS) have reviewed the Marble River Wind Power Project Draft Environmental Impact Statement (DEIS) and offer the attached comments on the DEIS for your Towns to consider as the Lead Agencies reviewing the project in your respective towns.

DPS Staff appreciates the opportunity to provide comments on the DEIS. Specific questions may be directed to Andrew C. Davis at (518) 486-2853.

Sincerely,

Douglas May

Douglas May, Chief
Energy Resources and the Environment

Attachment

NYS Department of Public Service
COMMENTS ON
DRAFT ENVIRONMENTAL IMPACT STATEMENT

MARBLE RIVER WIND POWER PROJECT

Turbine setbacks near NYPA transmission line

Town of Ellenburg Local Law No. 4 of 2005, entitled "WIND ENERGY
FACILITIES" at §16 Setbacks for Wind Energy Conversion Systems requires
Setbacks from electric transmission lines of 1.5 times the maximum facility
1 height. Turbines 67, 70-R, 89-R, and 96-S appear to be approximately 500 feet
from the NYPA transmission line. At potential heights of 400 feet, these
structures appear to not meet the setback requirements of the code. Given the
importance of the New York Power Authority (NYPA) transmission facility as a
component of the bulk transmission system, minimum setbacks should be met in
final project design.

Underground Electrical Collection System

The underground 34.5 kV cables proposed should minimize visual and land use
effects of the project, and simplify vegetation maintenance during facility
2 operations. Additional analysis of impacts and line locations should be required if
the applicant changes the proposal from underground to overhead collection
facilities.

The DEIS indicates that design and construction specifications will be developed
3 based on detailed analysis (page 17). Final design and specifications should be
documented in final construction plans, which should be provided to the towns for
review and approval prior to issuance of building permits and initiation of
construction. Substation and interconnection facility design information should
4 be reviewed and approved by NYPA prior to submittal to the Town.

Historic, Cultural and Archeological Resources

The scope of information to be included in the DEIS (App. B) included historic
structures survey, and identification of potential adverse effects either within the
project area or its visual study area; and discussion of mitigation measures for
5 direct disturbance and visual impact. The DEIS states that this information will
be presented in the Final EIS (FEIS). Thus, the DEIS is not complete in
addressing this potential impact.

DPS Staff has initiated consultation with the Office of Parks, Recreation and
Historic Preservation pursuant to the Parks, Recreation and Historic Preservation
6 Law (PRHPL) §14.09. DPS will not be in a position to address State

Environmental Quality Review Act (SEQRA) findings with regard to this matter until there is complete information and analysis, and determinations of project effect on cultural resources have been made by OPRHP.

Visual Assessment

7 The DEIS should acknowledge the requirements for visual analysis as contained in the Town of Clinton Local Law No. 1 of 2005, §17.B, which appears to require color photographs of each proposed "WECS" turbine site from at least two locations accurately depicting the existing conditions; and any visual screening incorporated into the project that is intended to lessen the wind energy conversion system's visual prominence.

8 Results of shadow flicker analysis should be provided to supplement the DEIS for analysis and identification of mitigation measures appropriate for evaluation in FEIS.

Cumulative Assessment

9 The discussion of cumulative visual impacts succinctly conveys the probable nature of full build-out of the Marble River and Noble Energy facilities proposed in the towns of Clinton and Ellenburg. The assessment does not, however, address the potential visual effects on any historic resources, since there has not been an evaluation of historic resource potential in the combined project areas. Thus, the DEIS warrants supplementation so that these issues are addressed and an analysis of impact, mitigation and offsets can be considered in development of an FEIS and findings.

Alternatives

10 The discussion of alternatives identifies alternative project design and layouts as having been considered, and "[i]n the case of visual impact, removal or relocation of one or two individual turbines from a 109 turbine layout [as] unlikely to result in a significant change in project visibility and visual impact from most locations" (page 179). While this statement is generally applicable, consideration of individual locations, such as potential historic resources, warrants specific attention. For example, the depiction of turbine visibility as simulated at Appendix K, Figure 18, Viewpoint 179, indicates the potentially significant change in landscape setting that a single turbine can represent at a particular location. Thus, the consideration of alternative layouts and individual turbine locations to minimize all adverse impacts must rely on further documentation and evaluation of resource information which has not yet been provided.

11 Consideration of additional overhead collection system circuits instead of underground locations warrants additional evaluation of line clearances,

vegetation maintenance practices and costs over facility life. If significant lengths of overhead lines are proposed, the DEIS should be supplemented to provide:

1. The advantages and disadvantages of maintenance of the overhead system versus the underground placement of the electric collection lines;

2. The thermal limits associated with underground collection lines;

3. A detailed cost estimate and justification for overhead placement versus overhead with all backup material including environmental concerns and specific costs of facility construction and maintenance including vegetation management over the life of the facility; and

4. An environmental analysis of the site-specific impacts on land use, visual ecosystem and cultural impacts of such an overhead placement versus underground.

Alternative substation considerations

Further analysis of substation location alternatives may be pending. Consideration of minimizing the number of interconnections to the NYPA 230 kV
12 transmission facility is likely to include consolidating into one location interconnection facilities for the Clinton and Ellenburg facilities of Marble River Wind project and the Noble projects. Engineering, environmental, visual and cost considerations warrant evaluation in rating and ranking alternative locations.
13 → NYPA should determine the optimal location for adding new facilities to its transmission line.
14 If new transmission facilities must be installed by the wind project developers to access the interconnection location to be determined, then additional information and analysis of line routing impacts must be provided.

Finally, additional consideration of alternatives will be needed upon conclusion of interconnection studies and final agreements with NYPA for the combined Noble
15 Clinton and Ellenburg projects, and in cumulative consideration of the Marble River Wind Project and the Noble Altona Project. The four projects represent nearly 500 megawatts of generating capacity to be added to the NYPA Plattsburg-Willis circuits. The amount of generation added to these circuits will warrant close coordination with NYPA.

New York State Department of Environmental Conservation
Division of Environmental Permits, 4th Floor
625 Broadway, Albany, New York 12233-1750
Phone: (518) 402-9167 • **FAX:** (518) 402-9168
Website: www.dec.state.ny.us

Denise M. Sheehan
Commissioner

June 2, 2006

Wind Project Comments
Town Board
Town of Ellenburg
106 West Hill Road
Ellenburg Center, New York 12934

Re: **State Environmental Quality Review (SEQR)**
Marble River LLC
Town of Ellenburg, Clinton County, New York

Dear Members of the Ellenburg Town Board:

New York State Department of Environmental Conservation (DEC) staff have reviewed the *Draft Environmental Impact Statement (DEIS) for the Marble River Wind Power Project*, March 30, 2006, prepared by ESS Group, Inc, and Environmental Design and Research, P.C. The project sponsor, Marble River LLC, proposes construction of up to 21 Wind Energy Conversion Systems (WECS), with related infrastructure, within the town. This action is part of a larger Marble River proposal to construct up to 95 additional WECS in the neighboring Town of Clinton, for a total of 116 WECS. Separate applications have been filed by Noble Environmental Power to the Towns of Clinton and Ellenburg for construction of up to 122 WECS in the two towns, and to the Town of Altona for construction of 67 WECS. Additionally, a proposal for construction of 10 WECS has been submitted to the Town of Beekmantown Zoning Board of Appeals by Windhorse Power LLC.

DEC concurred with the designation of the Town of Ellenburg Town Board as Lead Agency for coordinated SEQR review on January 11, 2006. The Lead Agency issued a Positive Declaration on January 9, 2006. Formal scoping was not conducted. The DEIS was accepted as complete on April 6, 2006. DEC initially recommended that a single Lead Agency be designated and one environmental impact statement (EIS) be prepared to address potential impacts related to the entire 116-WEC Marble River proposal in the Towns of Ellenburg and Clinton. This approach would have helped to address concerns regarding segmentation of the SEQR process that could occur when applications to each town are considered separately. DEC continues to recommend that the Final EIS (FEIS) for this application include consideration of all proposed wind power projects in the general area. This is important to identify and discuss the cumulative impacts associated with the total proposed build-out by the three project sponsors. Of particular concern to DEC are cumulative impacts associated with wildlife resources, wetlands and water resources, and the visual landscape. The following comments represent DEC's concerns for the Ellenburg proposal specifically and for cumulative impacts on the region from all proposed projects. (5)

Bird and Bat Impacts.

An avian and bat study included in the DEIS indicates that passage rates, mean altitude, and percentage of targets flying below the turbine height at the Marble River site are comparable to the Clinton/Ellenburg/Altona report by Noble Environmental Power, as well as other reports throughout the state. The number and species of bats detected at the Marble River site are also consistent with other reports from the area.

In addition to the pre-construction studies identified above, DEC recommends that the FEIS include a plan for post-construction mortality monitoring to collect data on the estimated mortality rate of birds and bats that pass through and use the project sites. A comparison of the number of estimated collisions with passage rates obtained through radar should be made during peak bird and bat migration periods at the Marble River site. Searcher efficiency and scavenger removal tests should be conducted. The use of Anabat detectors should also be included in the final post-construction study protocol. The plan needs to include an adaptive management strategy that identifies mitigation measures that will be implemented if adverse impacts are identified. The study protocol should be submitted to DEC for review and comment prior to implementation. (4)

Natural Resource Impacts.

Cumulative wetland impacts anticipated to result from all proposed wind power projects in the Towns of Clinton and Ellenburg should be discussed in the FEIS. Discussion of cumulative wetland impacts is important for permitting agencies to characterize the potential magnitude of wetland loss anticipated to result from a total build-out of proposed projects, available options for avoidance, reduction and minimization of wetland impacts, and consideration of activities to mitigate unavoidable wetland loss after projects have been configured to avoid, reduce and minimize wetland impacts to the maximum extent practicable. (5)

Projects that propose to disturb regulated wetland areas require permits from DEC and the U.S. Army Corps of Engineers (USACE). Before DEC can consider a permit request, wetland delineations prepared for the project must be verified by agency staff. Acreage impacts may vary based on DEC verification and jurisdictional determination of the wetland. (6) It is DEC policy that wetland impacts are not permitted, even with mitigation, until other alternatives have been explored, including avoidance, minimize or reduction of impacts. (7) Generally applicants are required to: 1) Examine alternative project designs that avoid and reduce impacts to wetlands; 2) Develop plans to create or improve wetlands or wetland functions to compensate for unavoidable impacts to wetlands; 3) Demonstrate overriding economic and social needs for the project that outweigh the environmental costs of impacts on the wetlands.

. Details to clearly define "temporary" impacts to wetlands need to be provided. Any 8
clearing or grading that disturbs wetland soils can result in permanent impacts to wetlands.
Simple re-grading to pre-construction contours may not be enough to restore the wetland, and
select vegetation may need to be planted, rather than simply allowing the areas to re-vegetate, 9
potentially with invasive species. Construction impacts can also result from improper handling of
concrete, which can negatively impact wetland ecology if not adequately contained within forms, 10
and allowed to run off into wetlands or streams, or if concrete trucks are rinsed in areas where
concrete slurry can affect water resources. Construction methods to properly manage concrete
delivery and use should be discussed in the FEIS.

Mitigation to offset permitted temporary and permanent impacts to wetlands must be 11
developed in consultation with DEC and USACE. Mitigation activities must be conducted
concurrently with other construction activities; not after other construction activities have been
completed. 12

Finally, consideration needs to be made regarding future recurrences of "temporary"
wetland impacts during the de-commissioning process, or during routine maintenance, when 13
large trucks and cranes may again need to access all or portions of the project site, permanent
roads may need to be temporarily widened, or vegetation removed. Subsequent or emergency
permits may need to be obtained to conduct these activities to ensure that wetlands are properly
restored. The Decommissioning Plan should include requirements for environmental permits that 14
may be needed during the decommissioning process.

Visual Impacts.

The Visual Impact Assessment (VIA) in the DEIS indicates that the Gulf State Unique
Area (Flat Rock Gulf), a visually-sensitive resource, is located adjacent to the northeast corner of
the Marble River project area, in the Town of Moores. VIA results describe this area as being 15
within the project viewshed; however there is no analysis of existing and proposed views from
this location. This analysis should be prepared and included in the FEIS. The VIA does consider
cumulative visual impacts of the Marble River and Noble Environmental Power projects in
Clinton and Ellenburg. The FEIS should also include additional visual assessment of the
cumulative impacts from all proposed wind project proposals in the Towns of Clinton, 16
Ellenburg, Altona and Beekmantown. This is particularly relevant to potential cumulative visual
impacts from sensitive receptors within the Adirondack Park, including the viewpoint from Lyon
Mountain, which has an unobstructed view to all proposed wind project sites in Clinton County.

The DEIS recognizes that the proposed action will be visible from numerous locations
within the study area, particularly in higher elevation and open agricultural areas. The DEIS
states that results of the VIA do not suggest that visual offsets are warranted as a mitigation 17
strategy, as no "significant adverse visual impacts" have been identified. DEC recommends that
the determination of "significant adverse impact" be made by re-visited following review of a
revised visual assessment as recommended above, including consideration of the Gulf State
Unique Area and cumulative assessment of impacts from the Lyon Mountain viewshed. Based
on these results, visual offsets as mitigation according to the DEC visual policy may be
warranted (*Assessing and Mitigating Visual Impacts*, DEP-00-2).

Cultural and Archeological Resources.

If any state agency approvals or permits are needed for this project, compliance with the New York State Historic Preservation Act of 1980, Section 14.09, will be necessary. In addition, should federal agency approval or permitting be needed, compliance with Section 106 of the National Historic Preservation Act will be required. The FEIS should identify the extent of any state or federal agency involvement and discuss the status and results of any historic preservation studies undertaken. (18)

Construction Monitoring.

DEC recommends that an environmental consultant be retained to monitor construction activities to ensure that contractors are aware of and conduct mitigation activities identified in the FEIS. (19) The FEIS should include plans for mitigation of potential environmental impacts during construction, including those associated with wetland and stream disturbance, vegetation removal, stormwater management and erosion control, and agricultural impacts. (20) The scope of work for the environmental construction monitor should include coordination of environmental monitoring activities, documentation of implementation of mitigation activities as they are conducted, and preparation of a final report available to involved and interested agencies.

In conclusion, DEC appreciates the opportunity to comment on the DEIS for this project. We look forward to continuing to work with the Town of Ellenburg throughout the remainder of the SEQR and permit review processes. If you have any questions or comments, please contact me at (518) 486-9955.

Sincerely,

Stephen Tomasik
Project Manager

cc: P. Doyle, Horizon Wind Energy
D. Spitzer, Hodgson Russ
D. May, NYSDPS
A. Davis, NYSDPS
J. Saintcross, NYSERDA
T. Hall, DEC Region 5
D. Wagner, DEC Region 5
R. Holevinski, DEC Region 5
L. Garofalini, OPRHP
Cynthia Blakemore, OPRHP
T. Sullivan, USFWS
K. Bruce, USACE

(9)

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Denise M. Sheehan
Commissioner

Comments same as Ellenburg Letter

June 2, 2006

Mr. Michael Filion, Supervisor
Town of Clinton
Town Hall
Churubusco, New York 12923

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Town of Clinton, Clinton County, New York

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In conclusion, DEC appreciates the opportunity to comment on the DEIS for this project. We look forward to continuing to work with the Town of Clinton throughout the remainder of the SEQR and permit review processes. If you have any questions or comments, please contact me at (518) 486-9955.

Sincerely,

Stephen Tomasik
Project Manager

cc: P. Doyle, Horizon Wind Energy
D. Spitzer, Hodgson Russ
D. May, NYSDPS
A. Davis, NYSDPS
J. Saintcross, NYSERDA
T. Hall, DEC Region 5
D. Wagner, DEC Region 5
R. Hoievinski, DEC Region 5
L. Garofalini, OPRHP
Cynthia Blakemore, OPRHP
T. Sullivan, USFWS
K. Bruce, USACE

ELLENBURG Public Hearing on NOBLE & MARBLE RIVER D.E.I.S.

(5)

SIGN IN SHEET

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[illegible]	Ellenburg [illegible]	594-3259	[signature]
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Anna Giannelli	140 Claremont Ave NYC 10027	860-395-9158	[signature]
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Donna Scott	PO Box 161 Ellenburg Depot NY	594-3961	[signature]
Bill Scott	"	"	William [illegible] Scott
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[illegible] McNeil	[illegible] Brandy Brook Rd Ellenburg Ctr NY 12934	594-7632	[signature]

ELLENBURG Public Hearing on NOBLE & MARBLE RIVER D.E.I.S.

SIGN IN SHEET

Printed NAME	ADDRESS	Phone	Signature
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Bob Heymore	614 Stone Hill Rd Merrill NY 12955	425-2314	[signature]
[illegible]	108 [illegible] St Plattsburgh NY	561-7824	
John Day	111 Youngs Rd Merrill	425-0135	John Day
[illegible]	7738 Star Rd Ellenburg Ctr NY	594-3259	[signature]
[illegible]	7837 [illegible] Rd. Ellenburg Ctr NY	594-3227	[signature]
[illegible]	8 Kathleen Avenue Essex CT 06426	860 5[illegible] 3957	[signature]
Charles Tarbuski	3 Columbia Place Albany NY 12207	301 0011	[signature]
John Heckl[illegible]	7823 Kellogg St. Clinton NY 13323	315 471-0688	[signature]
[illegible]	3 Columbia Place Albany NY 12207	201-[illegible]-9447	[signature]
Kathleen Pearson	2-3 [illegible] Road Merrill NY 12955	425-0304	[signature]
Rob Baker	582 Spear Hill Rd.	425-3368	Robert Baker
Dennis Semple	7681 Star Rd Ellenburg Ctr. NY 12934	594-3[illegible]	Dennis Semple
[illegible] Selkirk	PO Box 402 Chateaugay NY 12920	497-6038	[signature]
Todd R. Hopper	Marble River Wind Farm	594-7424	[signature]
[illegible]	" "	594-7424	[signature]
[illegible] Coleman	" " "	23-520-1015	[signature]
[illegible]	" " "	594 7425	[signature]
Cindy LaClair	251 [illegible] Churubusco	497-6875	Cindy LaClair
[illegible]	540 Pelkowski Rd Churubusco	497-3272	[signature]
[illegible]	21 [illegible] Farms Rd Killingworth CT	860-575-[illegible]	[signature]
[illegible]	Box 4 E [illegible]	425-3332	[signature]

ELLENBURG PUBLIC HEARING ON NOBLE & MARBLE RIVER D.E.I.S.

SIGN IN SHEET

Printed NAME	ADDRESS	Phone	Signature
[illegible]	[illegible] CT	[illegible]	[signature]
[illegible]	2 BRODERICK RD. Platts NY	562-2011	[signature]
[illegible]	Ellenburg Depot N.Y.	594-2318	[signature]
[illegible]	Ellenburg Ctr NY	594-3255	[signature]
William [illegible] Trombley	Ellenburg Ctr NY	594-7392	[signature]
[illegible]	7507 [illegible] Rd Ellenburg Ctr NY	594-3437	[signature]
[illegible]	Noble Environmental Power	[illegible]	[signature]
[illegible]	5540 [illegible] Rte Altona NY	518 493 5161	[signature]
[illegible]	7777 Rte [illegible] Ellenburg Ctr NY	518 594 3078	[signature]
[illegible]	[illegible]		[signature]
Rick [illegible]	166 [illegible] Trumbull CT	203 452 [illegible]	[signature]
[illegible]	77 [illegible] Rd [illegible]	425-0359	[signature]
[illegible]	6 Spruce Way Chateaugay NY	425-[illegible]	[signature]
[illegible]	276 Duley Rd [illegible] N.Y.	493-4785	[signature]
Dan Boyd	5125 St Rt 374 Merrill NY	425-6163	[signature]
[illegible]	[illegible] Rd Ellenburg [illegible] NY	594-[illegible]	[signature]
[illegible] Trombley	[illegible] Road Plattsburgh NY	594-3324	[signature]
[illegible]	PO Box 128 [illegible]	425-9943	[signature]
[illegible]	[illegible]		
Joe Kramer JOSEPH [illegible] KRAMER	232 SPEAR HILL MERRILL, N.Y.	425-6144	[signature]
[illegible]	7791 [illegible] Ellenburg Ctr NY 12934	594-3171	[signature]

ELLENBURG Public Hearing ON NOBLE & MARBLE RIVER D.E.I.S.

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Printed NAME	ADDRESS	Phone	Signature
[illegible]	[illegible] Ellenburg Ctr Rd. Ellenburg Ctr, NY	594-[illegible]	[illegible]
June Nichols	327 Gagnier Rd Churubusco NY	497-6040	June Nichols
Allan [illegible]	[illegible] Star Road Ellenburg Ctr, NY	594-7615	[illegible]
[illegible]	7811 Star Rd Ellenburg Ctr. NY.	594-3445	[illegible]
Nate Sandwig	345 [illegible] Malone NY 12953	483-3712	[illegible]
Kathleen Kanzelith	94 R[illegible] [illegible] NY	425-3509	
[illegible]	25 [illegible] Rd Ellenburg Ctr NY	594-[illegible]	[illegible]
[illegible]	[illegible] Ellenburg Ctr NY	594-[illegible]	[illegible]
[illegible] Hartley	[illegible] West Hill Rd [illegible]	594-3285	[illegible]

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Printed NAME	ADDRESS	Phone	Signature
Michael [illegible]	193 Salmon River RD. Plattsburgh, NY	563-2325	[illegible]
[illegible]	32 [illegible] Ellenburg Ct.	594-2533	[illegible]
[illegible]	At Home	493-4804	[illegible]
[illegible]	At Home	493-4801	[illegible]
[illegible]	7741 State Road Ellenburg Ct.	594-3277	[illegible]

ELLENBURG PUBLIC HEARING ON NOBLE + MARBLE [illegible] (6)

MAY 24, 2006

SPEAKERS SIGN IN SHEET

	Printed NAME	ADDRESS	Phone	Signature
1	[illegible]	[illegible]	497-6638	[illegible]
2	[illegible]	Box 902 Chateaugay NY 12920	435-[illegible]	[illegible]
3	[illegible]	6 Spruce Way Chateaugay NY	860-535-2477	[illegible]
4	[illegible]	21 Overlook Farms Killingworth CT	594-7517	Donald [illegible]
5	[illegible]	7326 State Rd Ellenburg NY 12934	483-4557	[illegible]
6	[illegible]	573 Cty Rt 12 N Bangor NY 12966	[illegible]	[illegible]
7	[illegible]	7851 [illegible] Rt [illegible]	497-3507	[illegible]
8	NORBERT [illegible]	94 [illegible] Ave Chateaugay NY [illegible]		
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ELLENBURG PUBLIC HEARING ON NOBLE [illegible]

MAY 24, 2006

SPEAKERS SIGN IN SHEET

PRINTED NAME	ADDRESS	Phone	Signature
Harry Felion	540 Patnode Rd Churubusco	497-3372	[illegible]
Glenn Fountain	12 Bushey Blvd Platt NY 12901	5612658	[illegible]
Darrell LaBare	Ellenburg Ctr. [illegible]	594-3254	[illegible]

ELLENBURG PUBLIC HEARING ON NOBLE + MARBLE [illegible]

MAY 24, 2006

SPEAKERS SIGN IN SHEET

Printed NAME	ADDRESS	Phone	Signature
JOSEPH KRAMER	273 SPEAR HILL RD MERRILL, N.Y.	425 6144	Jo Kramer

[illegible]

MAY 24, 2006

SPEAKERS SIGN IN SHEET

Printed NAME	ADDRESS	Phone	Signature
[illegible]			

Clinton County Farm Bureau
PO Box 42
Chazy NY 12921-0042

Kevin Hollister, President

At its regular meeting on May 11, 2006 the Clinton County Farm Bureau Board of Directors passed a resolution concerning the establishment of commercial wind power projects.
The resolution reads: *Be it resolved that the Clinton County Farm Bureau fully supports the establishment of commercial wind turbines on our member's farms.*
This resolution is intended to support those farmers who wish to participate in the projects being proposed for their property.
This is in keeping with the policies of New York Farm Bureau and American Farm Bureau Federation which support and encourage the establishment of renewable energy sources, including wind, solar and bio-fuels.

Kirby Selkirk
Field Advisor
New York Farm Bureau
POB 902
Chateaugay NY
518-497-2628
nykselkirk@fb.org

Policies of New York Farm Bureau regarding the siting of energy facilities on agricultural land

We encourage the development of more energy from wind and solar power sources.

We recommend companies with rights-of-ways on farmland identify the location of their underground transmission lines and/ or pipelines.

When siting utility right-of-ways, adverse agricultural effects on all farms should be minimized by:

a. Judicious routing to help avoid construction and operation through farmsteads, croplands, orchards, and sugarbush operations;

b. Utilization of state-of-the-art mitigation practices and full rehabilitation of all agriculture-related lands which are not otherwise avoided;

c. Utilization of qualified agricultural specialists to maintain on-going field contact with all affected farmers and other organizations from project design stage through final land rehabilitation;

(NYSDAM has qualified personnel whose job it is to do this work and their involvement should be included in local regulations governing the construction of any such projects)

d. Ensuring just compensation for right-of-way easements and damages; and

e. Consideration of all other viable routing options with preference being given to the use of previous utility right of ways and highway medians.

Productive farmland or aquaculture/fishing grounds should not be taken by eminent domain for the construction of a power generation plant nor should this plant's location negatively impact neighboring productive farmland or aquaculture/fishing grounds.

Public utilities should be required to investigate all complaints of stray voltage on farms within five (5) working days. The utility should be required to isolate or place a blocker on grounded lines if it is found that the utility system is imposing a voltage onto the customer system at a level at or above known levels of concern.

We support an amendment to the current Dig Safe New York Law 16NYCRR, Part 753 to read: "All utilities will be buried a minimum of (48") forty-eight inches deep and that Dig Safe NY will verify this with a letter to each agricultural property owner who has utilities crossing their property, and that it will relieve any responsibility from the owner if the utilities are disturbed".

We recommend that priority should be given to projects promoting naturally renewable sources of energy. Assistance from government (such as NYSERDA) for such projects should be prioritized. Local governments should receive incentives from the state and federal government for promoting such projects locally.

We support property tax exemptions for those farms that have solar or wind energy systems or farm waste energy systems.

All aspects of agriculture should equally be eligible to participate in government programs meant to protect the environment and/or conserve energy.

Wind towers should be allowed on private property.

Town of Ellenburg DEIS hearing regarding Noble Environmental Power's request for permit to erect a wind farm project.

Good evening my name is Kirby Selkirk. I'm a Field Advisor for New York Bureau and I'm here on behalf of Clinton County Farm Bureau.

At its regular meeting on May 11, 2006 the Clinton County Farm Bureau Board of Directors passed a resolution concerning the establishment of commercial wind power projects.
The resolution reads: *Be it resolved that the Clinton County Farm Bureau fully supports the establishment of commercial wind turbines on our member's farms.*
This resolution is intended to support those farmers who wish to participate in the projects being proposed for their property.
This is in keeping with the policies of New York Farm Bureau and American Farm Bureau Federation which support and encourage the establishment of renewable energy sources, including wind, solar and bio-fuels. I've included a copy of their statement for you.

Environmentally, the turbines are great for farmers - you can crop or pasture right up to the turbine and the development company takes great care in restoring the farmland impacted by construction. At the end, there is only a road that leads to the turbine.

This project and others could provide 6% of our nation's electricity, or about the same as hydropower, by 2020. A New York study found that if wind energy supplied 10% (3,300 MW) of the state's peak electricity demand, 65% of the energy it displaced would come from natural gas, 15% from coal, 10% from oil, and 10% from electricity imports. As many as 215,000 new jobs would be created by adding 50,000 MW of new wind installations in the U.S. - a $50 billion investment that could provide electricity for as many as 15 million homes with 39 million people.

Last year wind energy generated over 17 billion kilowatt-hours in the U.S., enough electricity to power 1.6 million homes. A single wind turbine can provide $4,000 - $7,000 each year in farm income and only use 2-5 percent of the land for the turbine and access road. Each megawatt (MW) of wind energy capacity installed in the U.S. provides 2.5-3 job-years of employment. In 2006, U.S. wind farms will be saving over 0.5 billion cubic feet of natural gas per day. To generate the same amount of electricity as a single 1-megawatt (MW) wind turbine, a traditional fossil fuel or nuclear power plant requires, on average, withdrawing about 60 million gallons of water per year from a stream or river. To generate the same amount of electricity as today's U.S. wind turbine fleet (6,740 MW) would require burning 9 million tons of coal (a line of 10-ton trucks 3,437 miles long, from Seattle to Miami) or 28 million barrels of oil each year.

I have prepared a list of the New York Farm Bureau policies pertaining to the situating and construction of energy facilities. These address our concerns of protecting the farmland. I will cite only one.

When siting utility right-of-ways, adverse agricultural effects on
all farms should be minimized by:
a. Judicious routing to help avoid construction and operation
through farmsteads, croplands, orchards, and sugarbush

operations:
b. Utilization of state-of-the-art mitigation practices and full rehabilitation of all agriculture-related lands which are not otherwise avoided:
c. Utilization of qualified agricultural specialists to maintain on-going field contact with all affected farmers and other organizations from project design stage through final land rehabilitation:
(NYSDAM has qualified personnel whose job it is to do this work and their involvement should be included in local regulations governing the construction of any such projects)
d. Ensuring just compensation for right-of-way easements and damages: and
e. Consideration of all other viable routing options with preference being given to the use of previous utility right of ways and highway medians.

I will submit written copies of this our policies and the resolution from Clinton County Farm Bureau

Kirby Selkirk
Field Advisor
New York Farm Bureau
POB 902
Chateaugay NY 12920
518-497-2628

May 15, 2006

Dear School Board Members:

My name is Glenn Fountain and I currently reside in Plattsburgh. My wife Faye and I highly support the proposed Marble River Wind Farm. We are land owners in Churubusco having 430 acres, and our intentions are to be a residents upon my retirement which is 18 months from now. We believe that taking advantage of future resources for the community would be beneficial all around. Creating jobs, royalties, tax payments, etc. in our community of Churubusco, would be a big step in the right direction. With the price of fuels, rising every day WIND as an alternative power source is the way the people of the United States must go. We are too dependent on foreign countries for our fuel resource. Respectfully with all the hard work and time the board has put forth, I hope you make the right decision and go ahead with the Wind Farm project. This would also benefit our children and grandchildren with future energy and pollution problems.

Sincerely, Glenn Fountain Sr.

Faye Fountain

Glenn Fountain Sr.

Faye Fountain

15 May 06

(1)

Supervisor Jim McNeil,

Dear Jim,

We strongly support the windfarm projects proposed for Ellenburg.

I have observed wind generating in Canada, foreign countries and other places in New York. My observation lead me to conclude that the noise level is not objectional, bird kill is almost non existent and the view is no more objectional than the high electric wires and other man made objects.

I hope the Town Board will consider the economic benefits of this project.

Sincerely

[illegible]

[illegible]

Dr. Anthony C. Cassani
OPTOMETRIST

16 EAST STREET
BARRE, VERMONT 05641
TELEPHONE 476-8937

MAIN STREET
BRADFORD, VERMONT 05033
TELEPHONE 222-4543

5/14/06

Dear Jim:

I enjoyed talking to you the other morning at Filion's Restaurant. I just wanted to say that I am in favor of the Wind Program in Ellenburg. I have 80 acres on the Plank Road and am a taxpayer in town.

I believe this project would be a tremendous boost to the community and might help us all with tax department.

We are fortunate to have such a clean + abundant commodity – Wind.

Sincerely

Dutch Cassani OD

'Whoosh' spells uneasy progress

Many say wind power is good for environment, economy; others say turbines are noisy, nuisance

Misty Edgecomb
Staff writer

(December 4, 2005) — Richard Foringer gives an ironic little laugh when he talks about being accused of "NIMBYism" — shorthand for "not in my back yard," or a selfish aversion to development.

Sitting at his kitchen table in Cazenovia, Madison County, he glances out the window to watch a 326-foot-high wind turbine's blades spin through the season's first snow. The behemoth, though not literally in Foringer's back yard, looms over his deck, just 1,000 feet from his house, on a neighbor's property. A slow, droning swish-thump is just barely audible through the walls and windows.

"You hear the whipping when a blade arcs. Sometimes it's like an engine running. You hear the gears creaking ... it's terrible," Foringer said.

"I'd sell the house immediately, but I don't think I could sell it now," he said. "As far as I'm concerned, they took away everything I had here ... it's all gone now."

Foringer's story is what many residents in rural western New York fear when they hear that a wind developer is targeting their town.

Many small towns lack zoning laws, and those that have them rarely mention such technologies as industrial-scale wind turbines — which are still uncommon in the United States, though older developments pepper the hillsides of western Europe.

The state is encouraging wind power for its environmental benefits, as today's best hope for affordable, renewable power. But, citing a long tradition of "home rule," it is leaving the details wholly up to local leaders.

Dozens of communities have been approached by developers, and many, overwhelmed at facing an industry relatively new in the state, have imposed moratoriums — only spurring developers to cross the town line and try again.

"The state created this monster, but they're not willing to do anything to control it," said Donna Farrington of Rochester, who expects that turbines will be built near the cabin she and her husband, Todd Sharrow, own in Prattsburgh, Steuben County.

"We're totally exposed," Farrington said.

Few regulatory hurdles

Like the gold, silver and land rushes of centuries past, wind power today has wide-open potential — and relatively few regulatory hurdles. The excitement among supporters is palpable: Finally, the promise of a future divorced from petroleum is being realized. As the cost of gas and oil has risen in recent years, wind is becoming more competitive, with prices that have dropped below those of natural gas, said Paul DeCotis of NYSERDA, the New York State Energy Research and Development Authority.

Much of the benefit is due to subsidies, created in hopes of reducing dependence on foreign oil and cutting air pollution here at home. A federal tax credit for new wind developments completed by the end of 2008 can reduce costs for a new project by nearly a third. In New York, a state program that collects a fee from electric customers and distributes the funds to boost renewable energy has provided more than $11.3 million for new wind projects, according to NYSERDA.

The energy standard championed by Gov. George Pataki adds another level of urgency -- the state must increase its production of renewable energy to 25 percent by 2013.

Supporters praise the state for its leadership, citing the growing concern over climate change and Albany's pledge to reduce greenhouse gas emissions in coming decades.

But if New York is to meet its goals, wind energy is key. New York currently gets just more than 19 percent of its energy from renewable sources — mostly hydroelectricity -- and less than 1 percent from wind. Meeting the 25 percent standard will mean adding 3,000 megawatts, or about 2,000 turbines, of wind generation over the next eight years. About 5,200 megawatts of new capacity already has been proposed, according to NYSERDA.

If just 3,000 megawatts of wind power replaces dirtier sources of electricity, that could keep 8.2 million pounds of carbon dioxide, the most prevalent greenhouse gas, out of the atmosphere, said Larisa Washburn of the Environmental Advocates of New York.

New York ranks 15th in the nation in terms of wind energy potential, based on both wind speed and open space. About 10,000 megawatts could be harvested — half on land and the other half offshore, in the Atlantic Ocean and the Great Lakes, says the American Wind Energy Association, the national trade association of the wind power industry.

Other approaches, such as solar power and hydrogen fuel cells, have potential, too, but the technology just isn't there yet. Wind is something we can do now, said Christine Vanderlan of Environmental Advocates of New York.

Critics, however, blame state leaders for creating an artificial rush that encourages developers to cut corners.

"Basically we have a governor saying, 'Let's do this,' and that has created almost a frenzylike push by companies and investors who want to get into this business for profit," said Tom Golisano, founder of Paychex Inc., who has dedicated some of his substantial personal resources to Save Upstate New York, a campaign against wind development.

"The green in this isn't green energy, it's money," said Sharrow.

None of the critics interviewed for this article said they opposed wind energy in theory. But turbines that are nearly as tall as Xerox Tower, the highest point on Rochester's skyline, don't belong in residential neighborhoods, they say.

"Most people have this vision of a little wooden windmill," Golisano said. "When they find out they're the size of a 20-story building, it's a whole different ball game."

Small town feels blow

Sixty miles southeast of Rochester, residents of Prattsburgh are living the wind debate every day. The dirt roads that meander over rolling hills are dotted with signs that identify residents not as Republican or Democrat but as pro- or anti-wind.

"It has been a battleground down there," said John Saint Cross of NYSERDA. "By nature a turbine can't be hidden. People want their power, but they don't want to see power plants."

Two companies, Ecogen and WindFarm Prattsburgh, have proposed a combined 120 turbines in this small town and its nearby neighbor, Italy. Many residents would see multiple turbines out their windows, and several believe that the towers, taller than the Statue of Liberty, could stand just 1,000 feet from their homes.

"They're plopping them in between people's houses," Sharrow said.

It makes for controversial projects, but that's the geographic reality of wind development in New York, explained Bruce Bailey, president of AWS Truewind, an Albany consulting firm.

Less than 1 percent of New York's land is suitable for wind turbines -- that is, offering average wind speeds exceeding 15 mph, open space for the turbines and nearby electricity transmission lines. Most of that is along the high ridges of the Finger Lakes region, the same areas in high demand for summer cottages and retirement homes.

"What's going to happen when all the out-of-town people sell at a loss and leave?" said Ruthe Matilsky of Rochester, who has a summer home in Prattsburgh. She said a majority of the town taxes are paid by part-time residents.

Bruce Taylor, on the other hand, has volunteered to lease land for as many as five turbines on his Prattsburgh farm, all within view of the bed-and-breakfast that provides much of his income.

"It's like telephone poles," said Taylor, who has visited wind farms at Fenner, Madison County, and Wethersfield, Wyoming

County. "Your mind kind of blocks out the turbines and you see the beauty of the land."

The good, the bad

Indeed, wind turbines are very much in the eye, or ear, of the beholder.

In Fenner, Donna Griffin pastures her cows near the turbines, watches them out her front window and sells T-shirts to the tourists who have inundated this small farm town. The noise that has annoyed Richard Foringer so much that he hopes to sell his house doesn't faze Griffin. "If you have a car going by or a flock flying over ... it drowns it out," she said.

But Wayne Danley, who lives across the ridge in Cazenovia, is considering legal action over a turbine so close to his home that it wakes him up at night.

"There's a flickering effect when the sun goes down. It's like you're out on the dance floor at a club," Danley said, describing the result of the sun shining through the blades at dawn and dusk that is known as "shadow flicker."

In Prattsburgh, supporters of the wind farms say that problems are greatly exaggerated and predict a $15 million windfall in new jobs, payments in lieu of taxes and a fund to help subsidize heat for low-income residents.

"I would say that 95 percent of the community is supportive," said Kim Lambertz, who has lived in the town for 11 years and now works for WindFarm Prattsburgh. "When Tom Golisano came down to tell the people of Prattsburgh what's best for them, that galvanized a lot of people" in support of wind farms.

Those who lease land for turbines can count on thousands of dollars in annual income. Many see the developers as saviors for a farm community that can't attract big industry.

"The wind farm brings money into the community that doesn't come out of our pockets," Taylor said.

But without statewide standards for wind farms, many residents fear the worst, Golisano says — corporations running roughshod over homeowners while local leaders, pacified by donations that are small change to wind developers, look the other way.

Golisano says Save Upstate New York is only getting started. And he predicts that lawsuits are inevitable.

Cynthia Cole of Prattsburgh agrees. The financial gains don't balance out what would be lost, she said.

"What are we going to get — a couple lawn-mowing jobs?" Cole said. "I want to look out my window and see God-made hilltops. ... I don't want this man-made technology looming over the hill."

MEDGECOM@DemocratandChronicle.com

HEATHER CHARLES staff photographer
Two wind turbines pierce the skyline in Fenner, Madison County. Some call them good neighbors, others are less charitable.

What's at stake
For environmentalists, reduced air pollution and less reliance on foreign oil.

For residents who live near wind farms, potential loss of property value and quality of life.

For residents who lease land for wind farms, increase in annual income.

For towns that host wind farms, improved finances from new jobs and payments in lieu of taxes.

Background
How important is wind power? One megawatt of wind power can power 340 homes. Used in place of coal or oil to generate electricity, that single megawatt prevents the release of 2.7 million pounds of carbon dioxide, the most common greenhouse gas; 3,672 pounds of nitrogen oxide, which contributes to smog; and 9,918 pounds of sulfur dioxide, which leads to acid rain. The two wind farms proposed for Prattsburgh, Steuben County, with a total of 120 turbines, would generate 180 megawatts of power, enough to power more than 61,000 homes in New York state.

Sources: American Wind Energy Association, Environmental Advocates of New York, Ecogen. Click on this story to hear more opinions in the debate. On Page 16A

A graphic shows areas where wind turbines are being proposed, and just how big they really are.

Stories examine impact of turbines on communities and the environment.

prin

14

Our Fenner Wind Farm Story

Pamela Foringer

Fenner, NY

Autumn 2004

(reprinted with permission)

It was almost 25 years ago that we built the home we hoped to retire in. While looking for land to build on, we searched high and low for a piece of property we could afford. We looked at the 3-acre parcel, that seemed so desolate, a number of times. We drove by in the early spring, trying to picture what it would be like atop this barren hillside in the cold, snowy months of a "Fenner winter." The one thing we did know was that in the summer months there was a magnificent view to the west, and the sunsets were incredible. We wanted the peace and quiet of the country, and this seemed like our best bet. So, in April 1981, we started to clear the property and construction began on our new home.

During the first couple of years we planted over 1500 pines in the 2 acres behind our house. We hoped to be able to cut our own Christmas tree in a few years. Eventually we'd have our own little animal sanctuary where deer could have shelter and the birds my husband loves would flourish.

Over the years Mother Nature has had a hand in changing the landscape. Trees have grown and trees have fallen due to several ice storms. We have quite a lovely little forest out back now. The pines have grown to somewhere between 20 and 30 feet - but they are dwarfed by the giant wind turbines that now dominate the landscape no matter what direction we look.

Never in a million years did we expect to be surrounded by these towers that passersby find so mesmerizing in their short 10 or 15-minute visits.

It must have been about 5 years ago that we noticed the construction of a test tower directly to our south, in the farm field next to our house. Soon rumors of the "wind farm" began to swirl. Eventually town meetings started to take place and more information was forthcoming. We were never given a chance to vote on whether this project would actually become a reality. The other residents of the town of Fenner seemed rather excited; they felt this was the best thing to happen to our township in years. My husband and I were concerned about the alteration of the landscape and what effect this project would have on us personally. There were a few other families that, like us, would be surrounded by towers, and they were also concerned.

The developer met with a group of 5 families a number of times to explain the plans and reassure us that there would be very little change to the landscape. We were told they would only remove trees where absolutely necessary, and all the cables and wiring would be underground. He reiterated that noise would not be a problem. The placement of the towers was explained to us and he even sent us computer renderings of what they would look like from our homes.

We worried about our property values and how this would affect our appraisals. My husband and I never really considered selling our home because of the project; we have too much time invested to just pull up stakes and leave. We were told the developer would extend a contract to us that would protect our property values for a period of 3 years from the time the project became operational. Basically, if we decided to sell and were forced to sell at a lower price due to the impact of the wind farm, the developer would pay us the difference. We received paperwork and sent it off to our lawyer to verify that it was an appropriate means of protecting our property values. He explained that it looked fine; there was certainly no harm in signing but it really did nothing for us unless we decided to sell and unless we indeed sold at a lower price.

Although my husband and I were not planning to sell we signed the contract and waited for the developer to stop by and pick up the copies, as he said he would. Days passed and it seemed like he had dropped off the face of the earth. We were told he was off to work on a new project. I e-mailed him to let him know the copies were ready. We later found out that the developer had sold the entire project to another company. We still have the signed papers in an envelope but the time period has since passed. I don't know if any of the other families have benefited from their contracts or not. One family has sold and moved away. We have had no contact with the other families; I have been told that one of the other families is in arbitration.

As the project began we knew we had been deceived. The number of workers and amount of construction equipment was staggering. We saw many hedgerows disappear as they cleared the way for access roads. That summer the dust covered every surface in my home. The crane used to lift the turbine as it is was placed on the tower is something to see, and of course people flocked to the site to watch the progress. Every time the crane had to be moved it was a major undertaking, as it didn't even fit on the roads. The huge tracks it made as it moved slowly across the farm fields like a giant snail could be seen throughout that summer. Caravans of trucks came loaded with 100-ft rotor blades. It was a very hectic time as these workers went about their daily duties and the towers inched their way toward the sky. In the autumn of 2001 the project went online and most of the workers moved on to their next job.

As I sit in my kitchen and type this on my computer, I hear the constant hum of the blades. It's early November, a brisk day and of course the windows are closed, so that muffles the sound a little. In the summer, with the windows open, there is nothing to block out the humming or the grinding sound that the turbine makes when it is being turned. For those who haven't seen a wind tower up close, they are about the height of a 30-story building and the unit on top is the size of a small travel trailer. Because the wind constantly changes direction the blades have to be turned to catch the wind. Imagine turning a 24-ton object perched on top of a 200 ft tower. That takes a bit of force and at times the sounds emitted are rather eerie. Depending on the weather, it can sound like a grinding noise or at times the shrieking sound of a wild animal. In the winter the noise always seems much louder, perhaps because of the starkness of the season and lack of foliage to muffle the noise. Anyway, when people tell you that the wind towers are virtually noiseless, they haven't lived a couple of football fields away from one 24/7.

It has been 3 years now and I must say I will never get used to the view that greets me every time I drive home. On sunny days the towers are a bright white—a huge contrast to the beautiful blue sky. When it is gray and rainy they take on a gray color that almost, I repeat, almost, makes them disappear into the gloom of the day. In the heavy fog that frequently blankets our road they are virtually invisible; not even the red blinking lights can be seen. Regardless of whether you see them or not, you still hear them—even when they are not operating. When the brakes stop the rotors (because it's too windy), you hear a clunking and grinding that sounds like freight train cars colliding. And when it's time to start them again, you can at times liken it to the roar of a jet engine.

We have some absolutely gorgeous sunrises and sunsets in Fenner. As the sun slowly rises to the east of our house it usually bathes our bedroom wall with its rays. Unfortunately, we now get a strobe effect that can drive you absolutely crazy. It's commonly called the "flicker factor." As the sun shines through the rotors it creates a shadow pattern that you would liken to a strobe light. Because of the close proximity of 4 of the towers to our house, we get this light show at various times of the day, as the sun travels from east to west. Most of the time I have to close our shades to prevent this from giving me a migraine.

And speaking of light shows, we get the nighttime show as well. Each tower has red blinking lights on top of the turbine, so unless the shades are closed in the bedroom at night there is a constant red light blinking in perfect view as we lie in bed. We have always enjoyed watching the night sky, but now, as we drive toward our road, what one immediately notices is a huge cluster of blinking red lights.

In the past we would see thousands of Canada geese as they made their way to the local swampland for a well-needed rest during their long journey each fall. The snow geese, whose migration pattern brought them directly over us, have since found a more convenient route—at least I haven't seen them recently. Proponents of the wind farm would say it's not so, but after 20+ years I think we can vouch for the fact. Our surrounding cornfields used to be full of geese this time of year. Not anymore. It didn't happen overnight but, slowly, the numbers have dwindled.

We've read in the newspapers how good this is for our local economy. I would like to know who, locally, is benefiting other than the select few who have towers on their property and the individuals who have a weekly ad in our local paper advertising the sale of Wind Farm T-shirts, key chains and bumper stickers. Someone is benefiting from this project, but many of us are paying in ways that have no monetary price.

My family and I will continue to live on the property we call "home." We'll watch our trees grow, knowing they'll never be tall enough to block the view of the tower that looms just on the other side of them.

I wonder what these towers will look like in 20 years. Let's hope they are not rusting giants.

The Albuquerque Tribune

(15)

Neighbors complain of wind farm nuisances

By Scripps Howard News Service
April 28, 2006

The idea of windmills brings to mind bucolic Renaissance paintings of Dutch landscapes and tulip beds.

But that's hardly the experience of some who live next to the 400-foot electricity-generating giants being built across America's breezy plains.

They complain about the incessant "whoosh-whoosh-whoosh" of the machines at work, the flashes of light and shade across their windows, and the occasional terrifying midnight screech of turbines repositioning themselves to catch shifting winds.

"It sounds like a train going through, except the train never comes through," said Wayne Darley, whose life had been turned upside down by a giant windmill located 800 feet from his house in rural Fenner, N.Y., where he has lived since 1970.

Darley said he fears the days when the winds come from the northwest. "Then whoop, whoop, whoop becomes a roar," he said. And in the spring before the trees sprout leaves, the turning turbine causes flashes of light in his living room that so annoyed his wife, the pastor of a local church, that she had to flee to the bedroom to get away from it.

Darley said he has nothing against windmills in the neighboring wind farm. He only wishes someone would do something about relocating the one on his doorstep. "It's too close," he said.

While the industry portrays electricity-generating windmills as a benign and natural source of power, community opposition to new windmill farms is cropping up across the country, particularly in Eastern states, where there are more people fleeing urban blight to live in idyllic rural towns.

Last week, authorities in Vermont rejected plans for a windmill farm on top of that state's scenic mountains near East Haven, while Peru, N.Y., declared a one-year moratorium on any construction of windmills so the town can further study the impact on the rustic charm of the Adirondacks.

Community activists in Dryden, N.Y., last year forced Cornell University to withdraw plans for a windmill farm in their tiny community, and in England - where opponents have ridiculed the huge machines as "lavatory brushes in the sky" - lawmakers are considering proposals that would require any new windmills to be located no closer than two miles from homes, and preferably out of sight.

John Semmler, an education consultant who has lived in Dryden for 30 years, said he's been ridiculed as being a NIMBY - meaning "not in my backyard" - for his role in leading the opposition to the Cornell project. Semmler and other residents argued that if Cornell wanted to build an industrial complex of windmills, it could easily do so next to the Ithaca campus eight miles from Dryden and leave their vistas and peace undisturbed.

"I'm not a NIMBY, I'm a NAMBY - 'not in anybody's backyard,'" said Semmler, who toured other wind farms in the region to find out how they have affected people's lives. "I resent the use of the word 'wind farm' to describe these projects - these are huge, monstrous pieces of machinery that make noise," he said.

The industry did not expect the intensity of community opposition that wind farms are getting, said Marion Trieste, publicist for the Alliance for Clean Energy New York, an organization that has the backing of industry and environmental groups.

"There's a lot of misinformation, and a lot of unfounded discussion about negative encroachment," she said.

Trieste said supporters of wind energy outnumber opponents. The group has put a video of testimonials from people living under windmills who enthuse about their experience with the machines, and the contributions windmills make to renewable energy.

"People are passionately concerned about their communities, and concerned about energy, and we have to come to terms with the alternatives," she said.

The American Wind Energy Association, which represents the industry, says it knows of only a few complaints about noise. Scores of new facilities are set for construction under incentives for wind energy that Congress included in last year's energy bill. The incentives expire in 2007.

"You can stand under a wind turbine and have a normal conversation," said Laurie Jodziewicz, a policy specialist for the association. "It's just a 'whoosh.'"

Jodziewicz said modern turbines are much quieter than the first generation of windmills, and that complaints about wind farms today "are very, very rare." She said there have been complaints about the strobe-light effects, but those occur only during certain months of the year and depend on the sun's angle to the turbine blades.

Robert Curtiss, a professor of chemistry at Frostburg State University in Maryland, says that's not his experience. He and his family have lived for the last three years under a wind farm built on Meadow Mountain, about a half mile from his home in rural Meyersdale, Pa.

Curtiss said he had a professional engineer measure the noise, and found the windmills showed an average reading of 75 decibels - about the level of noise from a washing machine.

The industry says the average windmill gives off only 45 decibels, but Curtiss said the mountainous topography around his home amplifies the volume - and it didn't help that developers clear-cut the trees on the top of Meadow Mountain to make way for the wind.

"It's a low frequency, a rumbling like you are listening to a bass drum," he said. "It's a constant background of 'whoosh, whoosh, whoosh.'" He said he and his family haven't adjusted to the sound. "If you've ever had a leaky faucet, you know it doesn't make a lot of noise, but it drives you nuts."

Curtiss, who stresses he's an environmental chemist, said he favored the windmill farm as the green way to go when the facility was built.

But he's now concluded that windmills aren't a very efficient way of generating electricity. The wind farm scrambled his TV and radio reception, and the turbine blades have claimed the lives of countless bats that used to keep control over the population of mosquitoes and other summer insects.

[illegible]'s advice to residents of other rural areas planned for wind farms: "Fight it."

Noisy turbine annoys neighbours

11 August 2003

By SETH ROBSON

http://stuff.co.nz/stuff/0,2106,2623336a11,00.html

Windflow Technology is shutting down its Gebbies Pass wind turbine each night because of noise concerns.

McQueens Valley residents met last week to discuss noise problems caused by the 500kW wind turbine, which has generated power for the Christchurch City Council since last month.

The turbine looms over a ridgeline above photographer Julie Riley's McQueens Valley property.

Ms Riley, who objected unsuccessfully to the project at its resource consent hearing on the basis of noise and landscape values, said the turbine was much louder than expected.

Windflow was not able to stick to its resource consent, and people 3km from the wind turbine could hear it whenever it was running, she said.

"They said it would be quieter than 30 decibels and we would only be able to hear it 3 per cent of the time.

"They would have had a lot more people complaining at the resource consent hearing if people down the valley knew they were going to be affected.

"We are hearing it almost 100 per cent of the time when it is running," Ms Riley said.

Two noises were emanating from the site, just more than 1km from her house.

"Two hydraulic pumps run all the time. I can hear those at night," she said.

"When they have the blades going it is terrible. It sounds like `grind, grind, grind'. It obliterates the bird sounds and all the nature sounds that we have all come here for."

Ms Riley said she bought her house in the valley as a retirement property.

"I don't think they (Windflow) realise what we came here for and what an invasion this is."

Coal-fired power stations, using new clean-burning technology, were a better option than wind, Ms Riley said.

"Wind power is OK if it is not annoying people who come to live in these places so they are in contact with nature. We didn't come here to be invaded by noise pollution."

Windflow director Geoff Henderson said the turbine was being shut down at night while the noise problem was sorted out.

"We are not running at night because the neighbours have a concern about the noise levels, and we have acknowledged we need to do something about it."

Mr Henderson expected the noise problems to be solved within a month.

Neighbours Warn of Din From Wind Turbines
Source: Dominion Post, New Zealand
Publication date: 2005-11-16

By CHURCHOUSE, Nick

Manawatu residents say they are being `driven stupid' by the sound.

MANAWATU residents say they are being "driven stupid" by noise from wind turbines, despite living twice as far away as those planned for Makara.

Two residents who live up to three kilometres from Te Apiti and Tararua wind farms spoke at the resource consent hearing for Meridian Energy's proposed Makara wind farm yesterday.

On the Makara Guardians group's last day of evidence, Wendy Brock described three consecutive days of relentless noise and throbbing from 18 turbines 2.5km from her Ashhurst home.

"You have this drone, you can't escape it. After three days the residents were just worn down, fed up."

Meridian's Project West Wind proposes 70 turbines, some within 1km of homes. The Makara turbines would also be 35 metres taller than Te Apiti's.

Mrs Brock said Meridian's consultation for Te Apiti did not prepare residents for the noise levels.

"The turbines make noise, lots of it."

In the past month she had complained to Palmerston North District Council seven times, but did not feel she was being taken seriously.

Meridian has already paid an undisclosed sum to move one Manawatu family who could not live in their house because of noise and vibrations.

Daniel Sproull's farm lies within sight of both wind farms. He said he feared for Makara residents if Meridian's 70 turbines were allowed.

"If these go ahead and your place is downwind, you're stuffed."

The turbines' sound at Te Apiti, 3km away, was "like a truck rumbling past his house, though "it doesn't pass in seconds, it can rumble for hours".

The turbines were enough to "drive you stupid".

Several nights he was woken by turbine noise, thinking the clothes dryer had been left on overnight or road works were directly outside his property, he said.

"All noise control could say was they would put mine with the other complaints."

Project West Wind would "destroy ordinary Kiwis' lives", he said.

Makara Guardians presented expert evidence that criticised Meridian's noise expert Malcolm Hayes, who had said the West Wind turbines would not exceed noise standards.

A report by Australian environmental consultant Robert Thorne said Meridian's evidence addressed only some of the noise issues that would affect residents. It was inadequate under Resource Management Act requirements.

The type of turbines proposed had special audible characteristics not considered by Meridian, which meant they could be heard as far away as south Karori, the report said.

(18)

Darrell Fox
6421 1550 E Street
Tiskilwa, IL 61368
(815) 646-4446

-- son of Dale & Janet Fox

September 25, 2005

I just got off the phone with Darrell. He is a young man, I would guess in his 30s, who lives with his parents in their 60s, and they are dairy farmers. These people are now surrounded by 33 1.5 MW industrial wind turbines (Neg-Microns, according to Bob Bittner, see below). Darrell promised they would install one kind of turbine, and yet they seem to have put in a different kind. The company, by the way, is Japanese that was fronted by a Chicago lawyer.

The Foxes live approx. a third of a mile or from the nearest turbine, and, again, his neighbors are half a mile, third of a mile—on that order. It was only in the last 2 weeks or so that all 33 went on-line. The company installing them had a myriad problems putting them in, including one of the turbines tipping over significantly. These turbines are about 400' feet high, and he was told that they are the tallest land turbines east of California. In California, they were told, these identical turbines are sunk into the bedrock, but here, in Tiskilwa, they were just put into the soil and that's why they had trouble keeping them upright.

The Foxes & their neighbors fought this with lawyers for several years and they lost. The farmers who signed on were desperate for the money, Darrell said, and did not read carefully the leases. Darrell and his parents were offered a lease and they took it to their lawyer and he said "Anyone would be crazy to sign this!" Darrell pointed out that in the lease these companies can do whatever they want with your property, the entire property—dictate what goes on. For instance, if, on your hundreds of acres, you wish to sell 5 acres to somebody in a corner over there and the wind company decides that this interferes with their operations, they can forbid this sale. And so on. Not surprisingly, the Foxes did not sign on. But a good many of the farmers did. He said they were desperate for the money: about $5K/turbine, ostensibly. He said "they would have let the turbines kill them, so eager were they for this money."

For the past 2-3 weeks the turbines have been up and running, and he said it's horrifying. Darrell said the sound they hear ("it's always there," he said) is a jet-plane noise. It's worse at night. A low rumble. He said to imagine a day when there is low cloud cover and a jet is going through the clouds and you can't see it; you hear it. Again, always.

When the wind is blowing from behind the blades, the jet noise is at its worst. They have several turbines to the west of their home, and with the wind out of the west it is terrible. Again, night the worst. When the wind is out of the east, so the wind hits their house before it strikes the turbines, it is the quietest. Darrell said, too, that the wind company, here, did the same thing that Noble & Zilkha have done: they took busloads of people to some windfarm, parked them right underneath, and the people said, "Well, these are totally silent!" The wind salesmen told folks the turbines "are about as loud as the gentle hum of a refrigerator." Darrell remarked on this: "This is an outrageous lie!" "You have to be about a quarter of a mile, or further, and then you actually hear them," said Darrell.

Their highway supervisor, an honest man (said Darrell), went on his own to this same windfarm, tape-recorded and videotaped the turbines, and said "these things are a disaster." "They're noisy," etc. He was ignored. Like me, Darrell suspects that when the bus trips visit the showpiece windfarms, the company feathers the blades.

He also described a pulsed sound, a "thumping" sound, but, again, mostly the loud roar. He also talked about the strobe effect. He described an incident recently where he went down the road to feed some cattle by the creek, it was late in the day, the sun was setting behind the turbines, and he had his back to the turbines. The shadow flicker covers the entire farm. On this occasion he became seriously nauseous from the shadow flicker.

He also described what he called a "siren" sound, from time to time. It's like an ambulance going by on the highway. This siren noise is also affected by the wind.

Darrell added that the turbines interfere with TV reception. That they chop the reception and they can tell when the blades are actually cutting through the reception. The wind company has promised to install satellite dishes for all of these folks, but the problem, here, is that the satellite dish does not pick up the good channels they regularly receive; the satellite dish only gives them TV out of some other part of Illinois that is inferior in programming to what they already have.

Lastly, he talked about the strobe lights: red lights at night, white during the day. Very obnoxious. His parents can't sleep at night. They are forced to sleep with "white noise" in their room. They run a noisy fan in their room, trying to mask the turbine noise. He and his parents are all rather irritable these days.

So far he has not noticed any problems with his livestock, but he's keeping an eye on this. Scott Smka came and testified before hearings, there, and he was very impressive.

Darrell said the county gave this wind company tax free status for 10 years. They declared this to be an Enterprise Zone (like our Empire Zone): no taxes for 10 years. When eventually they are taxed, they will be taxed only on the underground, concrete footers, not on the structures themselves. This just floored him. The above-ground structures are considered "removable property."

He went on to say there's a problem with the cables in the ground: they are not properly installed. The company said they would be put in on a bed of sand, then the cable laid, then sand on top--all this to protect the cable from breakage—but this was not done. They merely dug a trench and dropped in the cable and threw on the dirt.

The company also did some kind of daisy chain arrangement in putting the cables in the ground, with the result that, when they tried to start up the turbines, lo and behold almost no power was getting to the substation. It was being poured into the ground! It took the company some time to discover these breakages/disconnections and they "think" they've got them fixed, but nobody's really certain, including the company. So, there is the very real possibility, here, of underground current.

He said all the neighbors complain about inner ear, vestibular effects. One neighbor to the north of him, who is a little closer to the turbines than the Foxes, often comes over in the evening to escape the noise in his home.

Darrell said, "We're simple people. We're farmers. We were hammered by the wind company lawyers." The wind company overwhelmed them with a small platoon of lawyers, who were present at, apparently, many of the public meetings. The people who signed the leases won't talk, he noted. I told him they very likely signed a gag clause in their contract—that this is standard. He said, too, that they had already been stalked by Florida Power & Light, but this other, Japanese company, fronted (again) by a Chicago lawyer, had managed to undermine FPL and got in there instead.

Darrell has lived here pretty much all his life. The farm has been in the family for generations. The Bittners (Bob Bittner and his wife) are (were) his neighbors. Bob Bittner told me his forebears actually homesteaded this part of Illinois, from Providence, RI (as I remember). They thus founded this part of settled Illinois, 100 200 years ago. But the Bittners have been driven out. He and his wife hired a lawyer, took their case to Illinois Supreme Court, and lost. Bob Bittner told me they were told they had no standing in this case. As a result, Bob told me, he and his wife have bought a cabin in the woods 7 miles away and they have moved there. Basically, abandoning their ancestral home.

I neglected to ask Darrell about other neighbors being driven from their homes.

Darrell added, the wind companies were horrible. "They lie!" he repeated over and over in our conversation.

----- Original Message -----
From: Bob Bittner
To: rushton@westelcom.com
Sent: Saturday, September 24, 2005 12:29 AM
Subject: Wind Turbines - Illinois

Dear Dr. Martin:

Just this week, they managed to get all but one of the 33 turbines running. The operation was to have been completed last November. We are not a good one to give much current information since we have purchased a cabin in the woods seven miles away where we can not see them or hear them. Therefore, we are not a good source of information at this time.

At Crescent Ridge, they are Neg-Micron 1.5MW WTGs with a 279' hub height and 112' blades. The closest one to our home is 1360' and there are nine within 3/4 mile.

Neighbor Dale Fox may be measuring stray voltage since they are concerned about damage to their livestock -- 815-646-4446. Dale & Janet live 1/2 mile from us. The other neighbor is Cindy Jennings but I will have to get you her number.

Dr. Jay Pettegrew grew up on a farm just south of the wind project and vacations back at his family home. As I mentioned, he is a professor of neurology at the U of Pittsburgh. One of his concerns was the possibility of the strobing would cause epilepsy or invoke a seizure, particularly to vehicle operators.

pettegre@pitt.edu
(412) 638-4576 Mobile

Best regards,

Bob Bittner
Product Manager
Software Technology, Inc.
800-844-0884 X2115
309-256-1434 Cell
309-925-9115 Direct
309-925-3531 Fax
www.STI-K12.com

(19)

"windmills emitted a low frequency noise for three days on end, making their lives a living hell"

Flurry of complaints after wind change

http://tvnz.co.nz/view/page/411749/599657

Jul 24, 2005

A wind change at Meridian power company's giant wind farm on the Ruahine Ranges has prompted a flood of complaints from nearby residents.

Residents in the small Manawatu town of Ashurst say that in an easterly there is an intrusive rumble for days on end. They say the windmills emitted a low frequency noise for three days on end, making their lives a living hell.

The Te Apiti windfarm turbines have a steady sound in the prevailing westerly wind but when the wind suddenly, and unusually, turned easterly last weekend Ashurst residents say it bombarded them with noise and vibration.

"On Monday night the rumbling was so bad it sounded like one of those street cleaning machines was driving up and down near the house. In fact it sounded like it was going to come through the house," says Wendy Brock.

Geoff Keall said whether people were inside or outside it had an impact.

The blades on each of the 55 turbines are the size of a Boeing 747 wing and they produce enough electricity to power 45,000 homes.

Tararua District Council says measuring the noise is difficult, but it is concerned for the residents. Spokesman Mike Brown from Tararua District says he believes Meridian is also concerned and they will be talking together to see what can be done to resolve the issue.

But Meridian says it's a small number of people making a big noise about nothing.

Spokesman Alan Seay says they monitor the sound levels at a number of points and the monitoring has shown quite clearly they were well within the guidelines.

There's growing opposition from the public to windfarms.

Previously people have been generally supportive of windpower, but when a power company recently applied to instal a further 40 wind turbines, it attracted objections from more than 250 people.

However, despite the latest complaints windfarms on the Ruahine and Tararua ranges are expected to expand.

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... me following memo was sent by Sue Sliwinski, Sardinia, NY, on November 28, 2005.

Calvin

Calvin Luther Martin, PhD

In a message dated 11/28/2005 9:52:58 AM Eastern Standard Time, chuck.shick@infotonics.org writes:

Over the weekend my wife and I took a trip to the Tug Hill wind farm. Although the turbines are not yet running we wanted to see the area. The first thing my wife and I noticed was there were far fewer homes in the area. The site is mostly wide open farm land. The turbines seemed to be set back much more than 1000' from homes. Although without a range finder it was hard to give a true distance. We then went to Fenner and drove around there. I stopped and spoke with a land owner who leases property. I asked him if this was a typical day for the sound, he said it was quieter than normal. The day before was much worse, he said they sounded like airplanes. Again I noticed than lack of homes around the site. I stopped the car about 2500' to 3000' away and got out to see how loud it was. The turbines were very audible, I can't imagine getting use to the sound 24/7. The video attached was taken about 600' to 800' away and this is a quiet day. I am looking for any new material to send you.

Chuck Shick

Electronics/Photonics Packaging

infotonics Technology Center Inc.

Phone (585)919-3028

Fax (585)919-3011

chuck.shick@infotonics.org

(21)

David Brierley
"Whitriggs"
Tytup
Dalton in Furness
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LA15 8JW
01229-462912

Dr., Paul Golby
CEO OF E.on Uk
Powergen UK plc
Westwood Way
Westwood Business Park
Coventry
CV4 8LG
1st October 2004

Re:- Wind turbines at Far Old Park Farm Askam in Furness

Dear Sir,

I should like to refer you to numerous items of documentation provided by your staff and contractors to your company (over the last 5 years), to ourselves, other residents, the complainants, Parish Councils and District Council in relation to the above wind farm. I should like you to know, personally, how the residents of this area have been treated by your company, and in particular I should like to demonstrate to you the utter contempt shown towards us by your local staff, and in particular by Mr Matt Britton, your assets performance manager.

In the recent action under s. 82 of the Environmental Protection Act 1990 in Kendal Magistrates Court, the "defence" of "Best Practicable Means" (BPM) was successfully deployed. The District Judge found (after trial) that despite numerous instances of breaches of planning control, AND numerous instances of "nuisance" being recorded by the local EHO, that no statutory nuisance existed. Naturally, local people disagreed, but a verdict is a verdict, at least for the present.

Mr Britton claimed in evidence that BPM have "always" been employed by Powergen Renewables (PGR) and that B.P.M. will "continue" to be employed.

Your expert witness, Malcolm Hayes, of the Hayes Mackenzie Partnership stated that *"Areas for further investigation have been identified which may result in reductions in incident noise levels at neighbouring dwellings during the most sensitive periods of turbine operation. Further investigation is required to determine whether small changes to the range of wind directions and wind speeds will improve the existing noise environment at neighbouring properties."*
This was with reference to his findings at two properties, (Inshallah and Highfield, where:-

(HIGHFIELD) *"levels..... could be considered unacceptable with limited periods associated with amplitude modulation when noise levels are unacceptable further from the dwelling".*

(INSHALLAH) "*....a level that could be considered unacceptable*".
This therefore begs the questions below:-

What further identified investigations (if any) did he propose?
What further identified investigations (if any) have been implemented?
What results (if any) have been obtained?
What actions (if any) have been taken to *"improve the existing noise environment at neighbouring properties"*

In a letter to residents dated 6 March 2004 Mr. Britton stated :-

1. *"With regard to responding to noise complaints, the same reporting procedure will apply."* i.e. - reports/complaints to the Local Authority Environmental Health Officer.

I question whether such a step can ever amount to "Best Practicable Means", when the same Mr Britton, in evidence, threw doubt as to the methodology employed by the EHO?

Britton also said

2. *"As discussed at the recent court case at Kendal Magistrates Court and in the local press it is our intention to carry out some further monitoring and investigations on site with a noise expert. This will include the installation of monitoring equipment in the area and involve a programme of adjusting the settings of the*

NRMS……Your co-operation and feedback from this programme would be appreciated."

It is now October 2004. The residents of the two premises quoted by your expert witness as *"requiring investigation"* have not been approached.
There has been no monitoring or investigation at either of these two premises.
As *"co-operation"* by these residents has never been in doubt, it is therefore impossible for Powergen to obtain any *"feedback"*. Co-operation is, as the word implies, a two-way issue. It is Powergen who have failed to *"co-operate"*. The residents of this area, who are continuing to suffer the misery of living with this wind installation, still await PGR's proposals for improvement, some seven months after you claimed further investigation was required.

How can this inertia be construed as "Best Practicable Means"

3. *"I had hoped to be able write to you with the programme before now, however we are still formulating the details and as soon as I have some firm information I will write to you again. As you can well imagine the programme initiation will depend upon availability and the appropriate weather windows."*

Can I take it from this that as no one has received any communication from either your operators or yourself since 6 March

A) PGR is still *"formulating the details"*.
B) PGR has no *"firm information"*.
C) No one has been *"available"*.
D) There has not been an *"appropriate weather window"* in the eight months since the court case.

Could you please define for me what you consider are your perceived duties, in order to avail yourself of the defence of "BEST PRACTICABLE MEANS?

We have had enough. For more than five years we have lived with this horror on our doorstep. We have complained to anyone who will listen, from M P's downwards. We have kept to the law, complained to the EHO and called him out on numerous occasions. We have been to court, and obtained serious sworn undertakings from PGR and its staff. Yet nothing has changed. The wind farm continues to make an intolerable noise in some weather conditions, rendering sleep impossible, and driving residents to distraction. This just has to stop.

I ask you to come to Askam to see and hear for yourself what your installation has done to this community and to some of its residents. In what should be a shared endeavour to contribute to a small extent to the UK's renewable energy future, the poison of the Far Old Park Wind Farm, procured by deceit and bureaucratic incompetence, maintained by dishonesty, and now ignored by its owners has created a small corner of England where no-one in their right minds would come to live. It is not an attractive story.

I have studied the corporate responsibility claims which appear on your website. Without going into tedious detail, the performance of PGR at Askam flies in the face of almost everyone of them. I am aware that you have legal obligations to source renewables under the Utilities Act, and that every little helps. But this cannot, and should not, be achieved at the price you are asking us to pay.

In the case of Askam, you could create the most striking public relations advantage by recognising (with regret, of course) the horror which has been created, and taking it down, despite the expense. If you ask Mr Britton, he will just tell you that everything is fine, and that the residents are quiet. He despises this community. If you ask the EHO, who is an utterly useless performer, he will tell you what he said in Court, and narrate fewer complaints; that is because residents have moved away or are long term absent. The remaining residents are not quiet; they are worn out, angry, frustrated, and less and less likely to be reasonable as time goes on. A local farmer recently committed suicide; I do not ascribe this event to the wind farm, but his widow tells me that the ceaseless noise, pounding into their house day and night, was a contributor.

I have written in this graphic fashion because I want to get your attention. I will come and see you personally in your office if you would like to hear this from me, man-to-man. I am not an extremist, but a quiet, retired policeman with no history of stirring trouble for its own sake. My retirement has been utterly ruined by this windfarm, and I am not alone. If you can be persuaded to come to Askam, I will introduce you to others

with whom you will be impressed; the sort of people who make up the backbone of England and are being driven to places they would rather not go by the Askam windfarm and its noise.
I hope to hear from you.

Yours sincerely

David Brierley

CC.
The Clerk To The Justices, South Lakes Magistrates Court
The Right Honouraable John Hutton MP.
The Chief Executive Barrow in Furness Borough Council
The Media

To: Bob Grady, Managing Editor, Press Republican

From: David Brierley

Regarding: Letter to the editor

Date: November 1, 2004

Dear Sir,

I reply to Mr Hinckley's editorial, ""Wind Power Seen as Win for All."

The realties of living next door to a wind-farm (as I have for 6 years) are far removed from the cosy image portrayed by Mr Hinckley

The quality of life in our once peaceful, tranquil, rural communities has been degraded dramatically by the arrival of "our" wind-farm. This farming area has now been industrialised.

At properties, all around our site, there's now an all-pervasive "noise." Described by a cross section of residents as "A CLOG IN A TUMBLE DRIER." "A TRAIN PASSING THROUGH YOUR BEDROOM – CONTINUALLY." "A C130 HERCULES PARKED OUTSIDE YOUR BEDROOM WINDOW." "DISTANT PILE DRIVING." "SOMEONE MIXING CONCRETE IN THE SKY." In many authenticated reports this lasts for days and nights on end (dependent on wind direction and speed).

This noise is felt as much as heard. It is sometimes worse at properties 750 metres (half a mile) away from the site than it is directly below the turbines. Residents complain that they feel that their hearts and breathing are trying to keep in synch with the beat.

The local Environmental Health Department has confirmed much of this.

Some residents attempt sleep wearing headphones and playing music on their "walkman" just to break up the noise that invades their bedrooms (sometimes, every corner of their property). Others play "musical bedrooms" night after night – swapping from one room to another in a vain attempt to obtain some relief from the incessant noise.

Some residents are forced to move out of their properties for hours, sometimes for days, to try and obtain some respite. Farmers in adjacent fields complain they can't work for more than 2 hours at a time because the noise "*does my head in.*" Some house values already have been drastically reduced by the local authority (and, in another well documented instance, by a judge, following a court case).

No authenticated, permanent, local jobs were created, although I believe the land owner's son does odd jobs around the site, part time. Tourism has not noticeably increased. Local contractors were not awarded the contracts that were promised by the developer. There are no obvious benefits to the local community. JUST COMPLAINTS FROM RESIDENTS ADJACENT TO THE SITE.

Apparently the developer, the landowner and the electricity company are the only beneficiaries.

So Mr. Developer, please don't "green-wash" your poor unsuspecting communities; don't tell only half of the story. Give residents the full facts, so they can make up their own minds. Then, perhaps, they won't end up in the situation that we have.

I can put you (and them) in touch with other sufferers in New Zealand, Holland, Germany, Denmark, Spain, France, Scotland, & Wales this list grows daily, as these atrocities proliferate.

I can produce Government sponsored investigations, copy reports of findings by universities and other authorities that corroborate the fact that wind turbines are not as "green" as the industry claims. (That's before we debate exactly how much or how little "green" electricity they actually produce and, consequently, how much or how little emissions they actually save.)

Yours Sincerely

David Brierley
"Whitriggs",
Tytup,
Dalton in Furness
Cumbria, England

Ladies and Gentlemen,

It is my belief, following the experiences of the last 5 years, that the realities of living alongside a wind power station bear little (or no) resemblance to the cosy images, so falsely, so blatantly, so cynically, portrayed by the wind industry, the "greens" and assorted Government departments and agencies.

The image they would have the public believe, is one of a soft focus, pastel coloured scene, possibly showing children running through a flower-strewn meadow. This picture is intended to portray an image of an undisturbed, utopian, rural, idyll, (with possibly, - but far from mandatory,) - a barely discernible wind turbine in the far distance.

There is always, apparently, a complete symphony orchestra playing soothing, relaxing music, camouflaged and discreetly concealed somewhere in every field adjacent to every wind power station, but – elusively - always just out of camera.

I have so far failed to find them! The noise of the turbines is quite sufficient, thank you very much. Being forced to endure Beethoven's "Pastoral", Vivaldi's "Four Seasons" or Pachelbel's "Canon" every time I see a rotating turbine is just too horrendous to contemplate! (as much as I might appreciate those particular pieces, in other circumstances!)

One is inevitably, - I believe deliberately, subliminally led to the belief that this industry champions wind power stations existing unobtrusively in dreamy, peaceful, tranquil locations reminiscent of an impressionist painting, one, possibly signed by, or ascribed to, Claude Monet. However, the reality is totally different.

The European and British Wind Energy Associations both proudly and very publicly, proclaim, (in their Best Practice Guidelines,) the following:-

"WIND TURBINES SHOULD NOT BE LOCATED SO CLOSE TO DOMESTIC DWELLINGS THAT THEY UNREASONABLY AFFECT THE AMENITY OF SUCH PROPERTIES THROUGH NOISE, SHADOW FLICKER, VISUAL DOMINANCE OR REFLECTED LIGHT"

How I wish that this were true!

We, the residents of South West Cumbria, have all of these phenomena at one location.

We reported this to the BWEA, but basically they weren't interested. Neither (apparently) do they ever criticise, investigate or punish any developer affiliated to this industry body, who fails to comply with these grand sounding sentiments.

The reason?

These are only guidelines and they are not mandatory. Therefore, ANY "cowboy" developers (of which I believe there may be many) can choose to comply with those that suit them and those that don't are then conveniently ignored, apparently with the backing of the BWEA, to the detriment of the "quality of life" of residents. I believe "minimal cost" is the industry's driving criteria.

Further, there is no health and safety or any other legislation in this country that specifically covers wind power stations.

This, I feel, is one of the main problems which leads to the situations we, (and others), are now experiencing. This lunatic "dash for wind" guarantees that more and more residents of our once peaceful countryside are likely to be adversely affected, when they too, inevitably, become "the neighbours of wind turbines."

The "industry speak", which amounts to misinformation, lies, and deceit, will begin long before any planning application is entered to the local authority. It is usual for some (but not necessarily all!) residents to receive a "Dear Householder" letter, laying out the developers reasons for having selected <u>your</u> area, and how <u>he</u> proposes to deal with any of the problems that he assesses may arise.

DO NOT BE MISLED!

It is my experience that these letters either:-

Don't get circulated to all the residents who are likely to be affected. Or, as has happened locally, they are circulated to residents who are never likely to be affected, because they live several kilometres away from the proposed site.

OR :-

They contain statements that later turn out to be at the least misleading and in several known instances- out and out lies!

Examples – *and these are direct quotes.*

<u>"The turbines will be 40 metres in height</u>." – FALSE. We ended up with 63.5 metres - because the developer had failed, for some inexplicable reason, to inform the residents that he had not included the size of the blades (which incidentally are similar dimensions to a jumbo jet)

<u>"The development is small in scale and the site has been carefully designed to minimise any visual impact</u>." – FALSE. How on earth, can anyone, (honestly), declare that seven, 200 ft structures, painted brilliant white and with a blue "go faster" stripe on the turbine housing, – located at the summit of the highest hill overlooking three villages, (rising from sea level to 180 metres in just over 2 kilometres.) with blades the size of a jumbo jet's wing span, revolving at 26 rpm, flashing in the sunshine and making a noise like a broken down washing machine in its death throes, have been "carefully designed to minimise any visual impact."(?) Furthermore, this particular project was <u>so</u> "carefully designed" that they managed to miss-locate these turbines up to 900-ft (in total) away from the site where they were given planning permission. (What, then, is the validity of any safety cases, soil samples, ground integrity and noise surveys carried out on these spurious locations - NO ONE BUT US SEEMS CONCERNED!) Can I suggest that if any of you were to try building a house extension, a conservatory, a garage etc., 9 INCHES. away from where you were given permission, you would then see <u>exactly</u> who would be concerned! Everyone and his Uncle would pursue you unmercifully, with threats of sanctions and legal action unless you pulled down your project and build it <u>exactly</u> as permitted. BUT NOT A WIND FARM - *APPARENTLY.*

(Could this be why PPS 22 is so important to the wind industry, the Government and Mr. Prescott personally?)

"The design and control system will ensure that there will be no noise nuisance or effect on TV or radio at any property in the area." – FALSE. We have noise reported AND in several instances logged (by local authority environmental health officers) up to 2 kilometres away from the site. We have a verbal report, made in front of witnesses, by an independent acoustics engineer, of his identifying noise from "our" turbines 5 kilometres away, and across a wide river estuary. (He eventually declined to give a witness statement or to appear on our behalf at court, as he had just been offered employment at a nearby wind farm and would therefore have a "conflict of interest"). Funnily enough, this "conflict" excuse cropped up several times whilst we were attempting to compile our witness list!) We have a location that cannot see any of the 7 turbines, where these residents have to leave their premises, sometimes for days on end, in a desperate attempt to gain some respite from the incessant noise that keeps them awake and continually stops them enjoying their house and gardens. We have houses where residents are obliged to attempt sleep by means of playing a radio all night long, in an effort to drown out the noise of the turbines. We have another location where a young student is forced to attempt sleep (and studying for crucial examinations which would dictate her future), with a "walkman" and earphones, continually playing her type of music, to obliterate/break up the noise from the turbines. We have a location where the occupants regularly have to play "musical bedrooms", changing from one room to another several times during the night in a vain attempt to get some relief from the noise from the turbines. A noise which has been variously described as "a clog in a tumble drier", "a train continually passing though the room", "a c130 Hercules flying outside your window", "distant pile driving", and "someone mixing concrete in the sky" – CONTINUOUSLY - FOR DAYS (AND NIGHTS) ON END.

"It is our intention, as far as possible, to place the major construction contracts with local contractors to ensure maximum benefit to the area." - This one beats cock fighting, the major construction contracts amounted to £700,000; the amount placed with "local contractors" - a mere £60,000.

Once "our" wind power station began operation we very quickly found that promises made in pursuit of securing planning permission (and to a public inquiry), disappeared totally in a somewhat "Brigadoon" type scenario.
Safety margins of *"no turbines being placed less than their own fall over distance from any public access"* were compromised. Developers rationalised these unauthorised changes by stating – *"But they were only self imposed, we don't have to adhere to them"*.

Noise levels breached the planning condition and caused (and continue to cause - almost five years later) severe disruption and annoyance to residents. Several residents believe the noise is making them ill. Lack of sleep, anxiety, headaches, earaches, upset stomachs and a general feeling of malaise are reported by residents of all ages, all around the site. Unfortunately, none of these symptoms have (as yet) been corroborated (by a medical practitioner) as ill - effects originating from the presence of wind turbines.

Shadow flicker and glinting are experienced at properties up to 2.5 k away from the site. – When the developers were informed of these phenomena their reaction, as always, was immediate denial.

But these dreadful adverse effects are fact. They are very real. They have been witnessed by hundreds of people. They are still being suffered by many of our residents.

These ill - effects have also been witnessed by councillors and council officials. (Some of whom also declined to give statements or to be witnesses in our court case.)

Eventually the developers admitted everything that we had claimed – BUT STILL NOTHING HAS BEEN DONE TO RESOLVE THESE PROBLEMS TO THE SATISFACTION OF THOSE PEOPLE WHO MATTER.

THOSE WHO ARE SUFFERING.
THE RESIDENTS,
THE "NEIGHBOURS OF WIND TURBINES."
The developers (and the industry in general) claim it is difficult to predict shadow flicker, glinting and reflection – we totally disagree. The Egyptians, The Mayans, The Incas and Aztecs were all capable of building whole cities based on the movement of the sun.

In this country Stonehenge is a perfect example of prediction of the movement of the sun. If stone-age man was capable of this technology, why should the wind industry find it so difficult? Could it be another unwelcome cost eating into their profits?

Noise is another issue the industry finds "difficulty" with, they state that it is "impracticable" to measure noise lower than 30 dB. So they request, at planning, a noise condition based on 5 dB over this notional background level of 30 making 35 dB.
The background noise level in our location – prior to the wind farm - was recorded as low as 16.5 dB. (Somebody therefore found it "practicable" enough to take these readings.) Our night - time average would be about 19 dB. We now have readings regularly recorded in the middle to high 40's.

This (dB) scale is exponential. Every increase of 10dB means a doubling of the previous level of noise – so now we have an actual noise level of between 4 and 8 times that which we experienced prior to the development. The local authority claims that because of the court case of "Gillingham v Medway Council," the classification of "our" area changed with the passing of the planning permission for this, "our", wind power station. Consequently (in our once rural location,) we now find, as if transformed by a miracle, that we live in a mixed rural/industrial area and therefore our "expectations of noise" or should I say expectations of quiet - - should be in line with this industrialisation and are now "unrealistically" high.

Unrealistic for whom?

We are the residents.
We notice and live with this difference.
We have lived here for years.
We point it out.
Nothing happens.
WE SUFFER!

The World Health Organisation states that the minimum required noise level for uninterrupted, restorative, sleep should be 30 dB. So why do we have to suffer a much higher level? Is this another of those "unwelcome costs" for the wind industry?

It is not necessarily the noise level – as measured in dB - that is the problem. It is the nature of that noise. People report that this is a noise they "feel" rather than "hear". They report that their heart appears to be trying to keep in sync with the beat from the blades and they experience great discomfort should that beat change. Especially during the night - time hours – as is now totally exposed in the recent report by Van den Burg from Groningen University.

My wife is an asthmatic and has experienced, on several occasions, whilst suffering an attack, similar symptoms whereby her breathing wanted to keep in synch with the beat. She, (and I,) find this an extremely distressing situation.

People report tinnitus - like symptoms, sickness and dizziness, all of which they attribute to the "noise" from the wind farm. Because, when the "noise" ceases, for whatever reason – so do their symptoms. (Animals, too, show signs of stress at the "noise" and shadow flicker.)

Farmers working in adjacent fields cannot stand the "feelings" for more than two hours at a time because, quote, – "It does my head in". I believe medical research is in progress, along exactly these lines, in another area of the country.

People are continually forced out of the enjoyment of their gardens on days when the wind direction is such that the "noise" invades every corner of their properties. Some have been forced out of their houses for longer periods for exactly this reason. The developers deny this ever occurs - or rather they did deny it. They now reluctantly admit it, but add - "*Lets face it, if you live near a wind farm you've got to expect noise.*"

A quote from one of the defendants, at our recent court case, on oath, in the witness box, was, "The inevitable consequence of living next to a wind farm is........... NOISE!"
This same man, who currently holds a (relatively) high position of responsibility within Powergen Renewables, has previously stated, at another venue, and under far less "judicial" circumstances, that "*Wind Turbines are inaudible.*"

Which of his versions is the truth? I suggest that it is the former. The latter presumably being another example of "industry speak."

This "noise" is not a new phenomenon. It has been widely reported all over the world. About 3 years ago – Defra commissioned a report by Casella Stanger, into the sources of Low Frequency Noise. Within this report every one of the symptoms affecting our residents are described. We were totally unaware of it's existence and this report positively identifies wind farms as a source of nuisance (and states that health can suffer).

What is being done about this report? Apparently nothing.

We located this following a chance remark and we placed it with our MP the Rt. Hon John Hutton, Minister of State for Health. We believe, from his reactions, that his department was totally unaware of its existence. We had (initially) received support from Mr Hutton. He had been made aware of all of our problems. He was apparently at first, extremely sympathetic. He offered assistance, until , for some inexplicable reason, he felt that, despite organising a meeting with Lord Rooker within John Prescott's Office, which was suddenly, mysteriously abandoned - he could assist us no longer. I found this most peculiar and somewhat sinister. But not totally unexpected!

Subsequently, our diabolical situation has now dragged on for over five years and, in all honesty, we are no nearer to a resolution than we were when we first began.

We have actually achieved nothing!

There is no point denying that the result of the court case was a body blow to all of us. We believed that we were right. (We still believe that we are right). We were shattered.

We believed that by presenting, 6 complainants, 7 other residents, 3 council officials and producing in evidence certified local authority Environmental Health Officers records proving;-

26 noise nuisances,
14 border line noise nuisances
and ,
at least, 1 breach of planning conditions, in the 22 months immediately prior to appearing in the court, that we had done sufficient work to convince a district judge that a nuisance situation had existed, still existed or was likely to recur, under section 82 of the Environmental Protection Act 1990.

I (personally) persuaded MAIWAG members that if we were patient, if we did our work thoroughly, if we collated all the evidence, if we then presented it correctly and if we worked to the highest burden of proof – the criminal burden of proof, that of beyond reasonable doubt, - WE WOULD WIN. I believed it was so simple, so painfully obvious!
This I based on 30 years experience in the police force, where I genuinely believed in the due process of law and justice. Whereby, - if something was obviously wrong, - against public decency, - against commonly held beliefs and standards, - common law, - or against an act of parliament, and that complainants were able to prove it, they would obtain the correct verdict. Then the prescribed punishment for that particular crime, would inevitably follow.

THIS WAS THE SYSTEM.
THE ENGLISH LEGAL SYSTEM.
IT WAS SO GOOD THAT OTHER COUNTRIES BASED THEIR OWN LEGAL SYSTEMS ON OURS.

I forcefully, (perhaps sometimes too forcefully,) persuaded MAIWAG members to believe in, and adhere to, this maxim.
I committed them to 5 years extremely hard and time- consuming work, and not least, to an extremely large financial debt.
I thought that the system of justice that I believed in would always support "the wronged" against "the wrong doer."

I couldn't have been more wrong! And now -
I couldn't be more disillusioned!

In our case the judge decided that the evidence we presented *"lacked detail and specificity"* and that *"audibility and annoyance are not to be equated with nuisance"*. PARDON?

Immediately following the trial verdict, (and within minutes of returning to my home), I was phoned by a well- known, well respected, television journalist from London. He told me something which, at the time I had doubts about, but which I am now thoroughly convinced of, - that was, we "could not be allowed" to win this test case. Like us, he was shattered when the decision was made public. He didn't know how we could have failed. He informed me that right up to the verdict being made public, his information was that the wind industry believed WE had won. BUT WE FAILED! Two days afterwards he and a colleague travelled from London and interviewed both Les and I, and he there repeated his belief that we had been – to use his very explicit expression – "SHAFTED."

I now harbour grave doubts that the "holy grail" of "justice" exists, in any shape or form, Particularly in connection with our case against this industry. I now doubt that it has ever existed, or that under the current regime, it will ever be allowed to exist in the future. I was so shattered by this revelation that I resigned from MAIWAG - I just couldn't see any way forward.

I now believe that in matters where the financial interests of large corporate bodies and their interest rate, or monetary return to their share holders, or where government departments promoting dubious ministerial "sound bites", have become far more important than the human rights of "common or garden" residents. The individual HAS to be sacrificed.

AND ALL UNDER THE VOTE WINNING BANNER OF "GREEN ASPIRATIONS"

I'm actually a very simple man, with quite simple aspirations. One of my wishes is (or was) to retain my family's "quality of life." Something I believe, that I, and doubtless many of you, have aspired towards all our working lives and have already made huge, largely hidden, sacrifices in an attempt to achieve a better future for ourselves, which we then hope to pass down to our descendants.

The arguments from "greens" that they want to save the world for their grand children, are mine too, EXACTLY. However, achieving this by replacing one form of pollution with several others and then inflicted those on unsuspecting residents by stealth is NOT the way to achieve it.

Again,

I couldn't have been more wrong.
However, now, I'm (hopefully) wiser

I am /and MAIWAG are, continuing to gather, collate and disperse, information and evidence, to whoever requires it. Because no-one should have to go through what we have had to endure. We are all worn out. We are all totally disillusioned. We are also considerably poorer financially, but,

WE WILL NOT GIVE IN!

WE CANNOT GIVE IN - BECAUSE THIS SITUATION IS SO OBVIOUSLY, PATENTLY, CRIMINALLY - WRONG!

WE CONTINUE TO FIGHT THESE APPALLING INJUSTICES WITH JUST AS MUCH COMMITMENT AS WE HAD BEFORE OUR (VERY PUBLIC) DEFEAT.

BECAUSE WE KNOW , NO MATTER WHAT DECEIT IS EMPLOYED .... OR WHAT OBSTACLES ARE PLACED IN OUR WAY.........., WE ARE RIGHT!

We will continue in our attempt to achieve a legal redress to a situation that the Local Planning Authority, the Local Authority Environmental Health Department, The Government Office of the North West, The North West Development Agency, Defra, The Ministry for the Environment, The Health Ministry, and the several secretaries of state of innumerable government departments, are either incapable of resolving, reluctant to address, or deliberately, in the best traditions of one of Britains best known heroes, (Nelson) "turn a blind eye to."

(I wish that even half of those more often than not faceless people had small percentage of HIS backbone, whilst continually availing themselves of his ocular disability!)
Despite letters from Government departments telling us that Barrow Council have "all the powers necessary to deal with this situation speedily, efficiently and effectively" (now dated some 4 years ago), and a planning committee who have on 3 occasions voted to enforce planning breaches, ...we still await an outcome..... ....Consequently,

Ladies and Gentlemen,

I believe that if MADWAG's experiences are any yardstick, anyone facing the prospect of this desperate, diabolical, dash for wind, would be advised to fight any similar applications from the outset wherever possible. Don't even consider commencing your objections....., your resistance......, your fight. ..., once the problems associated with actually living close to a wind power station, have become - all to painfully - obvious. Apathy and lethargy are your worst enemies.

This industry with all its' hype, with all its' deliberately misleading claims, with all its' "industry speak", is not as "green" as they would have you believe. People must realise this.

Only then can anyone appreciate, that the painting I had alluded to, at the start of this presentation, could never, by any stretch of the imagination, have been ascribed to "Monet". The signature at the bottom of this "impressionist image," was always, (and who knows, in light of what we have learned, was perhaps deliberately) blurred, but, it finally falls into focus and now, so obviously, reads :-

"MONEY."

Take the letter "N" from the end of the word "green" and substitute if with a "D" and I think that the result is nearer the mark.

"GREED"

In the same vein, remove the letter "J" from the word "JUSTICE" ... .

Now............, I can see some puzzled looks. One or two of you are nudging your neighbours. "Take the "J" out of justice?" "He's got that wrong!" "The man's crazy." "It's all been too much for him poor soul." "What a shame!"

But.........., if you remember nothing else of what I have just said, remember exactly this last point.

You have just recognised, . . . in a few short seconds , something it took me 5 years to discover!

You have reached exactly the same conclusion that I did.

That is ....

in anything pertaining to the wind industry,

There's no "eff-in" justice!

Thank you for your attention.

Can I now hand you over to MAIWAG's chairman, LES NICHOLS.

AGRICULTURAL RESOURCE CENTER

University of Wisconsin-River Falls, 410 S. 3rd Street, River Falls, WI 54022-5001
(715) 425-0640 • FAX (715) 425-4479

UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY
This survey summary completed Thursday, May 16, 2001.
by David E. Kabes and Crystal Smith.

based on 233 completed surveys.

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

1. Are any of the following wind turbine issues currently causing problems in your household?

c. Blinking lights from on top of the towers

Question # 1c

1 Blinking red lights disrupt the night sky. They make it seem like we're living in a city or near a factory.
2 With winds primarily from the west, northwest, and southwest we have red flashing lights in our home.
3 Shine in bedroom windows
4 At night it is very irritating because they flash in the windows.
5 I have a large bay window with a reliance and it is distracting.
6 It interrupts a beautiful starry night.
7 Not causing problems, just annoying. They surround us.
8 Looks like a circus, live in the country for peace and quiet.
9 Get the blink of light in TV.
10 Disrupts my life
11 A horrible affect on the serenity of the night and blink into my home.
12 We have to keep drapes closed at night.
13 No but everywhere we look we see them. It looks like an airport.
14 We now live in a red light zone.

No problem.
15 An annoyance.
16 When we're lying in bed we see them.
17 They have ruined the night sky.
18 Yes when you lay in bed. It's not like just looking out and seeing clouds, etc. There is that wonderful red blinking light.
19 The blinking red lights can be seen from our bedroom window. What once was a serene night sky looks like flashing city lights.
20 Annoying and ruining the night landscape.

Anne (25)

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Sunday, September 25, 2005 12:36 PM
Subject: Turbines impacting landscape & wildlife & noise ...

... worth reading the following letter, in the *Caledonian Record* (Vermont, I believe), yesterday.

Calvin

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http://www.caledonianrecord.com/pages/letters_to_editor/story/1ccb784b5

Don't let wind turbines happen here
Saturday September 24, 2005

To the Editor:

My personal experience is that wind turbine "farms" are a terrible mistake. Before moving to Sheffield in 1993, I lived in Northern California. I drove often between Sacramento and the Bay area, 1981-1993, on what once was a scenic two-lane highway. It was a lovely drive, with fruit orchards and rolling open hills and dwellings.

Then came the wind farms - plantations, as it were - and the character of the countryside changed dramatically. The land dried up, became barren. No dwellings or orchards. The birds and other wild things disappeared. Even the turkey vultures vanished. There was no longer any carrion under the blades because no animals lived there any more.

A scenic area became ugly. And the sound of the machines, which you could almost hear before you could see them, was disconcerting: The ground seemed to tremble, the same as the sensation of driving through oil fields.

I hope we don't make similar mistakes in the Northeast Kingdom. Once the turbines are in, you can't get rid of them - and they are very unpleasant. I abandoned my route on the country road and switched to a thruway, where I could still see orchards, houses and wildlife.

Vermont's Northeast Kingdom is a national treasure and should not be for sale. Please don't let it happen here!

Respectfully,

Catherine S. Maier

Sheffield

(26)

see/

http://www.zwire.com/site/news.cfm?newsid=14532565&BRD=2259&PAG=461&dept_id=455154&rfi=6

05/16/2005

Waymart facility troubles residents

By Tom Venesky , Staff Writer

Standing at the base of one of the 43 turbines comprising the Waymart Wind Farm, it's easy to see how the towering structures dominate the landscape.

Each structure stands 213 feet high, and the three blades, each measuring 110 feet in length, spin effortlessly atop Moosic Mountain in western Wayne County. The first glimpse of the turbines from state Route 6 presents a surreal image like something from a Road Warrior movie.

"It's not beautiful or complimentary," said Waymart resident Donald Goetz. "From a distance, it looks like hell. It's not an asset to the community."

When the Waymart facility was constructed in 2003 in Clinton and Canaan townships, Goetz said residents in a 10-mile square area lost their television reception from turbine interference. He said FPL Energy has "piece-mealed" the problem by erecting two television towers, but it hasn't been solved.

"This is like a six-mile-long fence," he said.

In Bear Creek Township, Energy Unlimited will pay the municipality an initial sum of $39,000 plus an annual fee of approximately $3,000 per turbine for the Penobscot Mountain Wind Farm.

The facility is located on land owned by Luzerne County, and Energy Unlimited purchased the wind rights to the property from the Theta Land Corp. before it was sold.

The property is in the process of being turned over to the state Department of Conservation and Natural Resources for its state park system, which would allow public access.

Turbine blades can accumulate ice that can be thrown several hundred feet, according to Wells, which makes safety a concern.

She said the turbines are monitored for ice build-up and when it does occur, employees leave the area.

"We build our facilities on private property and it's our expectation that people abide by posted signs," she said.

"On those occasions when we do have ice, we don't want people near them."

Because the Penobscot Mountain site is on public property, the danger of ice presents a unique dilemma. Connelly said he never envisioned an ice accumulation on the blades. DCNR spokeswoman Gretchen Leslie said there's no precedent for wind facilities on state parks or forests, so her agency would have to discuss the matter with the owner.

"We would have to look at options, which could be shutting down the turbines during icing periods or closing off areas for safety reasons," she said. "It remains to be seen what the solution is, but we are concerned with public safety and would take precautions."

FPL Energy, which owns the Waymart wind facility, pays the private landowner a lease between $1,000 and $5,000 each year, according to Mary Wells, community outreach coordinator for FPL.

In Pennsylvania, machinery and equipment isn't taxed as real estate, so FPL Energy pays the townships $50,000 total in taxes for the buildings and tower pads.

Goetz said the municipalities have been seeking additional tax revenue from FPL Energy, but the company has been unwilling to compromise.

"In Bear Creek, they will realize financial benefits, but not here," he said. "That amounts to short-changing the community."

Wells acknowledged that residents were concerned about the project in the beginning, but she said worries have been quelled since construction was completed.

The scale of the project has attracted the interest of sightseers, she said, and the turbines have blended in with the community.

"In most places, they settle in very quickly," Wells said. "There are individuals who can't be reconciled and we understand that people like their view. But there's value to renewable energy and these are baby steps."

No matter how small the step, the project has impacted residents.

Rose Marie Derk, who lives a mile away from the turbines, said the noise and aesthetic impact have been significant.

She said the turbines sound like a large industrial fan and the disturbance is more noticeable at night when there is no traffic.

"When you go to bed and your windows are open, you're hit with this buzz and roar," Derk said. "They're in the wrong place."

Derk said numerous residents tried to stop the project at the township level to no avail.

Now that the turbines are up, she said they look "outrageous and scary" and the benefits to the community have been minimal.

"People thought they'd get their electric bill reduced, but ours went up and we're getting nothing," Derk said. "I can't understand what anybody thought they'd get out of this. This company came in, destroyed the top of the mountain and left us with it."

Prompton resident Raymond Vogt, who lives about three miles from the Waymart turbines, said the facility has destroyed the view of the area.

"As far as I'm concerned, they've been more of a detriment so far," he said. "They take up much more room than other forms of power and in Bear Creek there'll be people who won't like what they do to the view. It's like a fence."

Several residents, along with the Northeastern Chapter of the Sierra Club and the North Branch Land Trust, have opposed the Bear Creek Township location for Energy Unlimited's planned turbine facility.

The location was identified by the Nature Conservancy as one of the most environmentally valuable places in the county in 2001, namely due to the presence of oak barren habitat and rare plant species.

Bud Cook, director of the Nature Conservancy's Northeast Office, said they reviewed a map of the turbine locations in Bear Creek and determined the project would have a minimal impact on the barrens habitat.

Energy Unlimited has completed studies on bald eagles and has implemented an Indiana bat study to avoid any impact on those species, according to Project Manager John Connelly.

Energy Unlimited has also hired a consultant, Dr. Kenneth Klemow, to delineate wetlands and conduct a rare plant and oak barrens survey so the turbines wouldn't be erected in those areas.

Klemow also served as an environmental consultant for the Waymart site, which he said has a more diverse forest habitat than the Bear Creek Township location.

"At this site we will avoid the scrub oak (barrens) and we're looking at impacting woodland that is average or lower in the ecosystem," he said.

But environmental concerns do persist with the project.
Dr Henry Smith, a board member with Defend Our Watershed, said the property is the wrong place for a wind facility that he classifies as an industrial use.

Smith has started a Web site (www.savecrystallake.org) to raise awareness of the potential environmental impacts, which include the barrens habitat and the Crystal Lake reservoir, which supplies drinking water to the area. Nine of the turbines would border Crystal Lake, and Smith is concerned about degradation to the watershed.

"The Nature Conservancy has made it clear this is one of the most important parcels in the county and the Northeast for preservation. Industrializing it is grossly inappropriate," Smith said.

"I suspect we will only recognize our mistake when we witness the destruction of the watershed and forests required for installing these turbines. By then, it will be too late."

Derk agreed and said she has been through the same process with the Waymart facility.

She said a group of residents tried to warn the community about the negative aspects of the project-ranging from noise to aesthetics- but the damage has already been done.

"My message to the people in Bear Creek is keep saying no and keep fighting because it's horrendous. We feel we got shafted and there's nothing we can do," Derk said. "Unless they want their land values destroyed, keep fighting it. If you don't, you'll be sorry in the long-run."

tvenesky@citizensvoice.com

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CATHARINE M. LAWTON
7039 MT. PLEASANT DR.
WEST BEND, WISCONSIN 53090

January 27, 2004

BY EMAIL: sriffle1@aol.com

H. Stanley Riffle, Esq.
Arenz, Molter, Macy & Riffle, S C.
720 N East Avenue
P.O. Box 1348
Waukesha, Wisconsin 53187-1348

Subject: Addison Wind Energy, LLC CUP Application – FOR THE RECORD; Health Effects Associated with Windmill Noise

Dear Attorney Riffle:

Attached is a further submission for the record regarding windmill noise. The attached was published in the *Telegraph* (UK) on January 25, 2004.

If you have questions or need additional information, don't hesitate to call me at 629-5375 or 414-732-5618. My fax number is 262-629-4190. My email address is CMLawton3@aol.com.

Sincerely,

Catharine M. Lawton

Cc: Donna Schneider – By email: scavnger@nconnect.net
Ellen Wolf – By Delivery to Town Hall
Bob Bingen – By Delivery to Town Hall

Sunday Telegraph 25/1/2004

Wind farms 'make people sick who live up to a mile away'
By Catherine Milner
(Filed: 25/01/2004)

Onshore wind farms are a health hazard to people living near them because of the low- frequency noise that they emit, according to new medical studies. Doctors say that the turbines - some of which are taller than Big Ben - can cause headaches and depression among residents living up to a mile away.

One survey found that all but one of 14 people living near the Bears Down wind farm at Padstow, Cornwall, where 16 turbines were put up two years ago, had experienced increased numbers of headaches, and 10 said that they had problems sleeping and suffered from anxiety.

Wind farms: doctor claims they cause an increase in depression

Dr Amanda Harry, a local GP who did the research, said: "People demonstrated a range of symptoms from headaches, migraines, nausea, dizziness, palpitations and tinnitus to sleep disturbance, stress, anxiety and depression. These symptoms had a knock-on effect in their daily lives, causing poor concentration, irritability and an inability to cope."

Dr Harry said that low-frequency noise - which was used as an instrument of torture by the Germans during the Second World War because it induced headaches and anxiety attacks - could disturb rest and sleep at even very low levels.

"It travels further than audible noise, is ground-borne and is felt through vibrations," she said. "Some people are having to leave their homes to get away from the nuisance. Yet, despite their obvious suffering, little is being done to relieve the situation and they feel that their plight is ignored."

Similar problems have been found by Dr Bridget Osborne, a doctor in

Moel Maelogan, a village in North Wales, where three turbines were erected in 2002. She has presented a paper to the Royal College of General Practitioners detailing a "marked" increase in depression among local people.

"There is a public perception that wind power is 'green' and has no detrimental effect on the environment," said Dr Osborne. "However, these turbines make low-frequency noises that can be as damaging as high-frequency noises.

"When wind farm developers do surveys to assess the suitability of a site they measure the audible range of noise but never the infrasound measurement - the low-frequency noise that causes vibrations that you can feel through your feet and chest.

"This frequency resonates with the human body - their effect being dependent on body shape. There are those on whom there is virtually no effect, but others for whom it is incredibly disturbing."

A report by Dr Geoff Leventhall, a fellow of the Institute of Physics and Institute of Acoustics, has endorsed the findings. "Low-frequency noise causes extreme distress to a number of people who are sensitive to its effects," it says.

The claims have sparked an inquiries by the British Wind Energy Association and the Department of the Environment, Food and Rural Affairs, which has commissioned scientists at Salford University to research the effects of wind turbines on human health.

There are more than 1,000 turbines on 80 wind farms around Britain. They have rapidly increased in number during the past decade as a result of the Government's aim of getting 10 per cent of Britain's energy needs from renewable sources by 2010. To meet that target, there would have to be at least 5,000 turbines.

In Denmark, where wind turbines were introduced as long as 30 years ago, the government has responded to public demand and stopped erecting onshore turbines because of the noise hazard.

Dr Stephen Briggs, an archaeologist who lives in the village of Llangwryfron in West Wales, initially welcomed the news that 20 turbines were to be built in the hills behind his home.

He said: "I'm as green as the next man and the developers assured us that the windmills would cause hardly any disturbance, but once they began operating I couldn't work in my garden any more - the noise was unbearable. It was as if someone was mixing cement in the sky."

Two neighbours became ill from a lack of sleep and after four years of frustrated appeals, the Briggs family left their home of 17 years. House prices near to wind farms have also plummeted.

Mark Taplin, who has lived close to a wind farm near Truro in Cornwall for almost a decade, said: "It has been a miserable, horrible experience. They are 440 metres away but if I step outside and they are not generating I know immediately because I can hear the silence. They grind you down - you can't get away from them. They make you very depressed - the chomp and swoosh of the blades creates a noise that beggars belief."

National Wind Power, a company that builds turbines, recommends that they are erected at least 600 yards from human habitation, but government planning guidelines allow them to be put up just 400 yards from houses.

Alison Hill, the communications manager for the British Wind Association, said: "Wind farms make people feel better - they are a visible evidence of a cleaner, better future. However, we are currently doing research into the health impact of the turbines and shall be publishing the results within the next six months."

8 December 2003: Edmonds fights plans to build wind farms

21 November 2003: First offshore wind farm joins the national grid

External links

British Wind Energy Association

Institute of Acoustics

Royal College of General Practitioners

http://www.socme.org/innerjune05news.html#june06

Wind farm illness
Jun 6 2005

Duncan Higgitt, Western Mail, United Kingdom

SIR - There seems to be a great deal of controversy about the effect of wind turbine noises on human health.

I can assure everyone who needs to know, that some people like myself have found it impossible to live near them.

I had lived on our family farm for 27 years. I was living in the community where I grew up and where some of my family still live.

We had invested a great deal of our time into our home, and had even built a retirement home for ourselves, the place where I wished to spend the rest of my life.

However, in 2001, three massive wind turbines were erected within a mile of our home.

I wasn't very concerned about them, at the start.

Having been in the best of health, thankfully, for most of my life, I couldn't understand why I was suddenly feeling very unwell for no apparent reason.

Racing pulse, heart palpitations, a strange churning in my head, a feeling of nausea, a terrible unease and a need to escape. Sleep became difficult too.

I visited my doctor on several occasions, but she found nothing.

It took me about ten months to realise that there was a connection between my illness and the low-frequency noise emitting from the wind turbines.

At first I realised that, when I was away from home, I suddenly felt "normal" again which was a wonderful feeling, believe me.

I had suffered from tinnitus before this time and had been examined by a consultant at Glangwili Hospital. He gave me hearing tests and declared that I could hear very well, indeed especially in the low frequency range. Then I realised that when the turbines had their back towards me was when I felt most unwell.

I kept a diary of my illness, and I wrote to my MP.

I did not want to leave my home but eventually, after talking to another woman who had suffered the same symptoms as me, living near other turbines, I eventually had to face the fact the wretched things were there to stay and that we would have to move.

Now, 18 months later, after the trauma of leaving my home, I am again, thankfully, in the best of health.

Low-frequency sound sufferers exist. I also suffer from the low sound emitted by aeroplanes - before I can actually hear them I 'feel' them approaching, then I hear them and then I 'feel' them retreating.

Like everyone else I spoke to living near wind turbines, I could not hear any noise at all in the conventional way, not any sound at all. I have no axe to grind in this argument, I simply left.

But these wind turbines should not be built so near to people's homes.

GWEN BURKHARDT

The Nook, New Quay

(29) 45

AGRICULTURAL RESOURCE CENTER

University of Wisconsin-River Falls, 410 S. 3rd Street, River Falls, WI 54022-5001
(715) 425-3640 • FAX (715) 425-4479

UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY

This survey summary completed Thursday, May 16, 2001,
by David E. Kabes and Crystal Smith.

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

1. Are any of the following wind turbine issues currently causing problems in your household?
a. Shadows from the blades

Question # 1a

1 We get a "strobe effect" throughout our house and over our entire property (40 acres).
2 In the spring and fall there is a strobe effect inside the house and in our yard.
3 In the morning through the south bay window the blades can be watched on the walls.
4 On sunny mornings the strobe lighting comes in the windows even with the blinds down.
5 On sunny days we get shadows from blades.
None that we know of yet.
6 Around 4:00-5:00
Too far away
7 Unsightly blemish in a normally beautiful part of the country.
8 We are not yet living in or house, so our answer to some questions is no but we are greatly against having wind turbines near our home.
9 In fall I get a shadow.
Went sunshine we get in are backyard.
10 We installed vertical blinds but still have some problems.
11 Big time problems
12 Shadows are cast over the ground and affect my balance.
13 Strobing effect in living room on TV.
14 Very hard to watch TV or do any work in the kitchen, as the shadows are distracting.
15 Reception on equipment in my house
16 When the sun is setting it shines through the blades, causing sever flashing in our house.
17 They come across the lawn and one of the walls in the house
18 We get it all summer long and some winter months.
19 Circle across living room and kitchen in afternoon.
20 I know people who live closer and this is a problem!
21 Shadows from the blades sweep over our house and yard and ruin our quality of life.
22 Strobe light effect coming through the windows.
23 Strobe light affect

(30) 46

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UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY

This survey summary completed Thursday, May 16, 2001,
by David E. Kabes and Crystal Smith.

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

2. In the last year, have you been awakened by sound coming from the wind turbines?

Question # 2

I don't open the window at night anymore but the fan is on.

This man is 80 years old, others in the neighborhood have been awakened by the sound.

Not awakened but found it hard to fall asleep!!!

Enough to go to the doctor because I need sleeping pills. Sometimes it absolutely drives you 'nuts'.

We have had to keep our windows closed. Night time is the worst.

Have had difficult time falling asleep. Windows must be closed!

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Calvin Luther Martin

From: "Angela Kelly" <amk@clara.co.uk>
To: "Angela Kelly" <amk@clara.co.uk>
Sent: Thursday, July 28, 2005 6:18 AM

Wind turbine meeting

27 July 2005
Newsquest Media Group Newspapers

SEVERAL people who say they have suffered illnesses because they live close to Blaen Bowi windfarm, near Newcastle Emlyn, are expected to be at an open meeting next week called to discuss plans to construct more turbines at the site.

Local councillors and representatives of the farm operators Windjen, of Colwyn Bay, have also been invited to attend the meeting, at the Red Dragon Hall, Drefach Felindre, at 7.30pm on Wednesday, August 3.

One local, John Roworth, of Blaen Bran, told the Tivy-Side this week. "There are several people in this area who have had health problems since the first three turbines were put up. I live about 750 metres from them, but I work on the Dingle woods just 350 metres away and every time I work there I get headaches, dizzy spells and banging in the ears. And I have to come home to recover."

He added "Other people I know of have similar issues.

"However this meeting is not being set up as a protest. It is to give the local people in the communities close to the windfarm the chance to gain a more informed knowledge about windpower, its benefits and possible effects."

The main speaker will be Prof. Peter Cobbold, of Liverpool University, who will present his findings on the viability of wind turbines, their effect on the local environment and their part in saving CO_2 emissions. At the time of going to press Windjen could not confirm if they would have a representative at the meeting. A spokesman pointed out that the proposal is now in the planning process and that the application includes evidence from a "number of experts".

Newsquest Media Group Newspapers
Description: Articles from regional and local UK newspapers published by Newsquest, a Gannett company. Features general news from Barry, Bradford, Brighton & Hove, Eastbourne, Gloucester, local London, Ludlow, Penarth, Stratford-upon-Avon, Stroud, Worthing, York and regional coverage of Buckinghamshire, Cheshire, Dorset, Gwent, Hampshire, Herefordshire, Hertfordshire, Lancashire, Mid Sussex, Oxfordshire, Pembrokeshire, Wiltshire, Worcestershire, Ryedale, Trafford, Wirral, the Black Country, the Cotswolds, the North East, the West Country and the Lake District.

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Calvin Luther Martin

From: "Pastor K Danley" <pkdanley@rochester.rr.com>
To: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Sunday, February 12, 2006 8:25 AM
Subject: RE: Your address ...

Calvin, I would like very much to have this information of Dr. Pierpont's. I know I am a totally different person having been away from Fenner 2.5 years, I am also noticing changes in my husband who remains much of the time on the home property.

Rev. Kathleen Danley
15237 Ridge Rd.
Albion, NY 14411

Thank you, Kathleen

Pastor Kathleen Danley
Gaines Carlton Community Church
Albion, NY

33 149

"The Dark Side of Wind Power"

Malone, New York, Telegram, Feb. 12, 2005, p. 5

Eleanor Tillinghast
Great Barrington, Mass.
(Reprinted with permission.)

Noise may not be your first concern when considering whether or not to support wind power development in your community, but, for neighbors to wind turbines, it is tormenting.

Dave Pavoc, who lives more than a quarter-mile from the Waymart wind power plant in rural Pennsylvania, complains at a public meeting that the noise keeps him awake at night. **"It sounds like an airport ... my peace is gone forever."** Lou Orehek, whose relatives live nearby, writes, **"It is the opinion of members of my family that the windmills generate a low frequency 'grind' ... and this noise travels more than 7,000 feet."**

In New York, Pastor Kathleen Danley lives two good-sized fields from the Fenner wind power plant, and describes the noise to a reporter as **"a loud clothes dryer; that would probably be the closest sound, that constant turning sound."** She explains in a frustrated letter to her local newspaper, **"We were told that the windmills had been redesigned so as not to be noisy, but the grinding noise goes on 24 hours a day (when they are operating) and at times is far worse than other times."**

In Michigan, Kelly Alexander lives a quarter-mile from the Mackinaw City turbines. **The low-frequency sound creates a drumming that penetrates the walls of his home. Even with doors and windows tightly closed, there is no way to escape it. His 80-year-old mother lives next door. The noise keeps her awake at night.**

In West Virginia, Paula Stahl describes in a letter a hike up to the Mountaineer turbines (installed spring 2003). **"The noise was incredible. It surprised me. It sounded like airplanes or helicopters. And it traveled. Sometimes you could not hear the sound standing right under one, but you heard it 3,000 yards down the hill, where the wind carried the sound."**

Waymart and Fenner have 1.5-megawatt General Electric turbines. The Mountaineer turbines are the same size. The Mackinaw turbines are slightly smaller.

Sunlight strobing through spinning wind-turbine blades also distresses neighbors. A homeowner near the Lincoln wind power plant in Wisconsin responds to a survey by complaining, **"When the sun is setting, it shines through the blades, causing severe flashing in our house."** Another neighbor says, **"We get a 'strobe effect' throughout our house and over our entire property (40 acres)."** Others add, **"shadows are cast over the ground and affect my balance,"** and **"shadows from the blades sweep over our house and yard and ruin our quality of life."**

Physical reactions can be pronounced. In England, where the effects of wind power plants have been widely documented, Dave Brierley, a former policeman living in Cumbria, tells a reporter, **"I live 1,000 meters south of the wind farm and my wife, who is asthmatic, gets very distressed when the wind is coming from the north because she can feel her breathing trying to synchronize with the thump of the blades."**

A newspaper article titled *Wind farms 'make people sick who live up to a mile away'* reports on the findings of Amanda Harry, M.D.: All but one of 14 people living near a wind power plant in Cornwall have experienced increased numbers of headaches, and 10 say that they have had problems sleeping and suffered from anxiety. She says, "People demonstrated a range of symptoms from headaches, migraines, nausea, dizziness, palpitations and tinnitus to sleep disturbance, stress, anxiety and depression."

People living near wind turbines aren't the only ones affected. Federal law requires most turbines to be fitted with constantly flashing lights, and they can be seen for miles. One observer of the Waymart facility describes **"the multitude of red blinking aircraft warning lights that now trace across the ridge top at night." Others see those turbines 10 to 15 miles away. Of the Montfort wind power plant in Wisconsin, a person writes, "You see them from far away, lights and all." The Fenner turbines can be seen 25 miles away.**

What about the effect on property values? **Despite claims by wind power supporters that turbines have no depressive effect on nearby home sales, there's a lot of evidence to the contrary in areas where the landscape is the attraction.** At a public meeting on a proposed wind power plant in Lowell, Vermont, a realtor trying to sell a farm near the site tells a company representative his assertion that land values won't decrease is "ludicrous." **Don Maclure says that when he informs people interested in buying the farm about the proposed project he never hears from them again.**

In England, newspaper articles highlight the problem with such titles as *Wind turbines made our home unsellable*, *Wind farms stunt growth of property value*, and *Potential losses could run into millions*. Kyle Blue, a realtor in Cumbria, reports that when his company auctioned a farmhouse a half-mile from proposed turbines, it fetched nearly 30% less than its valuation before the plans were announced. Another farmhouse attracted a buyer who said the wind power plant wouldn't bother him because he was keen on renewable energy. "Then he went away, did some research and changed his mind," says Mr. Blue. In the Lake District, a judge ruled that a wind power plant reduced the value of a home 1,790 feet away by 20%.

Typically, wind power developers target economically-stressed communities, and make all sorts of promises. Jobs? Wind power plants generally employ one or two full-time workers, depending on the number of turbines. During construction, most workers are brought in from elsewhere by the contractors, because specialized skills are required. Tax revenues? Ask the people in Waymart, Pennsylvania, who now find that the wind power company there is trying to redefine turbines from real property to equipment, and thus reduce its tax burden from more than $1.3 million to less than $30,000 annually, according to the calculations of outraged citizen Ray Vogt. Apparently, the town is afraid that if it objects, it will be sued.

Wind power developers are not mom-and-pop operations. **They are huge corporations that have figured out they can make extraordinary amounts of money off the public purse, and have hired lots of lobbyists to make sure the money keeps flowing. A wind-industry lawyer said two-thirds of the value of these projects is in the tax benefits. In other words, corporations make more money off the tax breaks and other perks than from selling the electricity. One of the leaders in wind energy, FPL Group, had profits of $3.36 billion from 2001 through 2003, and paid just 0.4 percent of that in state income taxes. Those tax breaks mean more taxes paid by the rest of us.**

The only real beneficiaries of wind power plants are the investors and the landowners who lease the property. If you want to find out what neighbors to these facilities really think, go on the Internet and do searches. We have a lot of information and links at <www.GreenBerkshires.org>. Make sure the people you contact aren't leasing land to the companies (or employed by the companies, as in Fenner, NY), or haven't been silenced with confidentiality agreements (yes, that's happening – complaining neighbors are reluctantly accepting payments to be quiet because they can't sell their properties, and can't afford to sue.) Look for ordinary neighbors, and you will find out what it's like to have these wind power plants near your home. And, by the way, when you're making up your mind about wind power plants, notice where they're not being built: People in wealthy communities support them, just not in their back yards.

Eleanor Tillinghast is co-founder of Green Berkshires, Inc., an environmental group based in Great Barrington MA. Its website is www.GreenBerkshires.org

(34) 50

Promises gone with wind

Donald F. Goetz

Scranton Times Tribune

February 7, 2004

[Reprinted with permission from Mr. Goetz, who lives a quarter-mile from Florida Power & Light's Waymart wind power plant, which consists of 43 1.5 MW wind turbines on Moosic Mountain in Clinton and Canaan Townships, Wayne County, Pennsylvania.]

To the Editor:

I recognize that there is a place for the wind energy industry. But your readers should be aware of the negative impacts of wind energy on health, environment and welfare. The constant noise in your back yard, even inside the house. The incessant flicker caused by the shadow that sweeps across your land when the sun is low. The interference that makes listening to your television and radio a headache. The 20 acres of surrounding landscape consumed by each wind turbine. The visual intrusiveness. The garish string of strobe lights by day and blinking red lights by night.

Donald F. Goetz

Ouest France 23 octobre 2003

Côtes-d'Armor

Des riverains de la centrale de Plougras dénoncent "l'enfer sonore"

Eoliennes bruyantes, vent de Fronde

A Goariva, sur la commune de Plougras, la récente centrale éolienne fait réagir les proches riverains. Dénonçant des nuisances sonores "insupportables" et des travaux d'insonorisation longs et peu efficaces, ils exigent qu'une solution soit apportée rapidement. Enquête.

Goariva. Une dizaine de maisons. Altitude 315 mètres. Particularité: un silence exceptionnel. Du moins, c'était encore le cas il y a quelques mois avant que n'y soient implantées huit éoliennes d'une hauteur de 46 mètres (1). Fonctionnelles depuis juin 2003, "**ces monstres d'acier**", comme les appelle Florence Tallec, une habitante du site, ont considérablement modifié l'environnement sonore de ce hameau situé à quelques kilomètres de Plougras.

"**Des maux de tête**"..."

"**C'est un supplice chinois, un sifflement continu, ça vous coule dans les oreilles; même quand elle sont éteintes on a l'impression que cela continue**", explique Florence Tallec. En cause ? Les alternateurs situés en haut des appareils. Cette riveraine parle également d'un "**bruit type alarme de voiture quand les pales tournent rapidement**". Sa maison est située à 700 mètres des éoliennes mais "**la maison la plus proche n'est qu'à 300 mètres**". Les Tallec et la vingtaine de riverains concernés ont constaté "**maux de tête, acouphènes et insomnies**", voire même "**des dépressions**" et se demandent "**si les fréquences très aiguës des éoliennes ne sont pas à l'origine de ces maux**"

Le maire de Plougras, François Morellec, confirme ce problème de nuisance sonore. A mi-juillet, il a adressé un courrier à la société Jeumont Industrie, constructeur de ce nouveau type d'éoliennes (des J48 dotées d'un nouveau type d'alternateur qui augmente sa puissance) lui demandant "**de réaliser des travaux d'insonorisation le plus rapidement possible**". Il dit "**être étonné de la nuisance sonore**" d'autant que le site de Goulien (2) visité pour rassurer les riverains de Plougras, n'en présentait aucune. " **Mais il ne s'agissait pas des J48 de Jeumont ! Le conseil a donc accepté le projet sur des bases incomplètes et fausses**", précisent les riverains. Un sentiment partagé par le maire qui estime "**avoir été dupé**".

Responsable de la conduite du site et de sa maintenance, Jeumont SA, filiale du groupe industriel français Framatome - numéro un mondial du nucléaire - rappelle que "**des travaux d'isolation adaptés** (isolation phonique de la nacelle et des pales, réduction des émissions sonores des moto-ventilateurs) **ont été entrepris et qu'ils seront terminés prochainement**".

Mais sur le site, les riverains perdent patience: "**Déjà, à l'époque nous n'avons pas été consultés pour le projet mais seulement informés**" (NDLR: le permis a été délivré en 2001, l'enquête publique n'étant pas obligatoire à cette date). Et doutent de l'efficacité des travaux: "**Jeumont dit avoir fait des progrès mais nous les percevons à peine**". Si rien ne change d'ici la fin du mois, ils se disent prêts à demander au préfet Marie-Françoise Haye Guillaud **"l'arrêt du site"**.

De son côté, Francis Morellec précise que **"le conseil n'a encore rien décidé. Nous attendons la fin du mois pour réagir"**. La commision des sites devrait passer mercredi pour constater l'avancement des travaux.

Hélène PERRAUDEAU

(1) En régime de croisière, la centrale pourra alimenter environ 7600 ménages (hors chauffage);
(2) Dans le Finistère; fabricant Neg Micon, pilotage société CEGELEC

Des silencieux à Plougras, mais des nuisances persistent chez les riverains

09.07.2004

Ouest France

Les huit éoliennes du parc de Plougras ont été agrémentées de silencieux mais des nuisances persistent chez les riverains. Jeudi, le sous-préfet les a rencontrés pour envisager des solutions, en particulier avec l'isolation des maisons. Les basses fréquences sont en cause.

Parfois passionné, mais au final « positif », selon le sous-préfet, Alain Rousseau, le dialogue engagé, jeudi matin, à la mairie de Plougras, a permis de faire un point précis des nuisances provoquées par la ferme éolienne de la commune. « On avance », affirme le représentant de l'État

Entouré des riverains concernés, soit cinq familles, du fabricant, Jeumont SA, du directeur de la Ddass et des représentants de la Fapen (associations environnementales) et de l'association des Abers (protection de l'environnement et de la qualité de vie), Alain Rousseau a pu « prendre acte de la réalisation des divers travaux demandés, notamment la mise en place de silencieux sur les éoliennes ». Le mois dernier, la société Jeumont s'était engagée à équiper l'ensemble du parc, en service depuis un an, pour limiter les nuisances sonores.

Autre engagement tenu : « Pendant trois semaines, une étude a été menée chez les riverains par un cabinet pour apprécier si la ferme éolienne respecte la réglementation, reprend le sous-préfet. Elle démontre que, hors périodes de faible vent et seulement la nuit, lorsqu'il y a moins de bruit résiduel, la ferme est conforme à la réglementation. » Ce qui veut dire que la différence entre le bruit ambiant et celui fait par l'éolienne n'excède pas 3 décibels la nuit et 5 décibels le jour.

Basses fréquences

Néanmoins, « même si l'on considère que la réglementation est respectée, les riverains continuent de se plaindre » reconnaît le sous-préfet, qui ne « veut pas lâcher le dossier tant qu'il ne sera pas réglé ». Cette gêne n'est plus liée au sifflement persistant mais « elle semble provoquée par des basses fréquences, souvent plus dérangeantes à l'intérieur des maisons qu'à l'extérieur » , explique Alain Rousseau.

En fait, « on a agi sur l'émetteur du son. Il s'agit maintenant d'évaluer quels sont les matériaux qui entrent en vibration à cause de ces fréquences. Un acousticien va donc tenter de caractériser le phénomène et de proposer des solutions concrètes dans les maisons ». La société Jeumont s'est engagée à financer les travaux.

Une solution qu'apprécie l'association des Abers, dont le vice-président, Bernard Le Borgne, était présent, hier, à Plougras. « Ce parc commence à coûter très, très, cher à la société Jeumont », remarque-t-il. Son association conteste néanmoins vivement les mesures sonores effectuées par le cabinet privé. Mais se félicite que l'opérateur ait décidé d'arrêter les éoliennes lors des dépassements sonores relevés « pour les périodes de vent inférieur à cinq mètres par seconde ».

Pour Bernard Le Borgne, « dans ce dossier, c'est un problème législatif qui est aussi soulevé. Ce qui arrive à Jeumont serait arrivé à la plupart des autres opérateurs. D'ailleurs, depuis, la société ne construit plus d'éoliennes à moins de 500 mètres de toute habitation. A Plougras, les riverains qui subissent les nuisances sont installés de 300 m à 900 m du parc. »

L'association souhaite que « la loi fasse en sorte que les études d'impact soient menées par des bureaux compétents ». Sur la situation spécifique de Plougras, Bernard Le Borgne affirme que son association a obtenu du ministère de la Santé « une étude sur la santé des habitants ». Le sous-préfet, lui, convoquera une nouvelle réunion de bilan à l'automne.

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(36)

"And the beat goes on . . .and on and on"

Hawke's Bay Today (New Zealand), February 18, 2006

KATHY WEBB

They call it the train that never arrives. It's a low, rumbling sound that goes on and on ... and on.

Sometimes, in a stiff easterly, the rumbling develops into a roar, like a stormy ocean.

But worst of all is the beat. An insidious, low-frequency vibration that's more a sensation than a noise. It defeats double-glazing and ear plugs, coming up through the ground, or through the floors of houses, and manifesting itself as a ripple up the spine, a thump on the chest or a throbbing in the ears. Those who feel it say it's particularly bad at night. It wakes them up or stops them getting to sleep.

Wendy Brock says staff from Meridian Energy promised her the wind turbines at Te Apiti, 2.5km [1.6 miles] from her Ashhurst home in southern Hawke's Bay, would be no noisier than waves swishing on a seashore.

"They stood in my lounge and told me that."

But during a strong easterly, the noise emitted by the triffid-like structures waving their arms along the skyline and down the slopes behind the Brock family's lifestyle block is more like a thundering, stormy ocean. Sometimes it goes on for days. And when the air is still, there's the beat - rhythmic and relentless, "like the boom box in a teenager's car".

"It comes up through the floor of our house. You can't stop it."

Mrs Brock says she can feel it rippling along her spine when she's lying in bed at night. Blocking her ears makes no difference.

"It irritates you, night after night. Imagine you've done your day's work, then you go to bed, and there's this bass beat coming up through the floor and you can't go to sleep. You can't even put headphones on and get away from it.

"My older son sometimes gets woken up by the noise. He gets up and prowls around the house."

She tells of other Ashhurst residents who "feel" the sound hitting their chests in the Ashhurst Domain 3km [1.9 miles] from the turbines. She says one woman is so distressed by the sensation she has put her home on the market.

Not everyone in the village hears the infrasound – Mrs Brock reels off the names of residents wondering what the fuss is all about - but says those who do feel the sound are distressed by it and have nowhere to turn for redress.

There's little point complaining to the Tararua District Council because all it does is record each complaint and forward it to Meridian, and nothing ever happens.

"What are they (the council) going to do to Meridian - fine them, or shut down the turbines?" asks Mrs Brock.

Meridian is dismissive of complaints about noise from Te Apiti.

"Infrasound is just not an issue with modern turbines," insists spokesman Alan Seay.

"We take it very seriously. We have looked into it seriously, but the advice we are getting from eminently qualified people is that it is just not an issue."

Many people claiming to be putting forward scientific argument about noise from turbines "are not qualified in this area of expertise. I have a problem with some of their statements", Mr Seay said.

He asked Hawke's Bay Today for the names of those complaining about noise from Te Apiti.

Asked why he wanted the names, he replied: "There is a group of people there. They are opposed to wind farms per se".

Asked why he thought they were opposed, Mr Seay said "I don't want to speculate. They just are. Possibly for the visual impact."

Meridian had complied with all legal requirements for sound emissions from Te Apiti, and "the people of Ashhurst are very happy to have those turbines there. They have become an icon," Mr Seay said.

Meridian is currently appealing noise restrictions placed on its proposed 70-turbine wind farm at Makara, near Wellington, where some houses will be about 1km [0.6 miles] away, and downwind of, the turbines.

John Napier lives on the Woodville side of the Te Apiti turbines, about 2km [1.24 miles] from the nearest one.

When they first began operating, he couldn't believe the roaring noise they made.

"We can hear it in our bedroom at night."

One night, about 2am, he got out of bed to check whether the bedroom windows were vibrating, and about five times since, he has been woken up and thought "they're making a racket tonight".

He doesn't hear the infrasound beat so much. It's mainly "a roar like a train going through a tunnel or over a bridge, but it never stops".

He complained to Meridian about the noise, and the company put a noise meter on his property for a couple of weeks, but wouldn't tell him the results.

"Wind farm companies say noise from turbines is not an issue, but it is an issue all right. I would be very concerned if I lived in Karori (near Makara, in Wellington)," Mr Napier said.

Harvey Jones, who lives in a valley 3km [1.9 miles] from Te Apiti, says there is an easterly wind blowing across the wind farm about 10 percent of the time. The wind goes across the top of the hill, but the noise from the turbines rolls down the valley. It sounds like a train constantly passing by, and the stronger the wind, the louder the noise. When there's a westerly blowing, he can even hear the turbines in Woodville, 6-7km [3.7 to 4.3 miles] away.

"Once you get tuned in to it you can easily pick it up," he says.

Mr Jones says the amount of noise generated by the Te Apiti turbines was unexpected, and landowners prepared to put turbines on their land at Te Pohue should think very carefully about the possibility of a repeat scenario.

He predicts disaster for the residents of Makara and Karori.

"They're going to get hammered, but they don't realise."

Steve Griffin, of Te Pohue, is secretary of the Outstanding Natural Landscape Protection Society, formed to oppose two windfarms proposed for his area on the Napier-Taupo road.

Lines company Unison has resource consent to put up about 50 turbines, and Hawke's Bay Windfarms plans to erect 75 turbines nearby.

The landscape protection society is appealing all the consents in the Environment Court.

Mr Griffin, who is "sick to death of wind farms", says the prospect of 128 giant industrial turbines visually disrupting pristine skyline and covering more than 16km [10 miles] of prominent mountain range near Te Pohue is bad enough. But he and other residents are worried sick about the noise potential – both normal-range and infrasound – from the turbines. Each turbine will have an 80m tower and three 45m blades. They will be 125m high and 90m wide, each taking up the equivalent of 1.5 rugby fields.

They will encircle Te Pohue village and its school, in a valley downwind of the turbines in prevailing winds – and nobody in authority seems to care, he says.

The Government has thrown the doors wide open to wind farm developers, in a bid to meet its Kyoto commitments; there are no national guidelines specific to wind turbines. That stance is unbalanced and unfair, Mr Griffin says.

"Our view is that while wind farms are part of our energy solution, sites must be selected in a socially responsible manner.

"They should not be placed within 5km [3 miles] of schools, hospitals, rest homes, or the private homes of those not involved with a wind farm development."

They should also be kept out of coastal, and recreation areas, and those with high scenic value, he says.

The landscape protection society wants the Government to establish national guidelines for wind farms, and review noise-testing standards to include measurement of low-frequency sound.

Low-frequency sound – sometimes called infrasound – is controversial.

Dr Geoff Leventhall, a noise vibration and acoustics expert from the UK who looked into infrasound at the request of Genesis Power, says "I can state quite categorically that there is no significant infrasound from current designs of wind turbines".

He says "the ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it". Engineer Ken Mosley, of Silverstream, has an entirely different view.

The foundations of modern turbines create vibrations in the ground when they are moving, and also sometimes when they are not moving, Dr Mosley says.

"This vibration is transmitted seismically through the ground in a similar manner to earthquake shocks and roughly at similar frequencies.

"Generally, the vibrations cannot be heard until they cause the structure of a house to vibrate in sympathy, and then only inside the house. The effects inside appear as noise and vibrations in certain parts of a room. Outside these areas, little is heard or felt.

"However, the low frequency components of the noise and vibration can cause very unpleasant effects which eventually cause the health of people to deteriorate to an extent where living in the property can become impossible."

Dr Mosley says that wherever wind farms are built close to houses, people complain about noise and vibration.

He quotes a scientist in South West Wales, David Manley, who has been researching noise and vibration phenomena associated with turbines since 1994.

An acoustician and engineer, Dr Manley writes "it is found that people living within 8.2km [5 miles] of a wind farm cluster can be affected and if they are sensitive to low frequencies they may be disturbed".

Two GPs in the UK have researched the health effects of noise and vibrations from turbines. Amanda Harry documented complaints of headaches, migraines, nausea, dizziness, palpitations, sleep disturbance, stress, anxiety and depression. People suffered flow-on effects of being irritable, unable to concentrate during the day, losing the ability to cope.

Bridget Osborne, of Moel Maelogan, a village in North Wales, where three turbines were erected in 2002, is reported as saying "there is a public perception that wind power is 'green' and has no detrimental effect on the environment, but these turbines make low-frequency noises that can be as damaging as high-frequency noises.

"When wind farm developers do surveys to assess the suitability of a site they measure the audible range of noise but never the infrasound measurement – the low-frequency noise that causes vibrations that you can feel through your feet and chest.

"This frequency resonates with the human body, their effect being dependent on body shape. There are those on whom there is virtually no effect, but others for whom it is incredibly disturbing."

Dr Mosley says wind-power generators in New Zealand are aware of such literature on turbine noise and infrasound from all around the world.

"Are they therefore just ignoring what is happening in the rest of the world in the hope that once turbines are up and running, people will quietly endure, or when the noise/vibration situation really starts to damage their health, the community will cut their losses, leave their homes and quietly fade away? Of course, wherever they end up, they must still pay their electricity bills, which is rather like paying the landlord who has evicted you."

The New Zealand Wind Energy Association, which did not return calls from Hawke's Bay Today, acknowledges that turbines produce infrasound, but insists it is so minimal from modern turbines that human beings cannot perceive it. Its website says "there is no evidence to indicate that low frequency sound or infrasound from current models of wind turbine should cause concern."

Infrasound was more of a problem with older turbines, which had their blades downwind of the turbine tower, the association says.

"That caused a low frequency thump each time a blade passed behind the tower."

In contrast, modern turbines "have their blades upwind of the tower, thus reducing the level of this type of noise to below the threshold of human perception, thereby minimising any possible effect on human health or wellbeing".

The association has published excerpts of a report by Dr Leventhall, who suggests that infrasound is a concept that could be classified as pop-science, seized upon by emotionally-overwrought wind farm opponents.

"When a group of residents decides to object to a development, they often support each other with strong emotions, which can sometimes lead them astray. The emphasis on low-frequency noise is an example of this. Over the past 30 years there has been a great deal of confusion and misinformation about low frequency noise, mainly in the popular media. Much of it can best be described as "hot air" but complainants' uncritical acceptance of what they read in unreliable sources has two unfortunate effects:

- It detracts from those people who have genuine low-frequency noise problems, often from industrial exhaust fans, compressors and similar.
- It undermines the credibility of the complainants, who may be harming their own cause in their apparent 'grasping at straws' approach."

Dr Leventhall goes on to say "the rational study of low frequency noise, its effects and criteria for control, has been bedeviled by exaggerations, half-truths and misrepresentations, much of it fomented by media stories over the last 35 years. The result in the UK, and it is probably similar in other countries, is that an incorrect concept – 'low frequency noise is a hazard' – has taken root in the national psyche, where it lies dormant waiting for a trigger to arouse it. The current trigger is wind turbines."

Dr Leventhall says:

- High levels of low-frequency noise are needed before people can perceive it, and the levels must increase as frequency reduces.
- The ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it.
- When there are problems with predominantly low-frequency noise, that is because assessment methods do not cater for it. That leads to the noises being dismissed as not being a nuisance, which in turn leaves unhappy complainants in a distressed state.

Up on the Napier-Taupo road, the printer in Steve Griffin's office is working overtime in preparation for an Environment Court battle. It might be a David and Goliath confrontation, but there's too much at stake to sit back and take it quietly, he says.

Note: "*Hawkes Bay Today* is the regional daily newspaper for Hawkes Bay. Our circulation area ranges from Mahia in north to Dannevirke in the South and to the central ranges in the west. We are also the youngest newspaper in New Zealand, launched on May 3, 1999."

See:

http://www.hbtoday.co.nz/localnews/storydisplay.cfm?storyId=3673106&thesection=localnews&thesubsection=&thesecondsubsection

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Calvin Luther Martin

From: "KATHERINE BUSH" <Katherine_26435@msn.com>
To: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Friday, February 17, 2006 8:34 AM
Subject: Re: CD's

Mr. Gordon Yancey is the owner of Flatrock Inn. He is the gentleman whom my husband interviewed in the video we did of Tug Hill. I think I mentioned that video to you. Gordon has lived there all his life, I think he told me. We talked on the phone for a very long time about a month ago. His establishment is a bar/restaurant type business and he also has rooms that mainly ATV people use while they are out riding. Who knows now long those people will be able to use those vehicles due to the wind turbines. It is a huge business up there too. I do not know how some of those people will make it now. The Inn is surrounded by wind turbines and is absolutely heartbreaking to see in the video, and worse to hear Gordon talk about his life NOW. He has a lot to say and will talk to anyone who is in jeopardy of having wind turbines in their future. When we spoke, he told me that sleeping with them is nearly impossible. To quote him, "Take your vacuum cleaner, put it next to your bed, plug it in, turn it on, LEAVE IT ON, and try to go to sleep."

If you decide to call him, tell him I gave you his number. If he has forgotten my name, tell him that we are the ones that did the video of him. He may have forgotten my name since he has talked to many about this. He said that 8:00 PM is usually a good time for him to talk. I would think that the w/end, obviously, may be busier, but he will tell you if you need to call back. We found him to be a good source of info and almost has a "need" to share this information with others. I think you will like him.
Gordon Yancey
Flatrock Inn
Loweville, NY 13367 (315-376-2332)

or e-mail at gordon@wildblue.net

to see if it is the CD, my computer, or ME. I heard up to the part where the Mrs. talked about her migraines. What I have heard so far is just heartbreaking.
I meant to ask you if I have permission to copy and distribute. There are MANY who NEED to listen and see both of these. Thank you so much for all of your hard work and for sending them to me. I do so appreciate it and will not make any copies until I hear from you. I cannot wait to share all of this with my committee.
Katherine

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AGRICULTURAL RESOURCE CENTER

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(715) 425-0640 • FAX (715) 425-4479

UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY
This survey summary completed Thursday, May 16, 2001.
by David E. Kabes and Crystal Smith.

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

3. Have the wind turbines in Lincoln Township positively or negatively impacted your health?

Question # 3

1 They have disrupted the sense of peace we had by living in the country, adding to our stress. More or a psychological health effect. Who know what the long term affects of low frequency sound waves are?

2 The noise, flashing lights, interrupted TV reception, strobe effect and possible effect of stray voltage has created a level of stress and anxiety in our lives that was not present before the turbines installation. From the beginning there has been a lack of honesty and responsibility on the part of WPS.

3 Constant reminder of ugly use of wasted taxpayer money on out dated technology.

4 Less sleep brings stress on the job and family.

Who knows the long term affects.

5 Stray voltage has caused problems with our cattle. Eventually it will start to cause problems with humans. It's just a matter of time.

Free and clean electricity is positive for everyone's health.

Mental

Safer for production of current and better for the future production and conservation. No nuclear reactors which are known to cause health problems.

When you really don't like something I guess it does affect you!

Too early to tell about unknown long-term negative affects. Also electric prices have gone up.

Pleasing to see, relaxing to watch

6 Not that we're aware of. NO NEW WIND TURBINES

They have caused less CO_2 to be created because fossil fuels were not burned to generate electricity.

7 Noise bothers me, sight of landscape with windmills depresses me.

Don't know how it could affect your health in the future.

Unable to determine that fact.

2 I wake up with headaches every morning because of noise causes my to have very restless sleep at night!

I feel this is a statement that is undeterminable at this time.

How will a person know when the turbines have only been running for 2 hours.

9 Make living in the Town less desirable and causes stress on my family and me!

10 They affect my peace of mind and do not belong in rural areas where there are homes.

11 Gotten me mad, high blood pressure, and not a good night's sleep!

Non-use of fossil fuels

12 Colds that last all winter and also coughs.

I live about 4 miles from them.

I think the windmills are a good thing and very positive for the town.

13 They have changed the life style of peaceful country living. It makes one sick. They could have been put in places where they would not have bothered people.

14 Haven't seen any good for us around here.

15 Arthritis has been worse this past fall and winter than it has ever been. Maybe stray voltage.

It's a good feeling to have a good feeling of not polluting the air!

16 All family members have more headaches and joint pain.

17 If it's causing problems in my cows, what's it doing to me?

18 Hard on the nerves, very sad that our neighbors did this to the neighborhood. If the Town wants more why don't they put them by the board members that wanted them.

19 Our whole family has been affected. My husband just went to the doctor because of his stomach. He hates them. We have fights all the time about them. It's terrible. Why did you put them so close to our new home and expect us to live a normal life. If it isn't the shadows it's the damn noise. The only people that think they are so great and wonderful are those who really don't know. Great way to get energy but why should certain people get laughed at and pay the price.

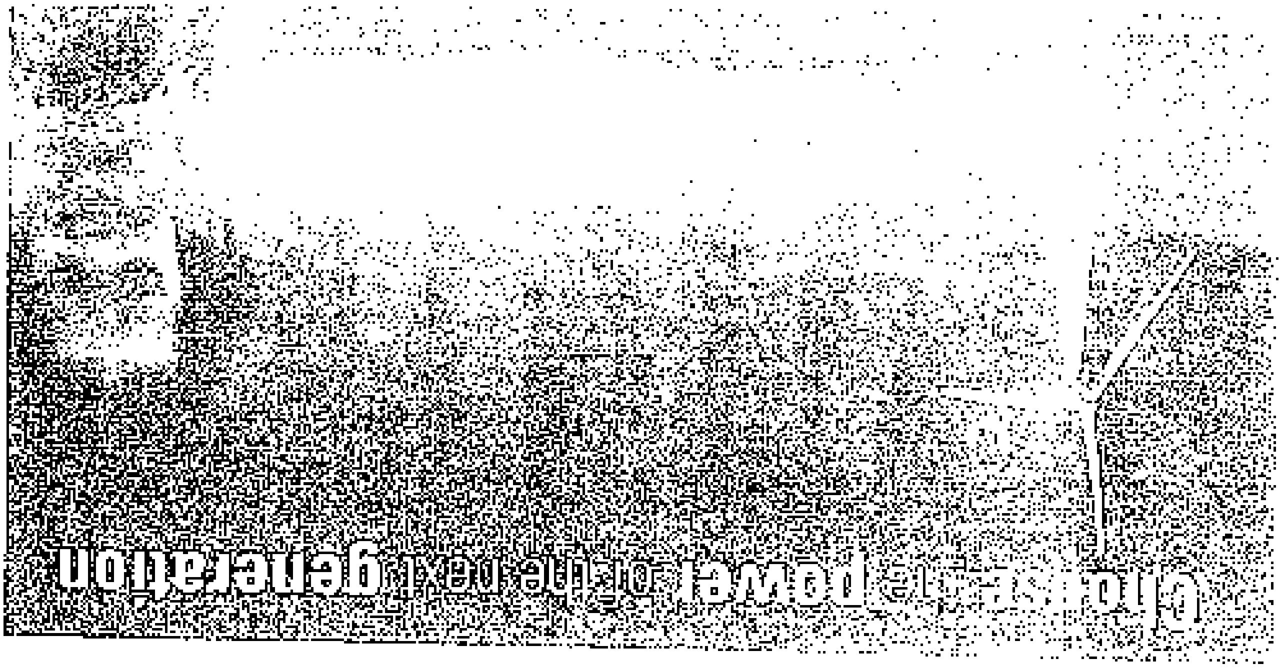
Shows we're showing concern for future generations.

Haven't affected me but I believe this would be a long-term issue!

20 We have no way of knowing long-term affects. Growing concerns with stray voltage and its affect on health. We've had frequent headaches, which we didn't have before. Especially in the morning, after sleeping at night. We need answers!

21 It has taken a long time not to have a totally negative attitude toward their existence. Now I just wish they weren't so close to my home. I doubt I will ever get "used" to them. Lucky I'm far enough away, I can understand the problems they are creating with anyone close to them. See if Door County wants them!!

22 Strobe light, headaches, sick to the stomach, can't shit everything up enough to stop the strobe coming into the house.



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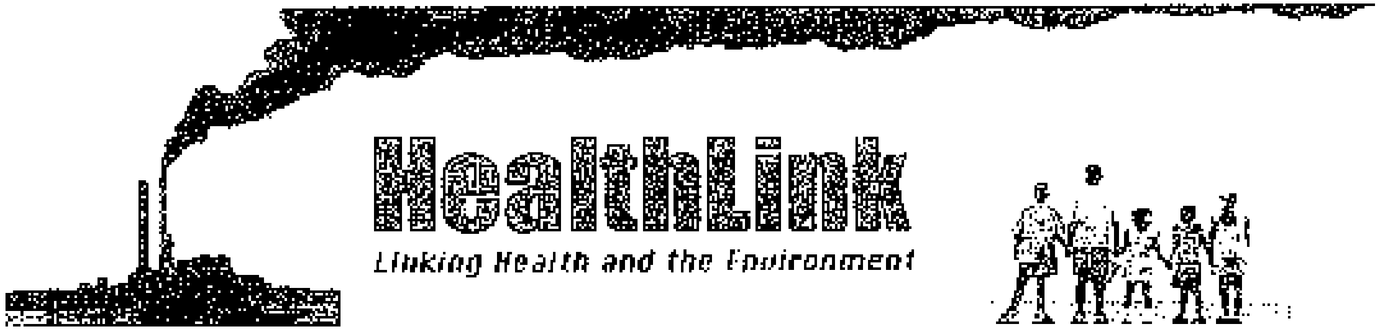
Sign up today to support

NEW WIND ENERGY

A program for customers who want to help our environment and make a difference for future generations

(40) 56



Linking Health and the Environment

Home | What's New | It's Our Health | Power Plant Cleanup | Wind & Renewable Energy | NS Air Grant | National Issues | Pesticides | PetLink

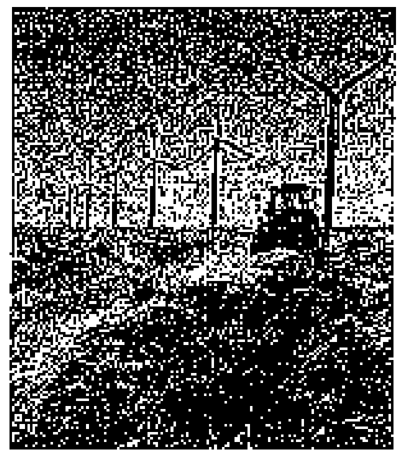
Wind Energy
Why Wind
Wind Events
Wind Economics
Wind Pros/Cons
Wind History
Wind Technology
Wind in Mass
Resources
Solar and Ocean Energy

HealthLink Supports Wind Energy

See HealthLink's Presentation on Wind

Wind: An Energy Bonanza

The U.S. possesses hundreds of billions of dollars' worth of a free, non-depletable, zero-emissions resource: wind (1). The urgency to develop renewable energy technologies that began so strongly in the 1970s following two oil price shocks, fizzled in the 1980s and 1990s. Fuel prices plummeted to artificially low levels and early renewables projects underwhelmed.



Recent technological breakthroughs however, have made wind power and other renewable energy sources viable components of a 21st-century energy solution. They're cost-competitive, reliable, and more efficient. Adopted into the mix, wind can help counter over-reliance on any one source and encourage the production of a leading source of clean, low-cost renewable energy.

HealthLink Wins Wind Grant

February 14, 2005

Grant Money Will Encourage Local Windpower

HealthLink has received a grant to forward the installation of wind turbines in local communities. Through the awarding of this money, the Massachusetts Technology Collaborative is looking to HealthLink to assess the current state of interest in wind energy in North Shore coastal communities and to encourage the installation of wind turbines in each town or city. Who will own the turbines? What might suitable locations be? How soon will they pay back? HealthLink will hold public forums and meetings to present the issues to the public for discussion and as a basis for decision-making.
's volunteer core was pleased with the grant which will help them to continue their work to protect public health by reducing toxic pollutants in the environment.

"We are very excited about being given the financial support to spread the word about a technology that produces energy from a free, inexhaustible fuel which does minimal damage to the environment and produces no harmful emissions," stated Jody Howard, one of HealthLink's key volunteers on the wind project.

"Understanding all the health damage caused by burning fossil fuels, we have concluded that the only hope for a healthy future is renewable energy, and in the northeast, the only practical renewable is wind. With this grant, the hard work of figuring out how to install wind responsibly can begin in the community," said Jane Bright

Added Gail McCormick, "Today's wind turbines are sleek, elegant and environmentally friendly. They are certified user-friendly by planet earth! Building a better tomorrow means taking action today!"

HealthLink has many plans to make the public aware of the benefits of wind energy. They include an Earth Day program at Salem State College with sessions, student research projects, and general activities open to the public; a spring wind festival on Lynn/Nahant causeway celebrating the power of wind, with participants' kite flying, sailing, windsurfing, twirling pinwheels, playing woodwinds, racing wind-powered go carts, and other wind-propelled devices; and working with local manufacturers and unions to develop a healthy turbine industry.

To launch the public awareness campaign, HealthLink is launching an information-gathering project. Travelers who have spotted wind turbines on their visits are asked to send photographs of these installations. These photos will be posted on the HealthLink website (www.healthlink.org) with informative descriptions and displayed in a traveling show.

"Clean air is our bottom line," said Lynn Nadeau. "Windpower is in the game. It's time to get off the bench!"

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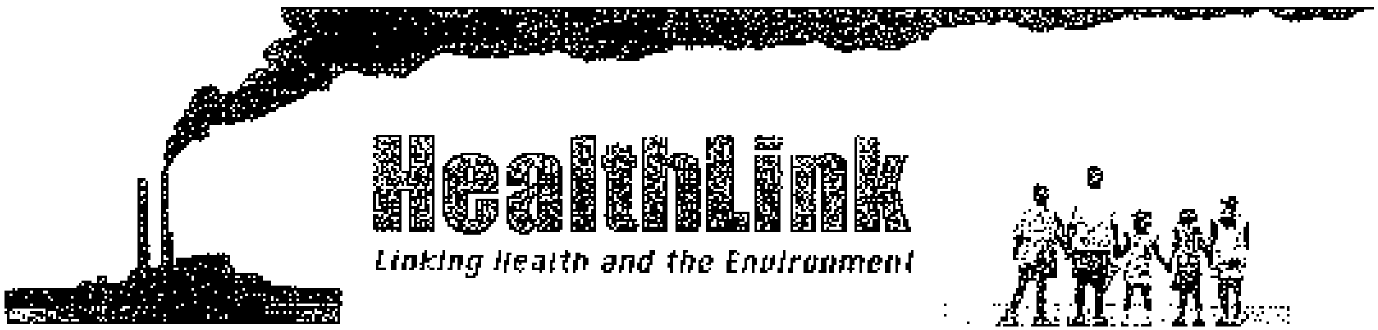


Wind... Past and Present:
7,000 years of wind energy

The Present:

2010

Pennsylvania, a coal state, will generate at least 10% of its energy from wind

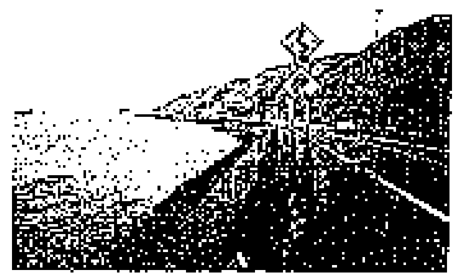
2001

Denmark now produces 20% of its power from wind and aims to generate 50% of its electricty from renewable energy (primarily wind) by 2030

By year end 2000, the top countries for wind power

Germany: 6,113 MW
USA: 2,554 MW
Denmark: 2,300 MW
Spain: 2,235 MW
India: 1,167 MW
All others: 2,931 MW

Worldwide: 17,300 MW



The Past

Early 1900s AD: US: small wind turbines used to charge batteries and power radios and other small appliances

1890 AD: Denmark: first wind-driven electric generators, aka, the first true wind turbines

Uses over the next centuries included:

- grind grain
- pulverizing chalk, lime, oil seeds, snuff
- draining lowlands (Holland)
- pumping water for railroads, livestock, crops, and to run sawmills (especially in US)

1100 AD

France and England (and elsewhere): first horizontal axis windmills

600 AD

Persia: windmill building an established craft

200 BC

Persia: first evidence of windmill use

1600 BC

Babylon: plans to use windmills for irrigation

5000 BC

Egypt: wind carries boats along the Nile

SOURCE:
John Berger, Charging Ahead: The Business of Renewable Energy and What It Means for America, 1997

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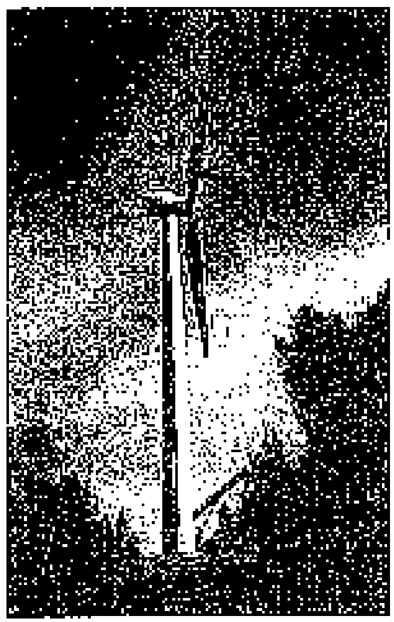
Wind Pros and Cons, Myths and Misconceptions

Myths and Misconceptions



Myths about birds: Turbines kill: Today, turbines are built larger and more efficiently, and as a consequence, they rotate much more slowly than earlier versions (see them spin! Link to video). Even Audubon supports the development and use of wind power. (bird mortality stats p. 155-6, Berger; also, AWEA Wind Energy Fact Sheet: Facts About Wind Energy & Birds)

A bird will collide with a given wind machine about once every 8-15 years; higher incidences may occur in locations with large concentrations of waterfowl or in areas of high migration

The only place where high mortality was found near wind facilities was Altamont (7,000 turbines), where 182 birds were found dead over a two year study. Collisions accounted for most of the deaths; the remainder were attributed to electrocutions from power lines, collisions with wires, and unknown causes

Each year, an estimated 57 million birds dies in collisions with vehicles, 1.25 million in collisions with tall structures (buildings, towers), and 97.5 million in collisions with plate glass. (1994 Kenetech Windpower study results reprinted on AWEA fact sheet.)

Contrast this with deaths from the Exxon Valdez oil spill in Alaska, when more than 500,000 migratory birds perished (1,000 times the amount that die in California's plants each year); Or the 3,000 recorded bird deaths on one fall evening near a coal-fired power plant in Florida (AWEA Fact Sheet)

Myths about Turbines:

Noise - Again, technological advances enable more wind to be converted to rotational torque, which results in less noise. (dB comparison from AWEA slide presentation

Unsafe - The only hazardous materials involved are small amounts of lubricating oils, and hydraulic and insulating fluids. As a result, soil contamination is minimal. Wind energy generators do, however, produce electric and magnetic fields (like all electrical generating facilities).

Expensive - Even without subsidies (due to expire in 2001), wind energy has become competitive with gas

Unreliable - while this might have been true in the 1980s, it's not true now. Modern turbines operate 98% of the time.

Unsightly - Turbines are no longer small and noisy. Far fewer produce the same if not more power. Consequently, they can be spread out over a larger area and are less unsightly. Whether one perceives them as an eyesore or a thing of beauty depends on ones values.

Fossil fuels are cheaper than renewables like wind - the real reason they've been cheaper is the subsidies coal, oil and gas receive; plus, they don't account for environmental costs (in other words, fossil fuels are artificially cheap) - a carbon tax or tax breaks (government research and development funding) would even the playing field or even tip it in renewables' direction

It's difficult to integrate wind energy into existing utilities systems (i.e., the power grid) - Utilities companies, especially those in California, have been doing this successfully since the 1980s. According to a DOE-sponsored study (year TK), operators and dispatchers say engineering issues such as intermittent availability or voltage regulation are of no concern. From an operational standpoint, utilities carry adequate energy reserves so that transmission disruptions (from turbine to supply lines, or from low wind conditions) would not result in power cuts to customers -- (from Wind Energy Weekly #680, 15 January 1996)

Photo by Bob Thresher of Searsburg, VT

Print out this table for easy reference. Then, see Myths & Misconceptions to answer wind power naysayers and inform others

PROS	CONS
Zero emissions - This means no CO_2, sulfur, nitrogen oxide, particulates, trace metals, or solid waste associated with global warming, acid rain, pollution, asthma, and other negative enviro/health consequences	**High initial investment** - About 80% goes to machinery, and 20% to site preparation and installation. *After that, however, there are minimal operating and routine maintenance expenses (no fuel to purchase!)*
Renewable - Wind is in constant supply, unlike coal, oil, and gas, which are finite natural resources	**Noise - Today's large wind turbines make less noise than the background noise you hear in your own home (45 dB versus 50 dB)!** (1)
Free - Because wind (not fuel) powers production, operation costs are effectively zero	**Aesthetic/visual impact** - Today's turbines are sleek and appealing to most people
Declining costs - As installed capacity has increased, costs have dropped 85% in 15 years to <$0.05 per kWh. The DOE has set a goal of $0.025 per kWh by 2002 (1)	Avian mortality - See Myths and Misconceptions
Creates new jobs? and new businesses, strengthening the U.S. economy	**Intermittent** - Wind must blow between 16 mph and 60 mph for power generation (2). At present, wind energy cannot be easily stored. *Electricity providers are trained to divert other energy sources to meet demand, however, and storage technology (batteries) should improve markedly over time.*

Quick Installation - Once a site has been selected and permits approved, wind turbine installation can be completed in months (compared to years for a gas, coal, or nuclear plant)	**Distribution** - Wind turbines must be situated nearby existing infrastructure (transmission lines), or else costs escalate.
Phased growth - You can increase production capacity as your needs grow	
Mass appeal - Opinion polls consistently demonstrate strong popular support for clean-burning, renewable technologies like wind power	
Self-sufficiency - Because it can be developed domestically, wind power reduces U.S. reliance on imported energy	
Price stability - Unlike fossil fuel prices, which fluctuate due to factors beyond our control, wind power comes with a relatively fixed price, one likely to drop considerably over time	
Small footprint - Wind turbine towers interfere little with surface activity (e.g., farming, livestock)	
Low Impact - Wind turbine operation offers little threat to wildlife and natural habitat	

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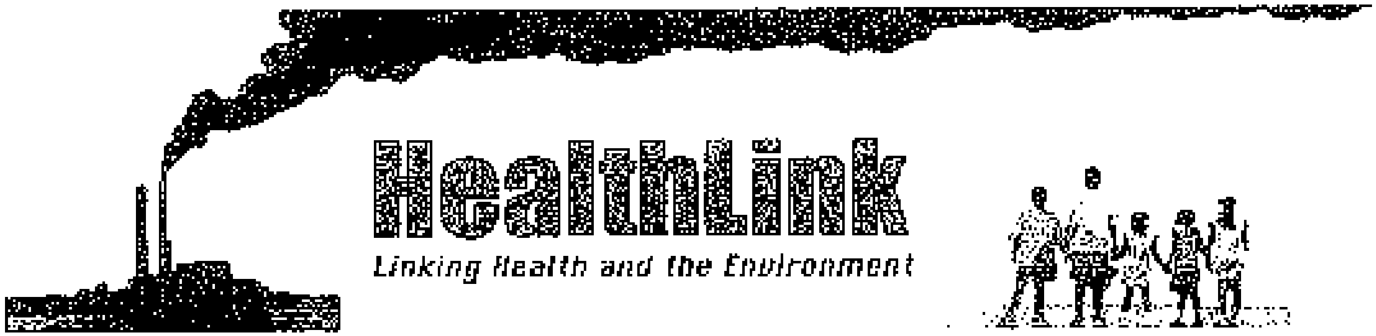
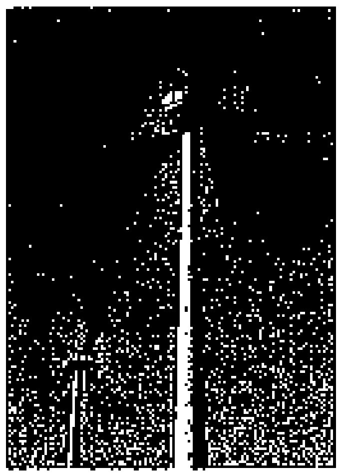


Wind Energy



Wind turbines use energy from the motion of the wind to make mechanical energy, which is then converted to electrical energy. This, in turn, is fed into the utility grid and distributed to customers.

"Wind power, once a costly proposition on the flaky fringe of the energy debate, is going mainstream fast."
(U.S. News & World Report, Nov. 12, 2001, p. 36)

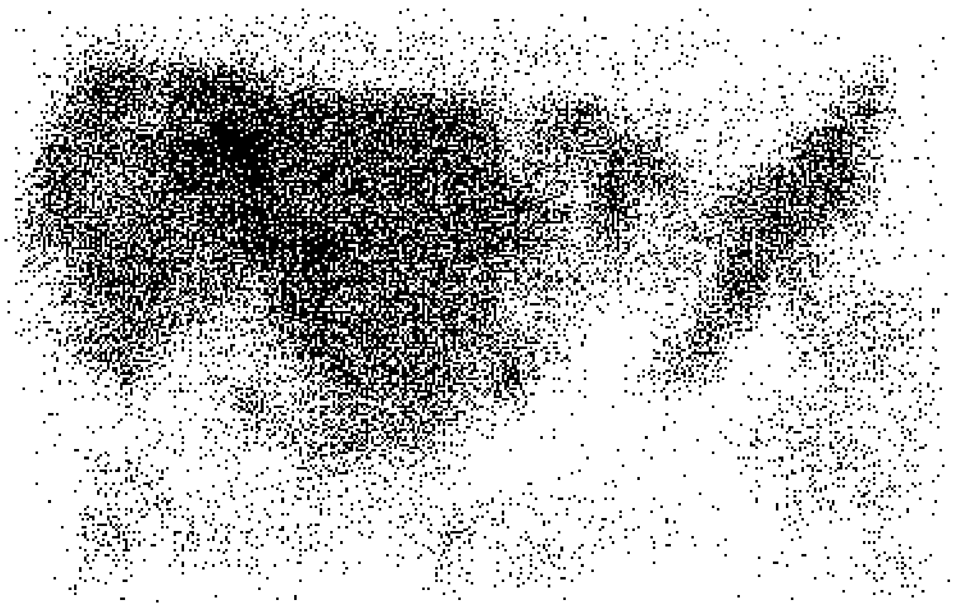
Wind power, like other renewable energy sources, is back on the public's agenda. The recent California energy crisis and nationwide rise in fossil fuel prices made sure of that. Fossil fuels are subject to extreme price fluctuations and more often than not influenced by geopolitical realities.

But U.S. reliance on finite supplies of fossil fuels is more than just risky business. Energy produced from these sources is dirty business. Sure, when prices are low, these sources are relatively easy on consumers' pocketbooks. But here are the hidden costs of fossil fuels, the so-called "cheaper" energy option:

OIL spills... Remember the Valdez?
COAL spews... greenhouse gases, carcinogens, particulates, etc.
NATURAL GAS leaks... harmful chemicals linked to asthma and other ailments

Add to this the liabilities of other traditional energy sources:

DAMS kill... not just fish, but entire river ecosystems
NUCLEAR frightens... no one wants radioactive waste buried in their backyard



Darkest areas of the map have the highest wind. Note the dark areas around the Massachusetts coast. Map by Dennis Elliot.

Wind power projects are ongoing in more than half of the country. CA, TX, IA, MN lead the nation in current output, but many other states, including MA, are potential "powerhouses."

WHY promote wind power?

No technology is perfect. We must weigh the benefits and costs of adopting wind power. Understanding both sides should lead to recognition that any tradeoff is a good one.

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To: The Ellenburg Town Board

YES, I __Donald Gray__
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

(44) 60

YES, I __Marie Gray__
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I __Harold Trombley__
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I __Christine Trombley__
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [signature]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [signature]
(name)

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(name)

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To: The Ellenburg Town Board

YES, I [signature]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Bob Harrigan
(name)

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Todd and Diane Harrigan
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Gary & Jill Harrigan
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Stephen Harrigan
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Aleta LaBarre
(name)
Aleta LaBarre

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Diane Vaincourt
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Kathleen Pearson
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Gerald Vaincourt
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Wayne Cashman
(name)

Reside at [illegible] Ellenburg [illegible] Ellenburg Ctr, [illegible] 12934

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible]
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Connie Tourville
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Gary Tourville
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Jeremy T. Tourville
(name)

....because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Mitchell A. Brassard
(name)

....because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Gerard J. LaBarre
(name)

....because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Bob Hatmoke
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I John Bohan
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Denis Dauphinais
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Donna Bohan
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Frank Abel Jr. + Patricia Abel
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible]
(name)

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To: The Ellenburg Town Board

YES, I [illegible]
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To: The Ellenburg Town Board

YES, I [illegible]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Jay J Carter
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Sandy LaBarre
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible]
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible] (name)

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Joanne LaBarre, [illegible] (name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible] (name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I [illegible] (name)

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Forrest Nelson
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Erik Nilson
(name)

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Nancy Munson
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Elena Normandix
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

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Please include this comment in the record for this proceeding.

From: Another Taxpayer for Wind!

To: The Ellenburg Town Board

YES, I Judith SCHROEDER
(name)

...because it will bring clean energy, new jobs, and economic development to Clinton County.

Please grant approval under SEQRA to the Noble Ellenburg Windpark!

Please include this comment in the record for this proceeding

From: Another Taxpayer for Wind!

(45) 61

NYSEG

October 06, 2005

Mr. Francis LaClair
7741 Star Rd.
Ellenburg Ctr, NY 12934

Dear Mr. LaClair:

Thank you for supporting the development of wind energy in New York State by purchasing 2 blocks of NewWind Energy® per month for a total of 24 blocks per year. Your purchase enables NYSEG to arrange for the delivery of 2,400 kilowatt-hours per year of wind-generated electricity into the New York State power grid.

NYSEG and Community Energy, Inc., (CEI) are pleased to give New York consumers the opportunity to purchase electricity generated from new wind farms in New York. Now, for the first time, New Yorkers are directly influencing how electricity is generated in the state, and we're pleased to see customers like you making a difference. Electricity produced by naturally occurring wind requires no fuel and produces no emissions. The environmental benefits of your purchase equate to a reduction of 8 pounds of sulfur dioxide (SO_2) emissions, and 3 pounds of nitrogen emissions annually. In terms of reduced carbon dioxide (CO_2) emissions, this is equivalent to not driving 2,338 miles per year, or planting 146 trees.

At the end of each year, you will receive a certificate indicating the number of kilowatt-hours of wind generated electricity delivered to the New York grid on your behalf. Using the New York State Public Service Commission tracking system, we will send you an environmental disclosure label describing your contribution to air quality. If you obtain your electricity supply from a supplier other than NYSEG, information about your purchase will be forwarded to them for environmental disclosure purposes.

Enclosed are the **Terms and Conditions** that govern your purchase. Please read them carefully and let us know immediately if you have any concerns or questions.

Again, thank you for your commitment to renewable energy and the development of wind power in New York State. If you have any questions, please call us at 1-800-356-9734.

Very truly yours,

John R Hatfield

John R. Hatfield
Program Manager

(46) 62

NYSEG

December 16, 2005

Important Wind Program Update

Mr. Francis LaClair
7741 Star Rd.
Ellenburg Ctr, NY 12934

Dear Mr. LaClair,

Thank you for your continued support of New Wind Energy through our wind program. Our customers are responsible for reducing toxic emissions from sulfur dioxide by more than 216,000 pounds. Nitrogen emissions have been reduced by almost 59,000 pounds. Environmental benefits are equivalent to not driving nearly 37 million miles, or planting almost 3 million trees each year. The positive environmental impact is very impressive.

Many NYSEG customers have signed up to support wind energy, and we are now nearing maximum capacity for our New York generated wind supply. New wind farms are being built in New York to serve the growing wind demand and they will be on line in 2006. In the meantime, we will be supplying a small part of your annual wind energy purchase from wind farms nearby in Pennsylvania. The only difference you'll see is more wind turbines on the horizon in New York State, thanks to your efforts!

Your participation in the program will continue to be tracked and verified through the NYS Public Service Commission and NYSEG.

Also, we are excited to inform you that during the upcoming year, we will be implementing a new billing system that will include wind charges directly on your regular electric bill. Your total annual wind charge will be divided evenly over 12 months. When the new system is operational and your next payment is due, you no longer will be billed separately for your wind purchase. The new system will cut down on paperwork, postage and time – making your participation in the program easier and more enjoyable. The process will take several months, so check your bill monthly to know when the change is in place

As always, we're more than happy to answer any questions or concerns about renewable energy, so please give us a call at 1.800.356.9734. Thank you again for your commitment to a cleaner, more secure energy future

Best regards,

John R. Hatfield
Program Manager

James A. Carrigg Center · 18 Link Drive · P.O. Box 5224 · Binghamton, NY 13902-5224

www.nyseg.com

47

Economic Impacts of Wind Power in Kittitas County

Final Report

A Report for the

Phoenix Economic Development Group

by

ECONorthwest

888 SW Fifth Ave, Suite 1460 Portland, OR 97204 (503) 222-6060

November 2002

Acknowledgements

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The Economic Impacts of A Proposed Wind Power Plant in Kittitas County, WA

An Evaluation of Potential Impacts on Property Values, Tax

- an increase of 11 percent over current property tax revenues. The majority of this increase is due to the property tax paid on the wind turbines.

- *Tax revenues to Kittitas County Government will also increase.* Tax revenues accruing directly to Kittitas County Government will be approximately $693,000 annually. This increase results from the County's share of new property tax revenue and from increases in other taxes.

Details on the analysis underlying each of these results are presented in the remainder of this report.

II. Property Value Impacts

One of the biggest concerns of the community is that the installation of numerous wind turbines will detract from the current viewscape in the Kittitas Valley and that the destruction of this view will ultimately reduce residential property values.

We conducted two separate analysis tasks to address this issue. First, we conducted a phone survey of tax assessors for counties that recently had wind turbines installed in their areas. In addition to interviewing tax assessors, we also reviewed the current literature for statistical studies that quantified the impact of wind turbines on property values. For comparison purposes, we also reviewed the literature on the impact that transmission lines have on property values.

A. Tax Assessor Interviews

The first step in our survey of tax assessors was to develop an appropriate sample of sites for the analysis. These sites were chosen using the following criteria:

- *Projects constructed within the last 10 years.* Recently completed projects were used to ensure that reliable information was obtained from the assessor. Recent sites are also more likely to have the same turbine technology that is planned for Kittitas County.
- *View locations.* As much as possible, we attempted to find wind farms that could be seen from residences rather than focusing only on sites in remote or very rural locations.
- *Multiple turbines.* We focused on those areas where multiple turbines were installed to be comparable with the projects proposed for Kittitas County.

We applied these criteria to information obtained from the American Wind Energy Association website to locate candidate wind projects in areas throughout the U.S. Table 1 shows descriptive information on 19 projects we located using this method.

Table 1: Location and Size of Wind Farms Used In Analysis

State	Location	County	Project Name	Year	MW	Turbine Manufacturer	# of Turbines
WY	Carbon County	Carbon	Foote Creek Rim 4	2000	16.80	NEG Micon	28
CA	San Gorgonio Pass	Riverside	Cabazon	1999	39.75	Zond Z-750	53
CA	San Gorgonio Pass	Riverside	Westwind	1999	40.50	NEG Micon	55*
CA	Tehachapi	Kern	Oak Creek Phase 2	1999	23.10	NEG Micon 700	33
CA	Tehachapi	Kern	Cameron Ridge	1999	56.00	NEG Micon	80
CA	Tehachapi	Kern	Pacific Crest	1999	45.54	Vestas V-47	69
WY	Carbon County	Carbon	Foote Creek Rim 1	1999	41.40	Mitsubishi	69
WY	Carbon County	Carbon	Foote Creek Rim 3	1999	24.75	NEG Micon	33

outside of town, and sit on a high ridge. There has been no impact on land values.

- Howard, Texas- There are no homes within two miles of the wind turbines, but because the terrain is so flat, the turbines are visible from as far as 25 miles away. Appraised land values have not declined because of views of the turbines. The appraiser reported that their office expected property owners to complain about lowered property values caused by a diminished view, but so far they have received no complaints.
- Walla Walla County, WA - The turbines are on a high cliff that has a lot of wind and low land values. The unincorporated town of Touchet lies about 8 miles from the turbines and some residents do not like the views of the turbines as it affects their view of the sunset. This factor has not translated into lower land values according to the assessor. Touchet's tax base rose from just over $100 million to $265 million with the addition of the wind farm and resulted in the addition of 20 to 25 permanent local jobs according to the assessor.
- Town of Lincoln, Wisconsin—The assessor reported that when the turbines were first installed, residents complained about the diminished view. However, in the three years since installation, residents have become used to them, and no one complains now. One homeowner had claimed that the assessed value of his property should be reduced because of the wind turbines. The County asked him to show that the value of sales of properties near the turbines had diminished, and he was unable to do so.

To investigate further the potential impacts on property values, Lincoln's assessor compared the 2001 assessed value to actual sales (for arms-length transactions of residential properties) and found that the ratio of assessed values to actual sales prices for properties less than one mile from the wind turbines was no greater than for properties more than a mile from the wind turbines. The assessor noted that the wind turbines had negatively impacted television reception for nearby properties, but the utility company provided the impacted homes with better antennas or a satellite dish to bring reception back to previous levels.

The wind farms have had no impact on neighboring property values in five counties as neighboring properties are in agricultural production. Assessors' offices in Alameda, California, Carbon, Wyoming, Crockett and Culberson in Texas, and Umatilla, Oregon reported that no residential properties have views of the wind farms. The neighboring properties are grazing land, and the value of the land is determined by its productivity, not its views. For Riverside County, California, the wind farm was built along the freeway with a buffer zone to separate it from residences. Consequently, very few homes have a view of the turbines in that county and the assessor reports that there has been no impact on property values. Nobles County, Minnesota reported that the wind farm in the county was installed in the past year, and it is too early to determine if they have affected neighboring property values.

One county reported that land parcels with wind turbines located on them have changed in value. Kern County, California reported that property eligible for a wind turbine greatly increases in value. The first step to siting a wind turbine is to change the land from a grazing zone to a "wind-energy" zone. By changing the zone, the land value increases from about $500 to about $1000 per acre. No other county reported such an impact to land values.

Wind farms in two counties, Howard in Texas and Umatilla in Oregon, have added to the tax base. The assessors' offices reported that the wind turbines are large capital improvements, and they have contributed to the tax base. This was not a specific question in the interview, and these two counties volunteered the information. The same is likely true in other counties, but the issue was not pursued during the assessor interviews.

small and relatively short-lived. The maximum impact on adjacent properties due to transmission lines is about a 10 percent reduction in value. Many studies use hedonic estimating techniques to measure the impact transmission lines have on property values while controlling for other features of the homes. The most recent study (Des Rosiers 2002) found a severe visual encumbrance due to a direct view on a transmission line pylon does exert a negative impact on property prices. Overall, the price reduction stands at roughly 10 percent of average house value. However, being adjacent to the easement will not necessarily cause a house to depreciate. It may even increase its value where proximity advantages (enlarged visual field, increased privacy) exceed drawbacks. Additionally, findings for the non-adjacent properties that have views of the power lines translates in most cases into higher values, due to the improved visual clearance.

Some earlier studies agree that transmission lines have a slight negative impact on property values. Hamilton (1995) found that properties adjacent to a line lose 6.3 percent of their value due to proximity and the visual impact. Properties more distant from transmission lines are scarcely affected, losing roughly 1 percent of their value. Delaney and Timmons (1992) found that, generally, real estate appraisers believe that transmission lines reduce the value of nearby residential properties by 10 percent. The authors' survey found that 84 percent of the surveyed appraisers believed transmission line have a negative impact, 10 percent believed that there is no impact, and 6 percent believed that there was a positive impact on property values. Colwell (1990) found that properties within 50 feet of an HTVL have a 6 percent to 9 percent lower value than comparable properties, but that drop in value lessens over time and tends to fade away.

As the literature indicates, the negative effect on property values due to transmission lines is 10 percent or less, with this effect diminishing over time. This is reported only for comparison purposes for the case of wind turbines. Again, information from tax assessors and the literature indicate that views of wind turbines do not negatively affect property values.

III. Local Economy

A second component of our analysis addressed the economic impact of the wind turbines on the Kittitas County economy. We interviewed representatives from both Zilkha and enXco to determine the amount of spending and employment for the proposed projects. Using this information, we used a regional "input-output" model with data specific to Kittitas County to estimate the economic impacts of the project. We used our model to estimate the economic impacts for both the construction phase and the operations phase of this project. Details on both these phases are reported below.

A. Construction

The construction of 260 individual wind turbines will involve a significant amount of employment and spending during the construction period. We have talked to representatives from both Zilkha and enXco to determine the likely employment and construction spending. Based on these conversations and our experience analyzing similar projects we developed estimates for use in our model. Our input parameters for the construction phase included:

- 85 full and part time local construction jobs
- 10 full and part time jobs for wind company and utility personnel to manage the plant construction phase

As shown in Table 2, the construction phase of the project will result in approximately 95 full and part time jobs. Spending from this project on labor and materials will result in an additional 90 jobs for a total of approximately 185 full and part time jobs during the construction period. Wages during this period will be $10,202,000 due to the hiring of local construction workers and the increases in services needed to support the construction work. Similarly, business incomes will increase by $1,391,000 due to spending on local materials and other items such as food and lodging for non-local labor hired for the project. Taken together, personal income is estimated to increase by $11,593,000 in Kittitas County due to spending during the construction phase. When the income of $864,000 from other sources is considered, the increase in income to the county totals $12,457,000.

Table 3 provides the same information broken out by industry sector. Most of the spending during this phase occurs in the Construction sector. Sectors that will support this sector such as the Wholesale and Retail Trade and Services sectors will also see a significant increase in spending.

Table 3: Construction Phase Economic Impacts by Industry

Industry	Wages	Business Income	Personal Income	Other Income	Jobs
Agriculture, Forestry, and Fisheries	$37,000	$7,000	$44,000	$15,000	1.7
Construction	7,978,000	$1,044,000	$9,022,000	$389,000	90.4
Manufacturing	42,000	$4,000	$46,000	$16,000	1.4
Trans., Comm., & Utilities	778,000	$34,000	$812,000	$57,000	9.7
Wholesale and Retail Trade	611,000	$56,000	$667,000	$90,000	36.2
Finance, Insurance, & Real Estate	66,000	$29,000	$95,000	$120,000	3.5
Services	618,000	$218,000	$836,000	$146,000	41.2
Government	71,000	$0	71,000	$31,000	1.3
Total	$10,202,000	$1,391,000	$11,593,000	$864,000	185.5

Note: Totals may not match due to rounding

B. Operations

Spending will continue in the local economy during the operation of the wind turbines once the construction phase has ended. During the operations phase, spending will consist of primarily:

- 22 employees hired to operate and manage the wind power plants
- Spending on equipment, maintenance and materials to operate the wind turbines
- Income to property owners that rent land for the wind turbines ($4,500 per turbine.)

The impact to the local economy due to the wind plant operations was modeled based on these factors. As during the construction phase, there is a direct effect from these factors as well as an indirect effect that results from the spending due to the increases in income from the new jobs and from the rental income. These impacts are summarized in Table 4 and Table 5.

Based on our review of Kittitas County budgets and spending and our evaluation of the proposed wind power facility, we have estimated the potential revenue impacts for the Kittitas County. Table 6 shows the estimated increases in revenue for the major tax revenue sources.

As shown in Table 6, the primary increase in tax revenues is from property taxes on the wind turbines themselves. For this calculation, we have valued each turbine at approximately $765,000, which is consistent with our experience in other wind projects and with the information provided to us by the wind companies involved with the Kittitas County project. The property tax rate used for the calculation is 1.35 percent for Kittitas County. Given these parameters, for the proposed 260 turbines we estimate new property tax revenues of $2,683,125 annually.

The development of this project will also have an effect of increasing the value of other properties due to the increase in wages and overall economic activity in Kittitas County. This results in an additional $201,971 in property tax revenues annually due to increases in other property values.

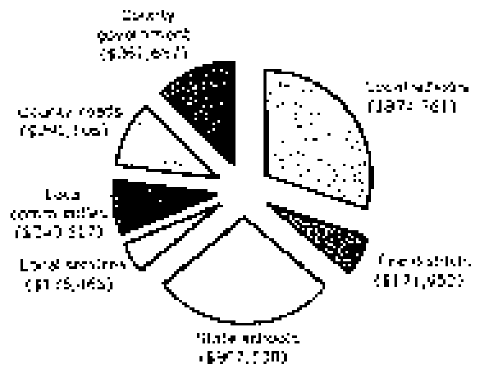
When the property tax revenues from both sources are combined, the additional tax revenue collected within Kittitas County totals $2,885,096 annually.[1] For comparison, property tax revenues from all sources in Kittitas County totaled $25,223,948 for the 2001-02 budget year. The increase in property tax revenues due to the wind farm amounts to an increase of 11 percent over these levels.

Table 6: Increases in Annual Property Tax Revenues in Kittitas County

Revenue Source	Amount
Property taxes on wind farms	$2,683,125
Taxes from higher values on other properties	201,971
Total	**$2,885,096**

A complicating factor in these revenue estimates is the recently passed Initiative 747 (I-747) in Washington State, which limits increases in tax levies to 1 percent a year. From our conversations with the Kittitas County assessor and from information provided by Washington State, it appears that most of the value of a wind turbine ($500,000) would be considered personal property and as such would be subjected to this limit. For Kittitas County, total personal property is assessed at $2,355.4 million. The addition of 260 windmills with a personal property value of $500,000 each would add $132 million to the total property value of the county - an increase of 5.5 percent. Since this increase is greater than 1 percent, it is possible that taxes in other areas would need to be reduced in order to comply with I-747. This might involve decreases in personal property tax rates and/or bond levies. It should be stressed that ECONorthwest is not an accounting firm, and the implication of I-747 is discussed here only as one possible scenario based on preliminary tax estimates. However, the tax revenue estimates provided here should be viewed with I-747 in mind, as actual

[1] Approximately 30 percent of the turbines are to be built on land managed by the Washington Department of Natural Resources rather than on private land. For these turbines, the rental fee for land will be paid to the State, which then returns these funds to schools throughout the state based on district need. At the annual rental rate of $4,500 per turbine, this amounts to an additional $351,000.



The property tax revenue estimates reflect funds that are spent in a variety of sectors, both inside and outside Kittitas County. In addition to these propertytaxes, we estimated the tax revenue that will accrue to the Kittitas County Government. This was done by comparing the current tax revenues as a fraction of total economic output for Kittitas County with and without the wind farm. Using the results from our input-output model, we estimated the total increase in economic output from the proposed wind plant. Given the increase of output with the project, we estimated the increase in tax revenues assuming that tax rates remained constant. For each individual tax, the increases were generally on the order of 0.2 percent annually.

The estimated increase in annual revenue for the Kittitas County Government from these taxes is shown in Table 8. The majority of these additional tax revenues are the property taxes collected for county government and roads. Other sources include smaller taxes such as those collected for fees and services as well as revenue returned to the county by the State. Together, these tax revenues total $695,777. Given the Kittitas County Government expenditures of $44,312,102 planned for 2002, the additional revenue generated by the wind farm represents an increase of almost 2 percent over the budgeted amount.[7]

Table 8: Additional Kittitas County Government Tax Revenues

Spending Category	Amount
Property taxes – County government and roads	$653,763
Sales and use taxes	$7,103
All other taxes	$2,927
Licenses and permits	$2,094

Because input output models generally are not available for state and regional economics, special data techniques have been developed to estimate the necessary empirical relationships from a combination of national technological relationships and county level measures of economic activity. This modeling framework, called IMPLAN (for IMpact Analysis for PLANning), is the technique that ECONorthwest has applied to the estimation of impacts.[1]

The IMPLAN model reports the following economic impacts:

- Total Industrial Output (output) is the value of production byindustries for a specified period of time. Output can be alsothought of as the value of sales including reductions or increases inbusiness inventories.
- Personal income consists of the wages and salaries received byhouseholds (employee compensation) and the payments receivedby small-business owners or self-employed individuals(proprietary income). Employee compensation includes workers'wages and salaries, as well as other benefits such as health and lifeinsurance, and retirement payments. Proprietary income, for example, would include income received by private businessowners, doctors, accountants, lawyers, etc.

[1] IMPLAN was developed by the Forest Service of the US Department of Agriculture in cooperation with the Federal Emergency Management Agency and the Bureau of Land Management of the US Department of the Interior to assist federal agencies in their land and resource management planning. Applications of IMPLAN by the US Government, public agencies and private firms span a wide range of projects, from broad, resource management strategies to individual projects, such as proposals for developing ski areas, coal mines, and transportation facilities, and harvesting timber or other resources. ECONorthwest has applied the model to a variety of public and private sector energy projects including a major US/Canada gas pipeline project and the proposed purchase of Portland General Electric by local counties.

- Other property type income (other income) in the IMPLAN modelincludes payments to individuals in the form of rents received onproperties, royalties from contracts, dividends paid bycorporations, and corporate profits earned by corporations.
- Job impacts include both full and part time employment.
- Tax revenues for various federal, state and local taxingjurisdictions.

Ideally, expenditures for the proposed wind farm would be available and specific enough to allocate to each of the 528 industry sectors contained in the IMPLAN model. In addition, the expenditures should be delineated between local and non-local providers, as purchases of goods and services from out-of-state vendors will have no economic impact on Washington employees and businesses.

In absence of this detailed information, ECONorthwest opted to use the production function data for the utility and government sectors contained in the IMPLAN modeling software. From an input-output modeling perspective, this is a standard modeling approach in the absence of detailed primary source data. Indeed, IMPLAN's production function data contains information, called regional purchase coefficients that describe the proportion of a given commodity that will be provided by Washington producers. Our previous modeling experience has shown that the data contained in the IMPLAN modeling system for the various sectors is sufficient to permit an accurate rendering of impacts.

Judy Baker

however, suggesting a more conservative approach to securing the removal of the turbines to provide the Town with the needed confidence in our approach.

Our proposal is to place a surety bond or equivalent financial security instrument on or before the commercial operations date for the facility in the amount of $50,000 renewable on an annual basis. The security instrument shall include a provision that should another instrument of equal value fail to be placed prior to it's expiration it may be drawn without any other requirement. Bi-annually the values for turbine scrap and removal costs shall be audited and confirmed by an independent third party engineer in a report to the Town Board. Any adjustment in security value recommended by the engineer's report shall be in place within 60 days of the delivery of the report to the board.

Secondly, we further propose to place a larger replacement surety bond or equivalent financial security instrument on or before the fifteenth anniversary of the commercial operations date for the facility. (The year fifteen value of the turbines are still approximately double the estimated cost of removal.) The proposed value for the security would be ten thousand dollars per turbine (a total value which is roughly ten times the expected cost of decommissioning less the scrap value of the turbines as noted in the calculations included herein) or other value to be recommended by the independent engineer in his report the year before.

Revegetation and Reseeding

All Project areas not under cultivation or reserved for some other use by property owners will be revegetated or reseeded, as appropriate.

February 2006
WECS Removal Cost Analysis

Removal Costs (per tower):

Remove Tower

6 Men @ 4 days @ 8 hrs @ $65 =		$ 12,480.00
Crane 5 days @ $2500/day	=	12,500.00
	$	24,980.00

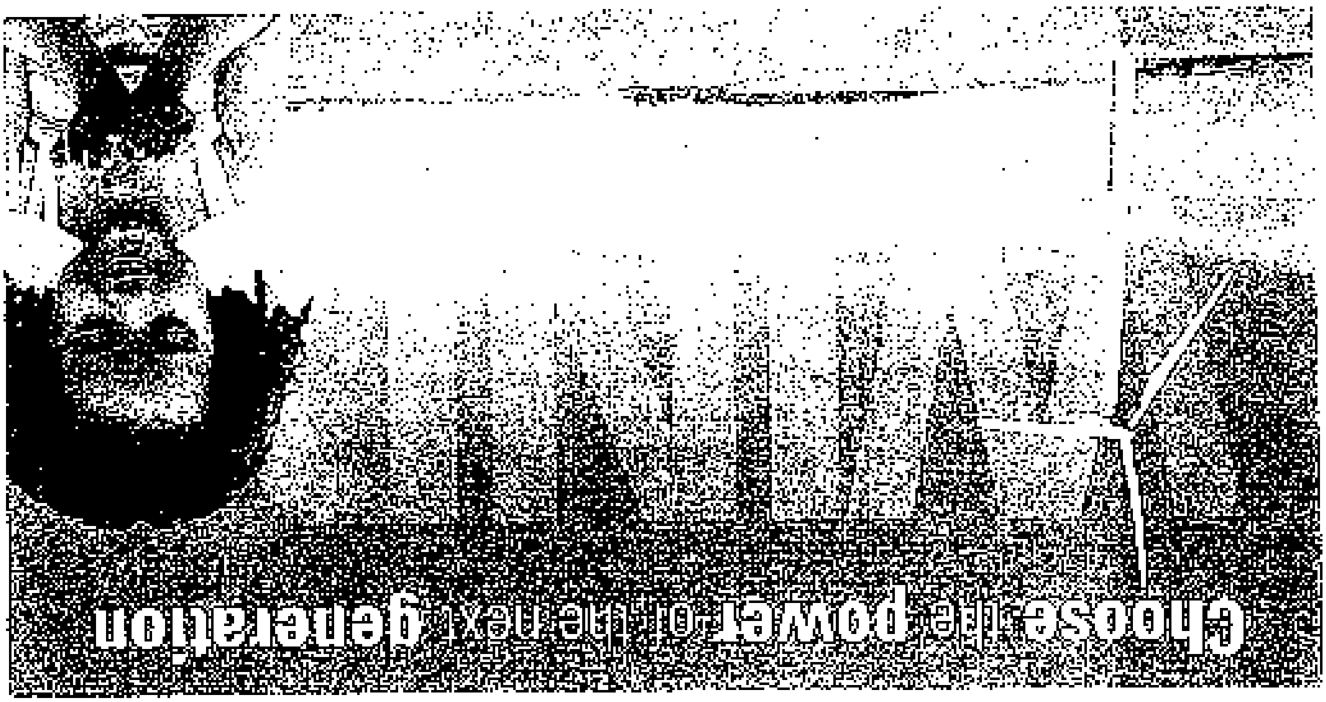
Remove Concrete to 3' Below Grade

4 men @ 24 hrs @ $55	=	5,280.00

Trackhoe 3 days @ $1600/day =		4,800.00
	$	10,080.00
Remove Roads (1,000' /Turbine)		
2 men @ 3 days @ 8 hrs @ 65 =	$	3,120.00
Grader & Loader 3 days @ $2,000 =		6,000.00
	$	9,120.00
Revegetation and reseeding	$	150.00
Sub-Total:	**$**	**44,330.00**

<u>Scrap Value:</u>

Scrap Steel Weight of Tower		336,000 #
	x	.10/ pound
Scrap value of tower only	$	33,600.00
Scrap value of nacelle		5,000.00
Total value of turbine scrap	$	38,600.00
Scrap value of padmount	$	5,000.00
Sub-Total:	**$**	**43,600.00**
Net removal cost:	**$**	**730.00**



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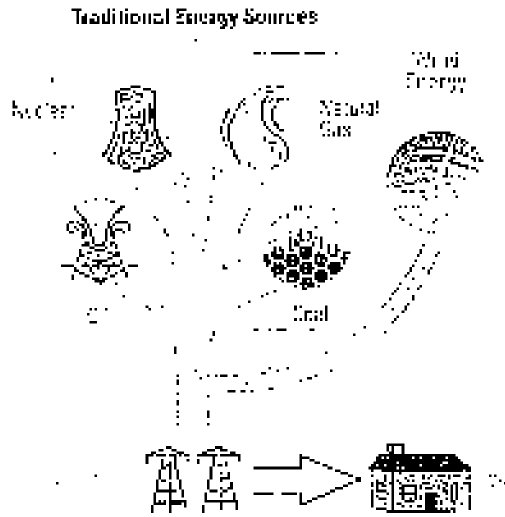

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FOR A CLEAN ENERGY FUTURE

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Wind energy and health

Are wind farms harmful to our health as sources of infrasound?

Infrasound and Low Frequency Noise are established as real causes of illness in some people, but there are no harmful infrasonic effects from wind turbines.

There are all sorts of sources of infrasound in the modern world such as cars and other road traffic, aircraft, diesel engines, trains, shipping, factories, combustion, artillery, mining and quarrying, fridges and other household appliances, fans, compressors and pumps, music, TVs and air conditioning. Infrasound is also ubiquitous in the natural environment from sources like air turbulence – even from earthquakes and storms, sometimes thousands of miles away.

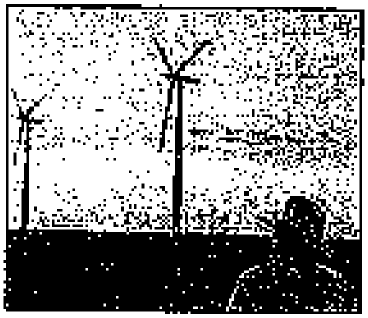
Extensive work has already been carried out on infrasound from wind turbines, which demonstrated that "Low frequency noise and vibration levels were both found to comply with recommended residential criteria even on the wind farm site itself with the acoustic signal, below 20 Hz, being well below accepted thresholds of perception." In the words of one infrasound expert, "There are no harmful infrasound effects from wind turbines."

If a generator were to emit infrasound, the turbine tower would be affected, noticeably vibrating, and although at below audible sounds, this would be detected by the on board power control systems which monitor the wind turbine and would automatically shut it off.

Tens of thousands of wind turbines have now been operating worldwide for up to 20 years, including in some of the countries with leading general studies on infrasound. No link or problem has been identified with the presence of wind turbines in these studies.

Nevertheless, to be absolutely certain, it looks like the British Wind Energy Association might well ask for the Government's Noise Working Group to be reformed and this work carried out again. Also, there are strict guidelines on noise, as prepared by the Working Group set up to address this issue back in 1996. Research on wind turbine noise has been carried out under the Department's New and Renewable Energy Programme. Copies of the reports from those studies are available on the DTI website at www.dti.gov.uk/publications. See www.bwea.com/ref/noise.html for more details.

Clean Power Comes on Strong: Wind Energy



Winds have shaped the rugged West Texas landscape for ages. Now those winds are fueling a clean energy revolution that is revitalizing the West Texas economy. Since 1999, wind energy has infused the state with more than $1 billion in capital investment, providing farmers, ranchers and local communities with new sources of income.

Wind energy is the fastest-growing source of power on the planet. With our tremendous wind resources, the United States can become a world leader in wind energy. Already, wind turbines in this country produce enough electricity to meet the needs of more than 1 million households. A single modern wind turbine can produce enough power to meet the annual electricity needs of 500 average homes.

In recent years the price of wind has fallen dramatically, making it increasingly competitive with fossil fuels. The federal government's National Renewable Energy Laboratory projects that the price of wind energy will fall even further over the next decade, making it the most economically competitive renewable energy technology.

As a growing power source, wind e n e rgy can become a major force for economic development. Wind development can save consumers money and bring construction jobs, leasing royalties, and increased tax revenues to local communities. Supplying even 5 percent of the country's electricity with wind power by 2020 would add $60 billion in capital investment in rural America, provide $1.2 billion in new income for farmers and rural landowners, and create 80,000 new jobs.

Farmers and ranchers can also use wind power as a new "crop," earning $2,000 per year in lease payments per turbine, helping insulate them from falling commodity prices. A single turbine takes up less than a quarter of an acre, including access roads, and farmers can grow crops or graze livestock right up to the base of the turbines.

How Does it Work?

Standing as tall as 300 feet to capture the full force of the wind, modern wind turbines use state-of-the-art technology to turn wind into electricity. When the wind blows, the blades begin to spin, t u rning an electric generator to create electricity. This electricity is carried through the turbine tower underground, where it feeds into the electric grid.

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Clean Energy

backgrounder

Environmental Benefits of Renewable Energy

Power plant air emissions are responsible for approximately one-third of nitrogen oxide emissions, two-thirds of sulfur dioxide emissions, and one-third of carbon dioxide emissions nationally. Renewables can avoid or reduce these air emissions, as well as reduce water consumption, thermal pollution, waste, noise, and adverse land-use impacts.

Moreover, renewables are sustainable energy resources: they avoid depletion of natural resources for future generations.

Renewables in a utility's generating mix can also reduce Clean Air Act compliance costs and make a region a more attractive place to do business by avoiding the imposition of costly emission-control measures in both the utility sector and in other industries and transportation. Under the Clean Air Act, emission reductions that are not achieved in one economic sector must come out of another.

Failure to capture cost-effective reductions in the utility sector will therefore require more stringent reductions from transportation and/or other industrial sectors, simply shifting rather than reducing costs. Because emission sources in those sectors are generally smaller and more numerous, they are generally more expensive to control. Moreover, most conventional emission-abatement measures in all sectors impose costs with no offsetting savings; renewables, on the other hand, produce fuel savings over their operating lives that cover some or all of their initial costs.

These environmental benefits can reduce the cost of complying with future environmental regulations as well. The science of environmental and health impacts of different pollutants develops unevenly. In addition, environmental regulators, faced with limited resources, must prioritize their activities. For these reasons, at any given moment environmental regulatory attention tends to be focused on a narrow range of environmental problems, or a single pollutant.

To meet incremental and piecemeal regulation of this kind, industry naturally turns to the compliance option with the

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lowest short-run incremental cost, most often a bolt-on technology designed solely to mitigate the problem at hand. That technology then becomes a sunk cost which does not enter into cost-effectiveness calculations for responding to the next priority pollutant. Renewables, by contrast, especially zero-emission technologies, avoid these kinds of costs once and for all.

The risks of future environmental regulatory costs are not insignificant or unexpected, especially with respect to fine particulates and carbon dioxide. A growing body of public health research has found that emissions of particulates smaller than 2.5 microns are a major cause of premature deaths from air pollution. As the scientific consensus grows, and the costs of inaction are more closely understood, the likelihood of future regulations increases.

The same is true of global warming gases, especially carbon dioxide. In July 1996, 134 nations, including the United States, agreed in Geneva to negotiate legally binding reductions on emissions of heat-trapping gases. These reductions will be negotiated in Kyoto in December 1997. The agreement was based on the fact that in 1995 the Intergovernmental Panel on Climate Change had reached several new areas of scientific consensus.

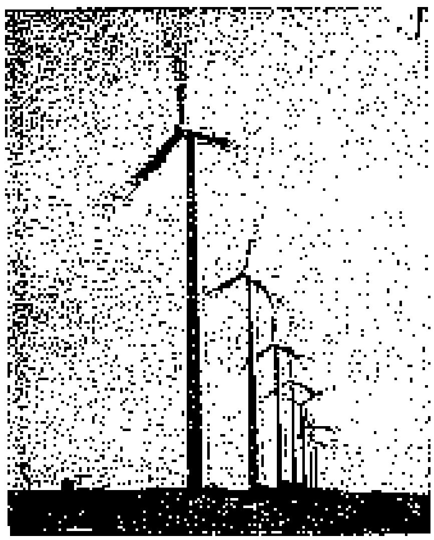
The panel concluded for the first time that global temperatures have risen and that human activities are having a discernible effect on the climate system. It projects adverse impacts from sea-level rise and coastal flooding; severe stress on forests, wetlands, and other systems; damage to human health; and dislocation of agriculture and commerce.

The panel's report also points out that early action may allow greater future flexibility in choosing strategies for stabilizing emissions of heat-trapping gases. Renewables are particularly valuable in mitigating these risks and, consequently, in mitigating the risk of future expenditures to reduce heat-trapping gas emissions by other means. Carbon emission controls are not available by any known technology, and while natural gas plants emit only about half as much carbon dioxide as coal, they still contribute significantly to the problem and offer no long-term solution.

Renewables, on the other hand, including sustainably managed biomass, result in virtually no net carbon emissions. The availability of significant quantities of zero-emitting renewables could help to mitigate the environmental impacts of energy use, now and in the years to come.

UWIG
Utility Wind
Integration Group

Utility Wind Integration State of the Art



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Utility Wind Integration Group

in cooperation with

American Public Power Association (APPA)
Edison Electric Institute (EEI)
National Rural Electric Cooperative Association (NRECA)

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Overview and Summary

In just five years from 2000-2005, wind energy has become a significant resource on many electric utility systems, with over 50,000 MW of nameplate capacity installed worldwide at the end of 2005. Wind energy is now "utility scale" and can affect utility system planning and operations for both generation and transmission. The utility industry in general, and transmission system operators in particular, are beginning to take note. At the end of 2005, the Power Engineering Society (PES) of the Institute of Electrical and Electronic Engineers (IEEE) published a special issue of its ***Power & Energy Magazine*** (Volume 3, Number 6, November/December 2005) focused on integrating wind into the power system. This document provides a brief summary of many of the salient points from that special issue about the current state of knowledge regarding utility wind integration issues. It does not support or recommend any particular course of action or advocate any particular policy or position on the part of the cooperating organizations.

The discussion below focuses on wind's impacts on the operating costs of the non-wind portion of the power system and on wind's impacts on the electrical integrity of the system. These impacts should be viewed in the context of wind's *total* impact on reliable system operation and electricity costs to consumers. The case studies summarized in the magazine address early concerns about the impact of wind power's variability and uncertainty on power system reliability and costs. Wind resources have impacts that can be managed through proper plant interconnection, integration, transmission planning, and system and market operations.

On the cost side, at wind penetrations of up to 20% of system peak demand, system operating cost increases arising from wind variability and uncertainty amounted to about 10% or less of the wholesale value of the wind energy.[1] These incremental costs, which can be assigned to wind-power generators, are substantially less than imbalance penalties generally imposed through Open Access Transmission Tariffs under FERC Order No. 888. A variety of means -- such as commercially available wind forecasting and others discussed below -- can be employed to reduce these costs. In many cases, customer payments for electricity can be decreased when wind is added to the system, because the operating-cost increases could be offset by savings from displacing fossil fuel generation.

Further, there is evidence that with new equipment designs and proper plant engineering, system stability in response to a major plant or line outage can actually be improved by the addition of wind generation. Since wind is primarily an energy -- not a capacity -- source, no additional generation needs to be added to provide back-up capability provided that wind capacity is properly discounted in the determination of generation

[1] These conclusions will need to be reexamined as results of higher-wind-penetration studies -- in the range of 25% to 30% of peak balancing-area load -- become available. However, achieving such penetrations is likely to require one or two decades. During that time, other significant changes are likely to occur in both the makeup and the operating strategies of the nation's power systems. Depending on the evolution of public policies, technological capabilities, and utility strategic plans, these changes can be either more or less accommodating to the natural characteristics of wind power plants.

capacity adequacy. However, wind generation penetration may affect the mix and dispatch of other generation on the system over time, since non-wind generation is needed to maintain system reliability when winds are low.

Wind generation will also provide some additional load carrying capability to meet forecasted increases in system demand. This contribution is likely to be up to 40% of a typical project's nameplate rating, depending on local wind characteristics and coincidence with the system load profile. Wind generation may require system operators to carry additional operating reserves. Given the existing uncertainties in load forecasts, the studies indicate that the requirement for additional reserves will likely be modest for broadly distributed wind plants. The actual impact of adding wind generation in different balancing areas can vary depending on local factors. For instance, dealing with large wind output variations and steep ramps over a short period of time could be challenging for smaller balancing areas, depending on the specific situation.

The remainder of this document is divided into four sections: wind plant interconnection, wind plant integration, transmission planning and market operation, and accommodating more wind in the future.

Wind Plant Interconnection

- Wind power plant terminal behavior is different from that of conventional power plants, but can be compatible with existing power systems. With current technology, wind-power plants can be designed to meet industry expectations such as riding through a three-phase fault, supplying reactive power to the system, controlling terminal voltage, and participating in SCADA system operation.
- Increased demands will be placed on wind plant performance in the future. Recent requirements include low voltage ride-through capability, reactive power control, voltage control, output control, and ramp rate control. Future requirements are likely to include post-fault machine response characteristics more similar to those of conventional generators (e.g., inertial response and governor response).
- Better dynamic models of wind turbines and aggregate models of wind plants are needed to perform more accurate studies of transmission planning and system operation.
- In areas with limited penetration, modern wind plants can be added without degrading system performance. System stability studies have shown that modern wind plants equipped with power electronic controls and dynamic voltage support capability can improve system performance by damping power swings and supporting post-fault voltage recovery.
- Because of spatial variations of wind from turbine to turbine in a wind plant – and to a greater degree from plant to plant – a sudden loss of all wind power on a system simultaneously due to a loss of wind is not a credible event.

Wind Plant Integration

- Utility planners traditionally view new generation primarily in terms of its *capacity* to serve peak demand. But wind is primarily an *energy* resource. Its primary value lies in its ability to displace energy produced from the combustion of fossil fuels and to serve as a hedge against fuel price risk and future restrictions on emissions.

- The addition of a wind plant to a power system does not require the addition of any backup conventional generation since wind is used primarily as an energy resource. In this case, when the wind is not blowing, the system must rely on existing dispatchable generation to meet the system demand.
- Wind plants provide additional planning reserves to a system, but only to the extent of their capacity value. Capacity for day-to-day reliability purposes must be provided through existing market mechanisms and utility unit commitment processes.
- The capacity value of wind generation is typically up to 40% of nameplate rating, and depends heavily on the correlation between the system load profile and the wind plant output.
- The addition of a wind plant to a power system increases the amount of variability and uncertainty of the net load. This may introduce measurable changes in the amount of operating reserves required for regulation, ramping and load-following. Operating reserves may consist of both spinning and non-spinning reserves. In two major recent studies, the addition of 1,500 MW and 3,300 MW of wind (15% and 10%, respectively, of system peak load) increased regulation requirements by 8 MW and 36 MW, respectively, to maintain the same level of NERC control performance standards.
- Fluctuations in the net load (load minus wind) caused by greater variability and uncertainty introduced by wind plants have been shown to increase system operating costs by up to about $5/MWH at wind penetration levels up to 20%. The greatest part of this cost is associated with the uncertainty introduced into day-ahead unit commitment due to the uncertainty in day-ahead forecasts of real-time wind energy production.
- The impact of adding wind generation can vary depending on the nature of the dispatchable generating resources available, market and regulatory environment, and characteristics of the wind generation resources as compared to the load. Dealing with large output variations and steep ramps over a short period of time (e.g., within the hour) could be challenging for smaller balancing areas, depending on their specific situation.
- Wind's variability cannot be treated in isolation from the load variability inherent in the system. Because wind and load variability are statistically uncorrelated, the net increase of variability due to the addition of wind is less than the variability of the wind generation alone.
- Commercially available wind forecasting capability can reduce the costs associated with day-ahead uncertainty substantially. In one major study, state-of-the-art forecasting was shown to provide 80% of the benefits that would result from perfect forecasting.
- Implementation of wind-plant-output forecasting in both power market operation and system operations planning in the control room environment is a critical next step in accommodating increasing amounts of wind penetration in power systems.

Transmission Planning and Market Operation

- Upgrades or additions to transmission facilities may be needed to access locations with large wind-energy potential. Current transmission planning processes are able to identify solutions to transmission problems, but the time required for implementation of solutions often exceeds wind-plant permitting and construction times by several years.
- Well-functioning hour-ahead and day-ahead markets provide the best means of addressing the variability in wind plant output.
- Energy imbalance charges based on actual costs or market prices provide appropriate incentives for accurate wind forecasting. Since wind plant operators have no control over the wind, penalty charges applied to wind imbalances do not improve system reliability. Market products and tariff instruments should properly allocate actual costs of generation energy imbalance.
- Wind turbine output or ramp rates may need to be curtailed for limited periods of time to meet system reliability requirements economically.
- Consolidation of balancing areas or the use of dynamic scheduling can improve system reliability and reduce the cost of integrating additional wind generation into electric system operation.

Accommodating More Wind in the Future

- Understanding and quantifying the impacts of wind plants on utility systems is a critical first step in identifying and solving problems.
- A number of steps can be taken to improve the ability to integrate increasing amounts of wind capacity on power systems. These include:
    - Improvements in wind-turbine and wind-plant models
    - Improvements in wind-plant operating characteristics
    - Carefully evaluating wind-integration operating impacts
    - Incorporating wind-plant forecasting into utility control-room operations
    - Making better use of physically (in contrast with contractually) available transmission capacity
    - Upgrading and expanding transmission systems
    - Developing well-functioning hour-ahead and day-ahead markets, and expanding access to those markets
    - Adopting market rules and tariff provisions that are more appropriate to weather-driven resources
    - Consolidating balancing areas into larger entities or accessing a larger resource base through the use of dynamic scheduling.

The *Power & Energy Magazine* articles summarized in this document are available to IEEE PES members at the following link:
http://www.ieee.org/portal/site/pes/menuitem.bfd2bcf5a5608058fb2275875bac26c8/index.jsp?&pName=pes_home

and to UWIG members at www.uwig.org through the Members link.

53 5/17

To Ellenburg Town Board: We the undersigned support the approval of Noble Ellenburg Windpark.

NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Aleta LaBarre	Ellenburg Ctr	Aleta LaBarre	5/12/06
2	Nicole LeClair	Plattsburgh 12901	Nicole LeClair	5/12/06
3	Heidi Davis	Plattsburgh 12901	H Davis	5/12/06
4	Michael B. Boyea	Ell. Ctr 12934	Michael B. Boyea	5/12/06
5	Christine Boyea	Chateaugay 12920	Christine Boyea	5/12/06
6	Debra Peters	Lyon Mt 12952	Debra Peters	5/12/06
7	Walter Trombly	Ellenburg 12934	Walter Trombly	5/12/06
8	Lisa Stevenson	Ellenburg 12935	Lisa Stevenson	5/12/06
9	Jeff [illegible]	44 [illegible] Rd 12919	Jeff [illegible]	5/12/06
10	John Schulz (John Schulz)	83 Natures Way 12901	John Schulz	5/12/2006
11	Dan Bushey	31 Barcomb Ave Morrisonville NY 12962	DJ Bushey	5/12/2006
12	Steve Chase	Box 162 Chat. NY 12920	Steve Chase	5/12/2006
13	Leo Lashway	Ellenburg Depot	Leo R. Lashway	5/12/2006
14	Marjorie Lashway	Ellenburg Depot	Marjorie Lashway	5/12/2006
15	Gerald Tourville	Ellenburg Center	Gerald Tourville	5/13/2006
16	Eric Otis	Brainardsville NY 12915	Eric D Otis	5/13/2006
17	Jonathan LaBarre	Ellenburg Ctr. NY 12934	Jonathan LaBarre	5/14/2006
18	Mindy King	Ellenburg Depot NY 12935	Mindy King	5/14/06
19	Jamie LaBarre	9 Cumberland Ave. Apt 6 Plattsburgh NY 12901	Jamie M LaBarre	5/14/06
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22	Sherry L. McNeil	Ellenburg Ctr. NY 12934	Sherry L. McNeil	5-15-06

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NO.	NAME PRINT	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Jay L. Carter	Ellenburg Center	Jay L. Carter	5-12-06
2	KEITH R. Brior	7942 Star Rd Ellenburg Ctr.	Keith R Brior	5-12-06
3	Vicki Brior	7942 Star RD Ellenburg Ctr.	[illegible]	5-12-06
4	Carolyn Brior	7940 Star Rd. Ellenburg Ctr.	Carolyn Brior	5-12-06
5	Ralph Brior	7940 Star Rd Ellenburg Ctr	RALph Brior	5-12-06
6	Cheryl Pursotti	[illegible] Ellenburg Ctr.	Cheryl Pursotti	5-12-06
7	Elena Normandin	7960 State Rte 190 Ellenburg Ctr. NY 12934	Elena Normandin	05-12-06
8	KATHLEEN KANZLER	94 RYAN Rd CHATEAUGAY, NY 12920	Kathleen Kanzler	5-12-06
9	NORBERT KANZLER	94 RYAN RD CHATEAUGAY NY 12920	Norbert Kanzler	5-12-06
10	Diane Harrigan	8541 Star Rd. Rte 190 Chateaugay, NY 12920	Diane Harrigan	5-12-06
11	Todd R. Harrigan	"	Todd R. Harrigan	5-12-06
12	Danielle Jock	8705 Star Rd. Rte. 190 Chateaugay, NY 12920	Danielle Jock	5-12-06
13	Stephen A Harrigan	"	Stephen A Harrigan	5-12-06
14	Gary Harrigan	8416 Star Rd. Rte. 190 Chateaugay, NY 12920	Gary Harrigan	5-12-06
15	SCOTT CARTER	30 Ryan RD. Chateaugay NY 12920	Scott Carter	5-13-06
16	Brennan Carter	30 Ryan RD Chateaugay NY 12920	Brennan Carter	5/13/06
17	Stacey Carter	30 Ryan Rd Chateaugay NY 12920	Stacey Carter	5/13/06
18	Christine Trombley	Ellenburg Ctr N.Y. 12934 7864 Star Rd. Rt 190	Christine Trombley	5/13/06
19	Gerald Trombley	7864 Star Rd RT 190 Ellenburg Ctr N.Y. 12934	Gerald Trombley	5/13/06
20	Charles Durkin	5114 Rt 11 Ellenburg Depot	Charles F. Durkin	5/13/2006

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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Gerard J. LaBarre	7738 Star Road Ellenburg Ctr. NY 12934	[illegible]	[illegible]
2	Francis D. LaClair	7741 Star Road Ellenburg Ctr. N.Y. 12934	Francis LaClair	5-12-06
3	Eugene Coryea	[illegible] Hill Rd Ellenburg Depot	Eugene Coryea	5/12/06
4	DIANE VAINCOURT	7891 STAR ROAD ELLENBURG CENTER NY 12934	Diane Vaincourt	5-12-06
5	Harry Carter	Ellenburg Center	Harry Carter	5-12-06
6	Bruce LaBarre	Ellenburg Ctr. NY	Bruce LaBarre	5-12-06
7	Hazel LaBarre	Ellenburg Ctr. NY	Hazel LaBarre	5-12-06
8	GERALD F. VAINCOURT	7837 Star Rd [illegible] Ellenburg Ctr. NY	Gerald F. Vaincourt	5/12/06
9	Carol LaClair	6140 [illegible] Rd Ellenburg Ctr. NY 12934	Carol LaClair	5/12/06
10	Janet LaClair	7741 Star Rd. Ellenburg Center NY 12934	Janet LaClair	5-12-06
11	DALE CARTER	7706 STAR RD. ELLENBURG CTR. N.Y.	Dale Carter	5-12-06
12	James Sample	7687 Star Rd. Ellenburg Ctr. N.Y	James Sample	5-13-06
13	Denise Sample	7687 Star Rd Ellenburg Ctr. NY 12934	Denise Sample	5-13-06
14	Rolland Magoon	1791 [illegible] Rd Ellenburg Center NY	Rolland Magoon	5-15-06
15	Walter R. Trombly	627 West Hill Rd Ellenburg Ctr. N.Y. 12934	Walter R. Trombly	5-15-06
16	Connie Tourville	7511 Star Rd Ellenburg Ctr. NY 12934	Connie Tourville	5-15-06
17	Kathleen Pearson	23 [illegible] Rd Merrill NY 12955	Kathleen Pearson	5-15-06
18	GERALD PEETS	7 [illegible] Rd Ellenburg Depot NY 12935	[illegible]	[illegible]
19	Richard [illegible]	57 [illegible]	[illegible]	5/15/06
20	GARY [illegible]	PO Box 14 Ellenburg NY 12933	[illegible]	5/15/06

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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Greg LaBarge	Ellenburg 12933	Greg LaBarge	May 10, 2006
2	Susan Curry	" "	Susan Curry	" "
3	Joanne LaBarge	" "	Joanne LaBarge	" "
4	Bob Dillon		[illegible]	" "
5	THERESA MINCKLER	Ellenburg Ctr. 12934	Theresa Minckler	May 10, 2006
6	Henry Minckler	Ellenburg Ctr, 12934	Henry Minckler	5/10/06
7	Gwen Magee	Ellenburg Ctr, 12934	Gwen Magee	5/10/06
8	Gary Magee	" " "	Gary Magee	5/10/06
9	Curt Snyder	Keeseville NY	[illegible]	5/10/06
10	Jeff Calkins	Peru NY	Jeff A Calkins	5-10-06
11	Bruce Nichols	Ellenburg NY	Bruce Nichols	5-10-06
12	Kathy Baker	Brandy Brook Ellenburg	Kathy E Baker	5-10-06
13	Jesse Koslowski	Ell Ctr	Jesse Koslowski	
14	BEN MALARK	P.O. BOX 131 / ELLENBURG, NY 12933	Benjamin A. Malark	05-10-06
15	Andrea Malark	"	Andrea Malark	05-10-06
16	Michael LABOMBARD	7196 State Road Ellenburg Center	Michael LaBombard	05-10-06
17	Janine M. Mann	Ellenburg, N.Y.	Janine M. Mann	5/10/06
18	Lou Brown	Ellenburg Center, NY	Lou A Brown	5/10/06
19	Robin Kelmini	Ellenburg Ctr NY	Robin A Kelmini	5/10/06
20	Cassie King	Ellenburg Corners NY	Cassie King	5/10/06

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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Stephen H Clark	6683 Military Turnpike Ellenburg NY	[signature]	5-10-06
2	Luella Compton	671 Bull Run Rd	Luella Compton	5/10/06
3	MIKE CURRY	6618 MILITARY TURNPIKE	[signature]	5/10/06
4	Richard Trombley	47 Avery St	[signature]	5/11/06
5	Vicki King	6663 Star Rd Ellenburg Ctr NY	Vicki King	5/11/06
6	Yvonne V. Taylor	5511 Rte 11 Po Box 83 Ellenburg	Yvonne V Taylor	5/11/06
7	[illegible]	[illegible] Rd NY	[signature]	5/11/06
8	[illegible]	6615 Star Rd Ellenburg	[signature]	5/11/06
9	Tom Bourey	Brandy Brook Rd	[signature]	5-11-06
10	Lynn Magoon	Barcomb Rd	Lynn Magoon	5-11-06
11	Amy Trombley	Bradley Pond	Amy Trombley	5-11-06
12	Eric Trombley	Bradley Pond	Eric Trombley	5-11-06
13	Scott Barcomb	Barcomb Rd	[signature]	5-11-06
14	Frank Drown	452 Brandy Brook Rd Ellenburg Ctr	Frank L Drown	5/12/06
15	Lori Drown	~~Ellenburg Depot~~	Lori A. Drown	5/12/06
16	Alicia Nolan			
17	Jim Coffey	1794 [illegible] Road Ellenburg Dep		
18	Andrew Minckler	54 Lake Roxanne Rd	[signature]	5/13/06
19	Stacy [illegible]	178 [illegible] Rd Churubusco	Stacy [illegible]	5/13/06
20	Lisa King	Ellenburg Center	Lisa King	5/13/06

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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Jeni Shutts	5282 Rt. 11 Ellenburg Dept	[illegible]	5-14-06
2	Debra M. Chilton	6623 Rt 190 Ellenburg Ctr.	[illegible]	5/15/06
3	Stephen H Chilton	6623 " "	[illegible]	5/15/06
4	Betsey Sturgeon	7145 Star Rd Ellenburg Ctr	[illegible]	5-15-06
5	[illegible]	13 [illegible] Rd Ellenburg [illegible]	[illegible]	5/15/06
6	[illegible]	5505 [illegible]	[illegible]	5-11-06
7	Giselle Carter	1503 Bro Clifford Rd	[illegible]	8/15/06
8	Wayne Maguire	34 Carlson St Ellenburg Ctr	[illegible]	5/10/06
9	Jennifer Trombley	188 Ellenburg Ctr Rd Ellenburg Ctr	[illegible]	5/16/06
10	Cathy Finlayson	345 LaDuanne Rd Ellenburg	[illegible]	5-17-06
11	Kevin Finlayson	345 LaDuanne Rd Ellenburg Ctr	[illegible]	5-17-06
12	[illegible]	300 LaDuanne Rd Ellenburg Ctr	[illegible]	5-17-06
13	[illegible]	345 LaDuanne R Ellenburg Ctr	[illegible]	5-17-06
14	Claire Finlayson	345 LaDuanne Rd Ellenburg Ctr	[illegible]	5-17-06
15	[illegible]	300 LaDuanne Rd Ellenburg Ctr	[illegible]	5-17-06
16	Eric LaBarbar	4810 St Rt 374 Merrill NY 12955	[illegible]	5-17-06
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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Brenda M. Bombard	2 Bombard Rd Ellenburg 12933	Brenda M. Bombard	5/15/06
2	Anthony M Bombard	3521 Rt 11 Ellenburg Ctr	[illegible]	5/15/06
3	Florence Brewster	6 Spruce Way Chazy 12921	Florence Brewster	5/15/06
4	Curtis E DeCoste	5480 Rt 11 Ellenburg Depot 12935	Curtis E DeCoste	5/15/06
5	Kevin Rabideau	1149 West Hill Rd Ellenburg Center	[illegible]	5/15/06
6	Bruce Brewster	6 Spruce Way Chazy NY 12921	[illegible]	5/15/06
7	Glenn Dowd	111 Youngs Rd		5/15/06
8	James Dowd	7446 [illegible] Rd Ellenburg Ctr 12934	James Dowd	5/15/06
9	Gisele Gagnier	111 Youngs Rd 12955	Gisele Gagnier	5/15/06
10	Jerry Gagnier	3884 Rt 374 Ellenburg Dpt 12935	[illegible]	5/15/06
11	[illegible]	[illegible]	[illegible]	5 15 06
12	[illegible]	[illegible]	[illegible]	[illegible]
13	Christal Dennis	1974 Plank Rd Ellenburg Depot	Christal Dennis	5 15 06
14	Don Mason	1974 Plank Rd Ellenburg Depot	[illegible]	5 15 06
15	Priscilla Dennis	286 Recore Rd Chazy NY	Priscilla Dennis	5 15 06
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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Patrick Brown	Ellenburg Depot 12935	Patrick Brown	5/13/06
2	Kelby K. Moore	Ellenburg Ctr NY 12934	Kelby Kenna Moore	5/13/06
3	Wayne Cashman	Ellenburg Ctr NY. 12934	[illegible]	5/13/06
4	Louis Pamphinnin	Ellenburg Depot NY 12935	[illegible]	5/13/06
5	Larry J. Moore	Ellenburg Dept. N.Y.	Larry J. Moore	5/13/06
6	Chad Spoor	Ellenburg Depot NY	Chad Spoor	5/15/06
7	Michael Guerin	Mooers N.Y.	Michael Guerin	5/15/06
8	Harry Frenyea	Ellenburg N.Y.	Harold Frenyea	5/13/06
9	[illegible]	Mooers NY	[illegible]	[illegible]
10	William Ryan	Ellenburg Depot NY	William Ryan	5-15-06
11	Sarah Ryan	Ellenburg Depot N.Y.	Sarah Ryan	5-15-06
12	Bobbie Clukey	22 Conaan Rd Ellenburg Depot ny 12935	[illegible]	5-15-06
13	Kristie Bushey	423 Main Rd Altona NY	Kristie Bushey	5-15-06
14	Mitchell Brassard	345 Stone Mill Rd Ellenburg Ctr. NY. 12934	Mitchell Brassard	5/16/06
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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Doreen Barcomb	56 Barcomb Rd, Ellenburg Ctr 12934	Doreen Barcomb	5/16/06
2	Danny Barcomb	56 Barcomb Rd Ellenburg Ctr	Dan Barcomb	5/16/06
3	Sandra Bolia	34 West Hill Ellenburg Center NY	Sandra Bolia	5/16/06
4	Ronald Bolia	34 West Hill Ellenburg Center NY	Ronald Bolia	5/16/06
5	Daniel Boyd	5125 St Rt. 374 Merrill NY 12955	Dan Boyd	5/16/06
6	Mark Lyons	267 Cedar Swamp Rd. Deep River, CT 06417	[illegible]	5/16/6
7	BOB ALTMORE	614 SPEAR HILL RD MERRILL	[illegible]	5/16/06
8	Sandra LaBarre	2777 Rt 190 Ell Ctr NY	Sandra LaBarre	5-16-06
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NO.	NAME	ADDRESS (Street, Town, ZIP!)	SIGNATURE	DATE
1	Ann Marie Coghlan	4151 Ellenburg Ctr Rd Ellenburg NY 12937	Ann Marie Coghlan	5/11/06
2	Warren Cluley	[illegible] Rd	[illegible]	5/17/06
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The Effect of Wind Development on Local Property Values

REPP

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Notice

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Chapter I. Project Overview

The Claim Against Wind Development

Wind energy is the fastest growing domestic energy resource. Between 1998 and 2002 installed capacity grew from 1848 MW to 4685 MW, a compound growth rate of 26 percent. Since wind energy is now broadly competitive with many traditional generation resources, there is wide expectation that the growth rate of the past five years will continue. (Source for statistics: www.awea.org).

As the pace of wind project development has increased, opponents have raised claims in the media and at siting hearings that wind development will lower the value of property within view of the turbines. This is a serious charge that deserves to be seriously examined.

No Existing Empirical Support

As a result of the expansion of capacity from 1998 to 2002, it is reasonable to expect any negative effect would be revealed in an analysis of how already existing projects have affected property values. A search for either European or United States studies on the effect of wind development on property values revealed that no systematic review has as yet been undertaken.

As noted above, the pace of development and siting hearings is likely to continue, which makes it important to do systematic research in order to establish whether there is any basis for the claims about harm to property values. (For recent press accounts of opposition claims see: The Charleston Gazette, WV, March 30, 2003; and Copley News Service, Ottawa, IL, April 11, 2003).

This REPP Analytical Report reviews data on property sales in the vicinity of wind projects and uses statistical analysis to determine whether and the extent to which the presence of a wind power project has had an influence on the prices at which properties have been sold. The hypothesis underlying this analysis is that if wind development can reasonably be claimed to hurt property values, then a careful review of the sales data should show a negative effect on property values within the viewshed of the projects.

A Serious Charge Seriously Examined

The first step in this analysis required assembling a database covering every wind development that came on-line after 1998 with 10 MW installed capacity or greater. (Note: For this Report we cut off projects that came on-line after 2001 because they would have insufficient data at this time to allow a reasonable analysis. These projects can be added in future Reports, however.) For the purposes of this analysis, the wind developments were considered to have a visual impact for the area within five miles of the turbines. The five mile threshold was selected because review of the literature and field experience suggests that although wind turbines may be visible beyond five miles, beyond this distance, they do not tend to be highly noticeable, and they have relatively little influence on the landscape's overall character and quality. For a time period covering roughly six years and straddling the on-line date of the projects, we gathered the records for all property sales for the view shed and for a community comparable to the view shed.

For all projects for which we could find sufficient data, we then conducted a statistical analysis to determine how property values changed over time in the view shed and in the comparable community. This database contained more than 25,000 records of property sales within the view shed and the selected comparable communities.

Three Case Examinations

REPP looked at price changes for each of the ten projects in three ways. Case 1 looked at the changes in the view shed and comparable community for the entire period of the study; Case 2 looked at how property values changed in the view shed before and after the project came on-line; and Case 3 looked at how property values changed in the view shed and comparable community after the project came on-line.

> **Case 1** looked first at how prices changed over the entire period of study for the view shed and comparable region. Where possible, we tried to collect data for three years preceding and three years following the on-line date of the project. For the ten projects analyzed, property values increased faster in the view shed in eight of the ten projects. In the two projects where the view shed values increased slower than for the comparable community, special circumstances make the results questionable. Kern County, California is a site that has had wind development since 1981. Because of the existence of the old wind machines, the site does not provide a look at how the new wind turbines will affect property values. For Fayette County, Pennsylvania the statistical explanation was very poor. For the view shed the statistical analysis could explain only 2 percent of the total change in prices.
>
> **Case 2** compared how prices changed in the view shed before and after the projects came on-line. For the ten projects analyzed, in nine of the ten cases the property values increased faster after the project came on line than they did before. The only project to have slower property value growth after the on-line date was Kewaunee County, Wisconsin. Since Case 2 looks only at the view shed, it is possible that external factors drove up prices faster after the on-line date and that analysis is therefore picking up a factor other than the wind development.
>
> Finally, **Case 3** looked at how prices changed for both the view shed and the comparable region, but only for the period after the projects came on-line. Once again, for nine of the ten projects analyzed, the property values increased faster in the view shed than they did for the comparable community. The only project to see faster property value increases in the comparable community was Kern County, California. The same caution applied to Case 1 is necessary in interpreting these results.

If property values had been harmed by being within the view-shed of major wind developments, then we expected that to be shown in a majority of the projects analyzed. Instead, to the contrary, we found that for the great majority of projects the property values actually rose more quickly in the view shed than they did in the comparable community. Moreover, values increased faster in the view shed after the projects came on-line than they did before. Finally, after projects came on-line, values increased faster in the view shed than they did in the comparable community. In all, we analyzed ten projects in three cases; we looked at thirty individual analyses and found that in twenty-six of those, property values in the selected view shed performed better than the alternative.

This study is an empirical review of the changes in property values over time and does not attempt to present a model to explain all the influences on property values. The analysis we conducted was done solely to determine whether the existing data could be interpreted as supporting the claim that wind development harms property values. It would be desirable in future studies to expand the variables incorporated into the analysis and to refine the view shed in order to look at the relationship between property values and the precise distance from development. However, the limitations imposed by gathering data for a consistent analysis of all major developments done post-1998 made those refinements impossible for this study. The statistical analysis of all property sales in the view shed and the comparable community done for this Report provides no evidence that wind development has harmed property values within the view shed. The results from one of the three Cases analyzed are summarized in Table 1 and Figure 1 below.

Regression Analysis

REPP used standard simple statistical regression analyses to determine how property values changed over time in the view shed and the comparable community. In very general terms, a regression analysis "fits" a linear relationship, a line, to the available database. The calculated line will have a slope, which in our analysis is the monthly change in average price for the area and time period studied. Once we gathered the data and conducted the regression analysis, we compared the slope of the line for the view shed with the slope of the line for the comparable community (or for the view shed before and after the wind project came on line).

Table 1: Summary of Statistical Model Results for Case 1

Project/On-Line Date	Monthly Average Price Change ($/month)	
	View Shed	Comparable
Riverside County, CA	$1,719.65	$814.17
Madison County, NY (Madison)	$576.22	$245.51
Carson County, TX	$620.47	$296.54
Kewaunee County, WI	$434.48	$118.18
Searsburg, VT	$536.41	$330.81
Madison County, NY (Fenner)	$368.47	$245.51
Somerset County, PA	$190.07	$100.06
Buena Vista County, IA	$401.86	$341.87
Kern County, CA	$492.38	$684.16
Fayette County, PA	$115.96	$479.20

While regression analysis gives the best fit for the data available, it is also important to consider how "good" (in a statistical sense) the fit of the line to the data is. The regression will predict values that can be compared to the actual or observed values. One way to measure how well the regression line fits the data calculates what percentage of the actual variation is explained by the predicted values. A high percentage number, over 70%, is generally a good fit. A low number, below 20%, means that very little of the actual variation is explained by the analysis. Because this initial study had to rely on a database constructed after the fact, lack of data points and high variation in the data that was gathered meant that the statistical fit was poor for several of the projects analyzed. If the calculated linear relationship does not give a good fit, then the results have to be looked at cautiously.

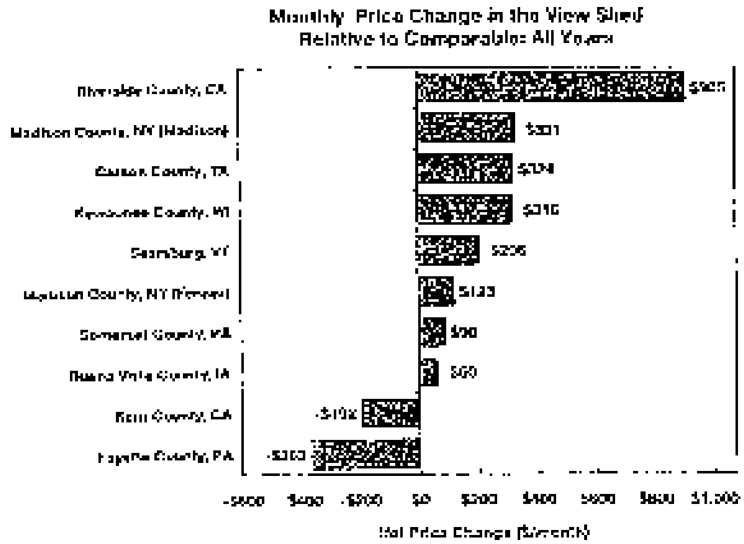


Figure 1: Monthly Price Change in the View Shed
Relative to Comparable: All Years

Case Result Details

Although there is some variation in the three Cases studied, the results point to the same conclusion: the statistical evidence does not support a contention that property values within the view shed of wind developments suffer or perform poorer than in a comparable region. For the great majority of projects in all three of the Cases studied, the property values in the view shed actually go up faster than values in the comparable region. Analytical results for all three cases are summarized in Table 2 below.

Table 2: Detailed Statistical Model Results

Location: Buena Vista County, IA
Project: Storm Lake I & II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Oct 02 Jan 96 - Oct 02	$401.86 $341.87	0.67 0.72	The rate of change in average view shed sales price is 18% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Oct 02	$370.52 $631.12	0.51 0.53	The rate of change in average view shed sales price is 70% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Oct 02 May 99 - Oct 02	$631.12 $234.84	0.53 0.23	The rate of change in average view shed sales price after the on-line date is 2.7 times greater than the rate of change of the comparable after the on-line date.

Location: Carson County, TX
Project: Llano Estacado

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 98 - Dec 02	$620.47	0.49	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 98 - Dec 02	$296.54	0.33	
Case 2	View shed, before	Jan 98 - Oct 01	$553.92	0.24	The rate of change in average view shed sales price after the on-line date is 3.4 times greater than the rate of change before the on-line date.
	View shed, after	Nov 01 - Dec 02	$1,879.76	0.83	
Case 3	View shed, after	Nov 01 - Dec 02	$1,879.76	0.83	The rate of change in average view shed sales price after the on-line date increased at 13.4 times the rate of decrease in the comparable after the on-line date
	Comparable, after	Nov 01 - Dec 02	-$140.14	0.02	

Location: Fayette County, PA
Project: Mill Run

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Dec 97-Dec 02	$115.96	0.02	The rate of change in average view shed sales price is 24% of the rate of change of the comparable over the study period.
	Comparable, all data	Dec 97-Dec 02	$479.20	0.24	
Case 2	View shed, before	Dec 97 - Nov 01	-$413.68	0.19	The rate of change in average view shed sales price after the on-line date increased at 3.8 times the rate of decrease before the on-line date.
	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	
Case 3	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	The rate of change in average view shed sales price after the on-line date is 13.5 times greater than the rate of change of the comparable after the on-line date.
	Comparable, after	Oct 01-Dec 02	$115.86	0.00	

Location: Kern County, CA
Project: Pacific Crest, Cameron Ridge, Oak Creek Phase II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Dec 02	$492.38	0.72	The rate of change in average view shed sales price is 28% less than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Dec 02	$684.16	0.74	
Case 2	View shed, before	Jan 96 - Feb 99	$568.15	0.44	The rate of change in average view shed sales price is 38% greater after the on-line date than the rate of change before the on-line date.
	View shed, after	Mar 99 - Dec 02	$786.60	0.75	
Case 3	View shed, after	Mar 99 - Dec 02	$786.60	0.75	The rate of change in average view shed sales price after the on-line date is 29% less than the rate of change of the comparable after the on-line date.
	Comparable, after	Mar 99 - Dec 02	$1,115.10	0.95	

Location: Kewaunee County, WI
Project: Red River (Rosiere), Lincoln (Rosiere), Lincoln (Gregorville)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Sep 02 Jan 96 - Sep 02	$434.48 $118.18	0.26 0.05	The rate of change in average view shed sales price is 3.7 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - May 99 Jun 99 - Sep 02	-$238.67 $840.03	0.02 0.32	The increase in average view shed sales price after the on-line date is 3.5 times the decrease in view shed sales price before the on-line date.
Case 3	View shed, after Comparable, after	Jun 99 - Sep 02 Jun 99 - Sep 02	$840.03 -$630.10	0.32 0.37	The average view shed sales price after the on-line date increases 33% quicker than the comparable sales price decreases after the on-line date.

Location: Madison County, NY
Project: Madison

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Jan 03 Jan 97 - Jan 03	$576.22 $245.51	0.29 0.34	The rate of change in average view shed sales price is 2.3 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Aug 00 Sep 00 - Jan 03	$129.32 $1,332.24	0.01 0.28	The rate of change in average view shed sales price after the on-line date is 10.3 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	Sep 00 - Jan 03 Sep 00 - Jan 03	$1,332.24 -$418.71	0.28 0.59	The rate of change in average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date.

Location: Madison County, NY
Project: Fenner

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Jan 03 Jan 97 - Jan 03	$368.47 $245.51	0.35 0.34	The rate of change in average view shed sales price is 50% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Nov 01 Dec 01 - Jan 03	$587.95 -$418.98	0.50 0.04	The rate of decrease in average view shed sales price after the on-line date is 29% lower than the rate of sales price increase before the on-line date.
Case 3	View shed, after Comparable, after	Dec 01 - Jan 03 Dec 01 - Jan 03	-$418.98 -$663.33	0.04 0.03	The rate of decrease in average view shed sales price after the on-line date is 37% less than the rate of decrease of the comparable after the on-line date.

Location: Riverside County, CA
Project: Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, Westwind

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Nov 02 Jan 96 - Nov 02	$1,719.65 $814.17	0.92 0.81	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Nov 02	$1,062.83 $1,978.88	0.68 0.81	The rate of change in average view shed sales price is 86% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Nov 02 May 99 - Nov 02	$1,978.88 $1,212.14	0.81 0.74	The rate of change in average view shed sales price after the on-line date is 63% greater than the rate of change of the comparable after the on-line date.

Location: Bennington and Windham Counties, VT
Project: Searsburg

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 94 - Oct 02 Jan 94 - Oct 02	$536.41 $330.81	0.70 0.45	The rate of change in average view shed sales price is 62% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 94 - Jan 97 Feb 97 - Oct 02	-$301.52 $771.06	0.08 0.71	The rate of change in average view shed sales price after the on-line date increased at 2.6 times the rate of decrease before the on-line date.
Case 3	View shed, after Comparable, after	Feb 97 - Oct 02 Feb 97 - Oct 02	$771.06 $655.20	0.71 0.78	The rate of change in average view shed sales price after the on-line date is 18% greater than the rate of change of the comparable after the on-line date.

Location: Somerset County, PA
Project: Exelon, Green Mountain

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Oct 02 Jan 97 - Oct 02	$190.07 $100.06	0.30 0.07	The rate of change in average view shed sales price is 90% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Apr 00 May 00 - Oct 02	$277.99 $969.59	0.37 0.62	The rate of change in average view shed sales price after the on-line date is 3.5 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 00 - Oct 02 May 00 - Oct 02	$969.59 $416.73	0.62 0.23	The rate of change in average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date.

Each of the three Cases takes a different approach to evaluating the price changes in the view shed and comparable community. By finding consistent results in all three Cases, the different approaches help to address concerns that could be raised about individual approaches. The selection of the comparable community is based upon a combination of demographic statistics and the impressions of local assessors and is inherently subjective. It is possible that arguments about the legitimacy of the selection of the comparable could arise and be used to question the legitimacy of the basic conclusion. However, since Case 2 looks only at the view shed and since the results of the Case 2 analysis are completely consistent with the other Cases, the selection of the comparable community will not be crucial to the legitimacy of the overall conclusion. To take another example, Case 1 uses data from the entire time period, both before and after the on-line date. We anticipate possible criticisms of this Case as masking the "pure" effect of the development that would only occur after the project came on-line. However, Cases 2 and 3 look separately at the before and after time periods and produce results basically identical to the Case 1 results. Because all three Cases produce similar results, Cases 2 and 3 answer the concerns about Case 1.

The Database

The results of the analysis depend greatly upon the quality of the database that supports the analysis. The Report is based on a detailed empirical investigation into the effects of wind development on property values. The study first identified the 27 wind projects over 10 MW installed capacity that have come on-line since 1998. REPP chose the 1998 on-line date as a selection criterion for the database because it represented projects that used the new generation of wind machines that are both taller and quieter than earlier generations. (REPP did not consider projects that came on-line in 2002 or after since there would be too little data on property values after the on-line date to support an analysis. These projects can be added to the overall database and used for subsequent updates of this analysis, however.) REPP chose the 10 MW installed capacity as the other criterion because if the presence of wind turbines is having a negative affect it, should be more pronounced in projects with a large rather than small number of installations. In addition, we used the 10 MW cut off to assure that the sample of projects did not include an over-weighting of projects using a small number of turbines.

Of the 27 projects that came on-line in 1998 or after and that were 10MW or larger installed capacity, for a variety of reasons, 17 had insufficient data to pursue any statistical analysis. For six of the 17 projects we acquired the data, but determined that there were too few sales to support a statistical analysis. For two of the remaining 11, state law prohibited release of property sales information. The remaining nine projects had a combination of factors such as low sales, no electronic data, and paper data available only in the office. (For a project-by-project explanation, see Chapter 2 of the Report.)

For each of the remaining ten projects, we assembled a database covering roughly a six-year period from 1996 to the present. For each of these projects we obtained individual records of all property sales in the "view shed" of the development for this six-year period. We also constructed a similar database for a "comparable community" that is a reasonably close community with similar demographic characteristics. For each of the projects, we selected the comparable community on the basis of the demographics of the community and after discussing the appropriateness of the community with local property assessors. As shown in Table 3 below, the database of view shed and comparable sales included more than 25,000 individual property sales. The initial included database of view shed and comparable sales included over 25,000 individual property sales. After review and culling, the final data set includes over 24,300 individual property sales, as shown in Table 3 below.

Table 3: Number of Property Sales Analyzed, by Project

Project/On-Line Date	Viewshed Sales	Comparable Sales	Total Sales
Searsburg, VT / 1997	2,788	552	3,340
Kern County, CA / 1999	745	2,122	2,867
Riverside County, CA / 1999	5,513	3,592	9,105
Buena Vista County, IA / 1999	1,557	1,656	3,213
Howard County, TX / 1999*	2,192	n/a	2,192
Kewaunee County, WI / 1999	329	295	624
Madison Co./Madison, NY / 2000	219	591	810
Madison Co./Fenner, NY / 2000**	453	591	1,044
Somerset County, PA / 2000	962	422	1,384
Fayette County, PA / 2001	39	50	89
Carson County, TX / 2001	45	224	269
TOTAL	14,842	9,504	24,346

*Howard County, TX comparable data not received at time of publication

**Both wind projects in Madison County, NY, use the same comparable. Column totals adjusted to eliminate double counting

Recommendations

The results of this analysis of property sales in the vicinity of the post-1998 projects suggest that there is no support for the claim that wind development will harm property values. The data represents the experience up to a point in time. The database will change as new projects come on-line and as more data becomes available for the sites already analyzed. In order to make the results obtained from this initial analysis as useful as possible to siting authorities and others interested in and involved with wind development, it will be important to maintain and update this database and to add newer projects as they come on-line.

Gathering data on property sales after the fact is difficult at best. We recommend that the database and analysis be maintained, expanded and updated on a regular basis. This would entail regularly updating property sales for the projects already analyzed and adding new projects when they cross a predetermined threshold, for example financial closing. In this way the results and conclusions of this analysis can be regularly and quickly updated.

Chapter II. Methodology

The work required to produce this report falls into two broad categories – data collection and statistical analysis. Each of these areas in turn required attention to several issues that determine the quality of the result.

According to the American Wind Energy Association (AWEA), approximately 225 wind projects were completed or under development in the United States as of 2002. The first wave of major wind project development in the United States took place between approximately 1981 and 1995. Wind farm development slowed considerably in 1996, with only three wind projects installed, the largest of which was 600 kW. The first major post-1996 project was the 6 MW Searsburg site in Bennington County, Vermont, which came on-line in 1997.

A. Project Selection Criteria

This report focuses on major wind farm projects that constitute the second wave of wind farm development. This second wave of projects employs modern wind turbine technology likely to be installed over the next several years as part of continuing U.S. wind farm development. Compared to the previous generation of wind turbines, modern wind turbines generally have greater installed capacities, taller towers, larger turbine blades, lower rotational speeds and reduced gearbox noise.

In addition to the 6 MW Searsburg wind farm, this report analyses potential property value effects for wind farms of 10 MW capacity or greater installed from 1998 through 2001. Projects completed in 2002 and later are excluded from this analysis because not enough time has elapsed to collect sufficient data to statistically determine post-installation property value effects. To determine property value trends prior to wind farm installation, we collected property sales data from three years prior to the on-line year to the present for each of the wind farms analyzed.

Twenty-seven wind farm projects met the project selection criteria.

B. Data Compilation

Once the projects were selected for analysis, the process of acquiring data was initiated through phone calls to county assessment offices. For each project, varying sources of data and information were available, ranging from websites with on-line data, purchased data on CD-ROM or via e-mail from government offices, purchased data from private vendors or postal carried paper records. In many cases data was only available in paper, but not by mail – a person would physically have to appear before the assessment office clerk and search storage boxes, which in some cases had been archived to remote locations for long-term storage. Many states do not require local offices to retain records past certain age limits, often between one to five years. After that, files may be destroyed, and in some cases had been.

Where paper records were obtained, data was transferred into electronic form through scanning or manual data entry. In many cases, both with paper and/or electronic data, the fields we received did not provide good geographic specificity. For example, in some cases, townships and/or cities, but not street addresses were identified. Where street addresses were included, in some cases not all properties had street addresses given, or street addresses were truncated or otherwise incomplete.

Out of the 27 counties with wind farms meeting the project selection criteria, ten sites were selected for statistical analysis based on availability of property sales data. The other 17 eligible sites were excluded from statistical analysis for a number of reasons, including insufficient sales to perform statistical analysis (for example, one site had only five sales in five years), lack of readily available data (data requiring in-person visits to the Assessors Office to manually go through paper files), and two cases where state law prohibited the Assessors Office from releasing property sales data to the public.

This report contains one section for each of the ten sites analyzed, with project site and community descriptions, view shed and comparable selection details, and analytical results and discussion. In addition, the report contains one section providing detailed explanations of why each of the 17 other sites are excluded from analysis. The dataset used in this report, exclusive of proprietary data, is available on the REPP web site at www.repp.org, or by request from REPP.

C. View Shed Definition

In order to determine whether the presence of a wind farm has an adverse effect on property values in the wind farm's vicinity, the area potentially affected by the wind farm must be defined. In this report, the area in which potential property value effects are being tested for is termed the "view shed."

How the view shed is defined will affect the type of data required to test for property value effects, as well as the analytical model employed. Choosing the value of the appropriate radius for such a view shed is subjective. To help determine the radius, numerous studies regarding line-of-sight impacts were reviewed, and interviews with a power industry expert on visual impacts of transmission lines were conducted. In the end, three separate resources for estimates of visual impact were used to support defining the view shed as the area within a five-mile radius of the wind farms. These resources are:

- The U.S. Department of Agriculture (USDA). In a handbook titled "National Forest Landscape Management" (1973) developed for the Forest Service by the USDA, three primary zones of visual impact are defined: foreground, middleground and background. These zones relate to the distance from an object in question, be it a fire lookout tower, tall tree, or mountain in the distance. In this definition, foreground is 0 to 1/2 mile, middleground is 1/4 to 5 miles and background is 3 to 5 miles. The USDA handbook states that for foreground objects people can discern specific sensory experiences such as sound, smell and touch, but for background objects little texture or detail are apparent, and objects are viewed mostly as patterns of light and dark.

- The Sinclair-Thomas Matrix. This is a subjective study of the visual impact of wind farms published in the report Wind Power in Wales, UK (1999). Visual impact is defined in a matrix of distance from a wind turbine versus tower hub height. At the highest hub height considered in the matrix, 95 meters [312 feet], the visual impact of wind towers is estimated to be moderate at a distance of 12 km [7.5 miles]. The matrix estimates that not until a distance of 40 km [25 miles] is there "negligible or no" visual impact from wind turbines under any atmospheric condition. Of the ten sites considered in this REPP report, the majority of towers have hub heights of 60 to 70 meters, which, according to the Sinclair-Thomas matrix, corresponds to moderate visual impact at a distance of 9 to 10 km [5.6 - 6.2 miles].

- Interviews with Industry Experts. A power industry analyst with extensive experience in quantitative analysis of visual impacts of transmission lines stated in an interview that a rule of thumb used for the zone of visual influence of installations such as transmission lines and large wind turbines is a distance of approximately five miles.

There are other possible definitions of the view shed. At present, new proposals are sometimes required to conduct a Zone of Visual Influence (ZVI) analysis to determine the extent of visibility of a development. The zone comprises a visual envelope within which it is possible to view the development, notwithstanding the presence of any intervening obstacles such as forests, buildings, and other objects. Digital terrain computer programs are used to calculate and plot the areas from which the wind farm can be seen on a reference grid that indicates how many turbines can be seen from a given point. One weakness of the standard ZVI analysis is that all turbines are given equal weight of visual impact. That is, a turbine 20 miles from the viewer is assigned the same visual impact as a turbine one mile away.

Possible definitions for view sheds include the set of real properties that have a view of one or more wind turbines from inside the residence, that have a view of one or more turbines from any point on the property, or that are simply within some defined distance from the wind turbines, whether there is a view from each property in that area or not. In the last case, it is assumed that property owners in the area will still be potentially affected by views of the wind farms, as they will see them while traveling and conducting business in their vicinity.

Because this project lacked the resources to determine (through site visits, interviews, or other means) whether or not individual properties in the vicinity of the ten selected wind farms have a direct view of the wind turbines, the view shed is defined as all properties within a given radius of the outermost wind turbines in a wind farm. The value of this radius will clearly affect the results of the analysis. If the radius is too large, including many properties not potentially affected will overshadow the potential effect of the presence of wind turbines on property values. If the radius is too small, not all potentially effected properties will be accounted for in the analysis, and the number of data points gathered may be too small to yield valid statistical results.

D. Comparable Criteria

With the view shed of the wind farm defined, a set of neighboring communities outside of the view shed is selected to evaluate trends in residential house sales prices without the potential effects of wind farms on property values. These townships and incorporated cities are required to be clearly outside of the view shed area and not containing any large wind turbines. This selection is the "comparable" region. To define the comparable REPP consulted with local County Assessors and analyzed 1990 and 2000 U.S. Census data for the townships and incorporated cities under consideration.

Criteria used in selection of comparable communities include economic, demographic, and geographic attributes and trends. The goal in selecting comparable communities is to have communities that are as similar as possible with respect to variables that might affect residential house values, with the exception of the presence or absence of wind farms. When possible, comparable communities are selected in the same county as the wind farm location. If this is not possible due to placement of wind farm or availability of suitable data, comparable communities are selected from counties immediately adjacent to the county containing the wind farm.

After considering a number of criteria, including population, income level, poverty level, educational attainment, number of homes, owner occupancy rate, occupants per household, and housing value, five criteria from 1990 and 2000 U.S. Census were selected for evaluation:

- Population
- Median Household Income
- Ratio of Income to Poverty Level
- Number of Housing Units
- Median Value of Owner-occupied Housing Units

Data for these criteria is obtained for both the wind farm and comparable communities. Percent change from 1990 to 2000 for each criterion is calculated for each township or city considered as potentially comparable areas. The criteria are used in the following manner:

a) Change in population is calculated to identify any communities that had excessively large changes in population relative to the change in population from 1990 to 2000 in the wind farm area. Such large changes could indicate either a major construction boom, or major exodus of habitants from an area, which could skew comparisons in residential home values over the period in question. These communities are eliminated as possible comparables.

b) The average median household income in the wind farm communities in 1990 and 2000 is calculated. The first criterion is that comparable communities should have similar median household incomes in 2000. The second criterion is that median incomes should not have changed at significantly different rates from 1990 to 2000 between wind farm and comparable communities. Communities that meet both criteria are considered as potential comparables.

c) The percent of the population whose income is below poverty level is calculated from the ratio of income to poverty level. Absolute poverty levels and percent changes in poverty levels from 1990 to 2000 are compared. Communities that have significantly different poverty levels or rates of change of these levels as compared to the wind farm areas are eliminated as possible comparables.

d) Change in the number of housing units is used to identify any communities that had excessively large changes in housing relative to the change in housing from 1990 to 2000 in the wind farm area. Such large changes could indicate a major construction boom, or reduction in housing stock, which could skew comparisons in residential home values over the period in question. These communities are eliminated as possible comparables.

e) The average median house value in the wind farm communities in 1990 and 2000 is obtained from Census data. These values are owner-reported, and therefore may not accurately reflect actual market value of the properties. The criterion is that comparable communities should have similar median house values. Communities meeting these criteria are considered as potential comparables

Communities that meet all five of the above criteria are selected for consideration as comparable communities. In addition to analysis of Census data, interviews with County Assessors, other local and state officials, and in some cases with knowledgeable real estate agents are taken into account in the selection of comparables.

E. Analysis

i. Literature Review

In selecting the type of analysis to use in determining whether there is any statistical evidence that wind farms negatively affect property values, we first conducted literature research to identify any studies previously conducted for this purpose. We found only four studies relating wind and property value effects, three of which are only qualitative.

A 1996 quantitative study, Social Assessment of Wind Power (Institute of Local Government Studies, Denmark), applied regression analysis to determine the effect of individual wind turbines, small wind turbine clusters, and larger wind parks on residential property values. The regression used the hedonic method, discussed in more detail below, in which site-specific data on a number of quantitative and qualitative variables is used to predict housing values. The study concluded that homes close to a wind turbine or turbines ranged in value from DKK 16,200 to 94,000 (approximately $2,900 to $16,800) less than homes further away. The study had a number of weaknesses, including a lack of definition of the distance from turbines, lack of specification of the size and number of turbines, and regression on a very small data sample. In contrast, a 2002 qualitative study, Public Attitudes Towards Wind Power (Danish Wind Industry Association), quoted the 1997 Sydthy Study as concluding that residents closer than 500 meters to the nearest wind turbine tend to be more positive about wind turbines than residents further away.

A 2001 qualitative study, Social Economics and Tourism (Sinclair Knight Merz), said that for highly sought after properties along Salmon Beach, Australia closer than 200 meters from wind turbines, the general consensus among local real estate agents is that "property prices next to generators have stayed the same or increased after installation." However, the study concluded that while properties with wind turbines on them may increase in value, other properties may be adversely affected if within sight or audible distance of the wind turbines. Finally, the 2002 qualitative study, Economic Impacts of Wind Power in Kittitas County (ECO Northwest), concluded from interviews with assessors around the United States that there is no evidence of a negative impact on property values from wind farms. The weakness of the study is that it relies on subjective comment to arrive at its conclusion.

We also reviewed several studies that attempt to quantify the visual and property value impacts of electric transmission towers and lines. There is a large body of information on this subject, as transmission lines have been the subject of scrutiny and regulation for many years.

A 1992 study, The Effects of Overhead Transmission Lines on Property Values (C.A. Kroll and T. Priestley), reviews the methodology and conclusions of a number of studies on overhead transmission lines and property values over the 15 year period of 1977 through 1992. This study was very helpful in identifying the types of analysis, and their strengths and weaknesses, which could be adopted for use in this REPP report. The study concluded that appraisal offices have the longest history of studying and evaluating line impacts, but lack in-depth statistical analysis to verify obtained results. Data collected from face-to-face conversation and through surveys attempts to ascertain the attitudes and reactions of property owners to transmission equipment, but personal opinions were found to produce widely varying results. Statistical analysis of appraiser findings provided a better interpretation of appraiser information, but produced varying results due to different methodologies.

ii. Choice of Analytic Method

A number of analytic methods may be used to assess property value impacts from wind farms, ranging from interviews with assessors and surveys of residents to simple regression models and hedonic regression analysis. In order to produce results that could determine whether or not there was statistical evidence that wind farms have a negative impact on property values, simple linear regression analysis on property sales price as a function of time was selected.

A more complex method, hedonic regression analysis, can also be used to gauge property value impacts. Hedonic analysis, used in a number of studies on visual impacts of transmission lines, employs both quantitative and qualitative values to describe the property and local, regional, and even national parameters that may influence housing values. Property data such as number of bedrooms and bathrooms, linoleum or tile floors, modern appliances, kitchen cabinets or not are collected for each property in the study area, as well community information such as school district quality, subjective criteria derived from interviews with every resident in a study area, and other parameters. However, because this report is based on historic data, much of the detail needed for a hedonic analysis may not be available. An important consideration for this analysis, given the limits of the data, was to apply a consistent methodology to the site analyses. The only data consistent across all sites is sales date and sales price.

iii. Data Analysis

The key variables used in this analysis are sale price, sale date, and one locational attribute allowing data to be separated into view shed and comparable data sets. The first step of analysis was to remove any erroneous data from the dataset. Sales with incomplete information, duplicate sales, and zero price were removed. Parcel sales under $1,000 were also removed, as they often represent transfer within a family or business, rather than a bona fide sale. Finally, any sales with values much higher than any other sales were researched to determine whether or not that sale was bona fide. Interviews with assessors with knowledge of the properties in question were used to determine whether these high value sales were erroneous. Where they were, they were removed.

The second step in data analysis was to reduce cyclic effects of the real estate market on sales prices, as well as to reduce the high variability and heterogeneity of the data when viewed on a day to sale basis. First, for each month, we calculated the monthly average sales price for each month to eliminate the variability of day-to-day sales. In some cases data supplied was already in monthly averaged form. Second, a six-month trailing average of the average monthly sales price is used to smooth out seasonal fluctuations in the real estate market. The averaging technique used the current month sales plus the previous six months of sales to compute trailing averages.

Third, a unit of analysis is defined. Because this project generally lacks resources to identify properties by street address, the smallest units of geographical analysis used are townships and incorporated cities within each county. Townships that are partly but not fully within the view shed radius are excluded from the view shed. In some cases zip code 4-digit ZIP+4 regions are used to identify location, and in some cases where the data offered no other alternative, individual street locations were manually identified in order to define the location of properties within the view shed and comparable.

Fourth, as stated above, linear regression is selected as the method to test for potential property value impacts. A least-squares linear regression of the six-month trailing average price is constructed for the view shed and comparable areas to determine the magnitude and rate of change in property sales price for each of the areas. The regression yields an equation for the line that best fits the data. The slope of this line gives the month-by-month expected change in the price of homes in the view shed and comparable areas. The regression also yields a value for "R2."

The R2 value measures the goodness of fit of the linear relationship to the data, and equals the percentage of the variance (change over time) in the data that is described by the regression model. The value of R2 ranges from zero to one. If R2 is small, say less than 0.2 to 0.3, the model explains only 20 to 30 percent of the variance in the data and the slope calculated is a poor indicator of the change in sales price over time. If R2 is large, say 0.7 or greater, then the model explains 70 percent or more of the variance in the data, and the slope of the regression line is a good indicator for quantifying the change in sales price over time. Regression models with low R2 values must be interpreted with caution. Often, knowledge and examination of factors not included in the regression model can help one understand why the regression provides a poor fit.

iv. Case I, II, and III Definitions

This report tests for effects of wind farms on property sales prices using three different models, or cases. All employ linear regression on six-month trailing averaged monthly residential sales data as outlined above.

Case 1 compares changes in the view shed and comparable community sales prices for the entire period of the study. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in the view shed than in the comparable. Case 1 takes into account the wind farm on-line date only in that the data set begins three years before the on-line date. An appropriate comparable is important in this case in order that meaningful comparison of sale price changes over time can be made.

Case 2 compares property sales prices in the view shed before and after the wind farm in question came on-line. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in view shed after the wind farm went on-line than before. Case 2 is susceptible to effects of macro-economic trends and other pressures on housing prices not taken into account in the model. Because Case 2 looks only at the view shed, it is possible that external factors change prices faster before or after the on-line date, and the analysis may therefore pick up factors other than the wind development.

Case 3 compares property sales prices in the view shed and comparable community, but only for the period after the projects came on line. If wind farms have a negative effect, we would expect to see prices increase slower (or decrease faster) in view shed than comparable after the on-line date. Again, an appropriate comparable is important in this case in order that meaningful comparison of sale price changes over time can be made.

Chapter III. Site Reports

Site Report 1: Riverside County, California

A. Project Description

The topography ranges from desert flats to and mountains with views of snow capped peaks in winter - all of which encompass areas both in and out of the view shed.

The area has extreme elevation changes from the Palm Springs flats at an elevation of 450 feet, to the San Gorgonio Pass at an elevation of 2,500 feet. The Pass cuts through the two peaks of Mt. San Gorgonio to the north and Mt. San Jacinto to the southeast, and is five miles from the western edge of Palm Springs (15 to downtown), and about 80 miles east of Los Angeles.

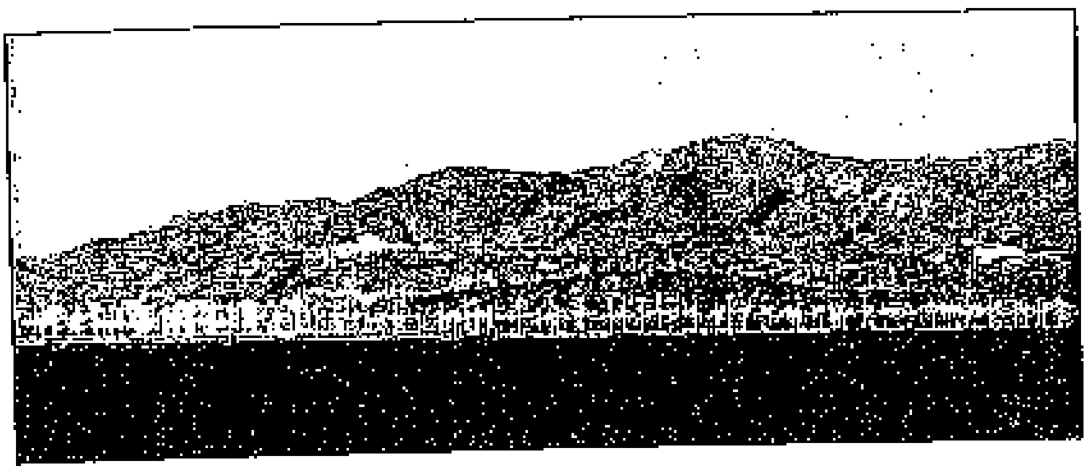


Figure 1.1 View of wind farms at San Gorgonio Pass, Riverside County, CA

Photo by David F. Gallagher, 2001 - www.lightningfield.com

The projects are located in the San Gorgonio Pass immediately west of the Palm Springs area in Riverside County, California. Developers installed 3,067 turbines from 1981 to 2001, with the tallest turbine at 63 meters (207 feet). Repowering projects built 130 modern turbines. They begin northwest of Palm Spring heading up Interstate 10 from Indian Avenue; then they extend more than 10 miles along the flats up into the San Gorgonio Mountains, along the Pass, and stop shortly before reaching Cabazon.

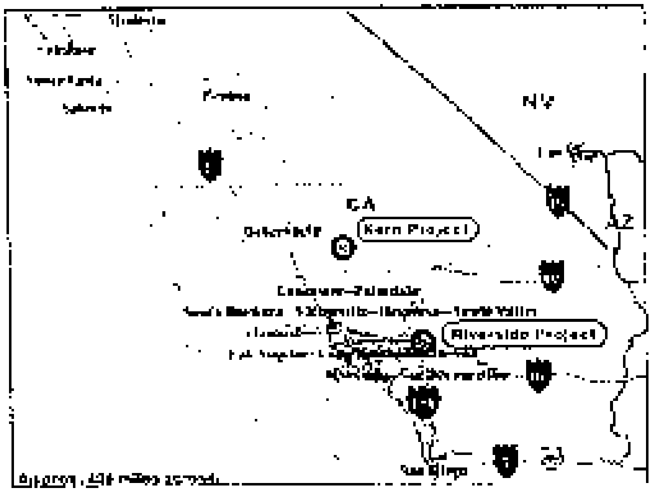


Figure 1.2 Regional Wind Project Location
(Note approximate wind farm locations)

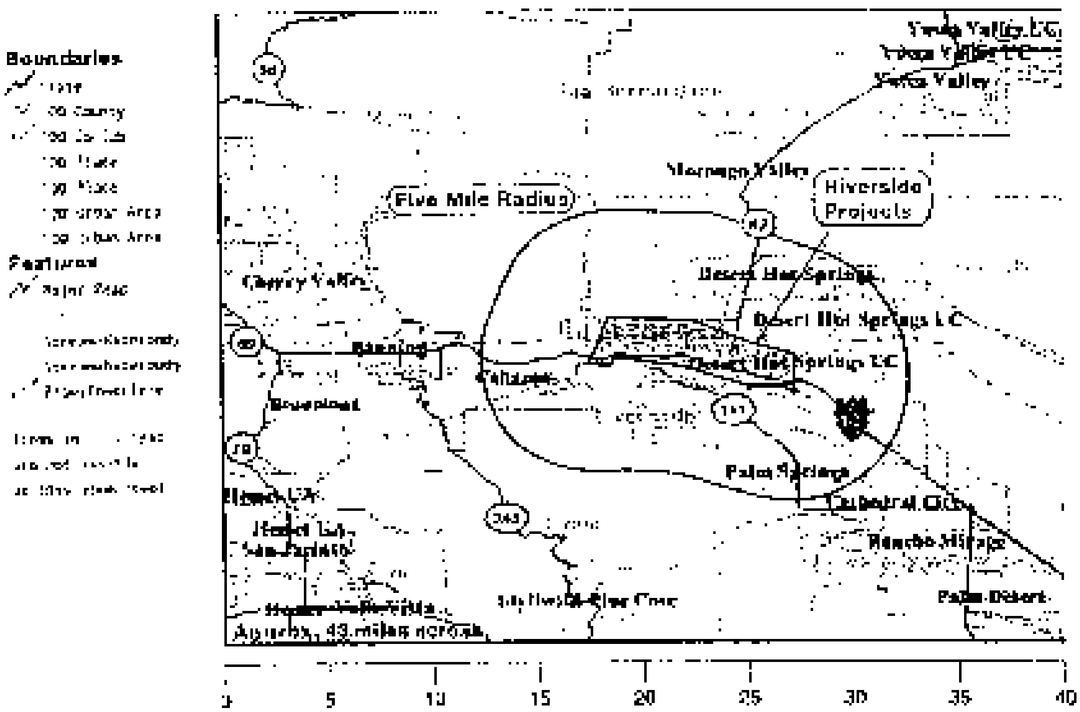


Figure 1.3 San Gorgonio, Riverside County, California View shed
(5 Mile Radius from project sites)
Map Source: U.S. Census Bureau Website
Project Location Details: Interviews and Aerial Photographs

The county is considered a metro area with 1 million population or more, but that is due to the population of the Los Angeles area. See Appendix 1 for a definition of rural urban continuum codes. The view shed represents fewer than 30,000 people.

B. Project Timeline

Table 1.1 Wind Project History, San Gorgonio, CA

Project Name	Completion Date	Capacity (MW)	Project Name	Completion Date	Capacity (MW)
Mountain View Power Partners I	2001	44.4	Altech 3	1981-1995	21.7
Mountain View Power Partners II	2001	22.2	Westwind Trust	1981-1995	15.7
Enron Earth Smart/Green Power	1999	16.5	Painted Hills B & C	1981-1995	15.3
Energy Unlimited	1999	10.0	Difwind, Ltd.	1981-1995	15.0
Pacific West I	1999	2.1	Energy Unlimited	1981-1995	14.5
Westwind-Repower	1999	47.3	Enform Hill	1981-1995	11.0
Cabazon-Repower	1999	39.8	So. Cal. Sunbelt	1981-1995	10.5
Westwind - PacifiCorp-Repower	1999	1.5	Difwind V	1981-1995	7.9
East Winds-Repower	1997	4.2	Meridian Trust	1981-1995	7.5
Karen Avenue-Repower	1995	3.0	Kenetech/Wintec	1981-1995	7.3
Dutch Pacific	1994	10.0	San Jacinto	1981-1995	5.0
Kenetech (various)	1981-1995	30.3	Painted Hills B & C	1981-1995	4.0
Zond-PanAero Windsystems	1981-1995	29.9	Altech 3	1981-1995	3.3
Alta Mesa	1981-1995	28.2	San Gorgonio Farms	1981-1995	3.2
Section 28 Trust	1981-1995	26.2	San Gorgonio Farms	1981-1995	2.0
San Gorgonio Farms	1981-1995	26.1			

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained from First American Real Estate Solutions in Anaheim, CA. The dataset is quite detailed and contains many property and locational attributes, among them nine-digit zip code (ZIP+4) locations. Sales data was purchased for four zip codes encompassing the wind farm area and surrounding communities. These zip codes are Palm Springs (92262), White Water (92282), Cabazon (92230), and Banning (92220).

Sales for the following residential property types were included in the analysis: Condominiums, Duplexes, Mobile Homes, and Single-Family Residences. Upon initial analysis, of the 9105 data points analyzed, approximately 10 sales in the view shed had unusually high prices. Conversations with the Assessors Office confirmed these were incorrect values for the data points. Correct values were obtained and the data corrected.

Projects that went on-line during the study period are the Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, and Westwind sites. Of these, two sites added 87 MW of repowered capacity in May 1999, two sites added 27 MW of new capacity in June 1999, and two sites added 66 MW of new capacity in October 2001.

ii. View shed Definition

All ZIP+4 regions within five miles of the wind turbines define the view shed. The location of the ZIP+4 regions were derived from the latitude and longitude of the ZIP+4 areas obtained from the U.S. Census TIGER database. The view shed includes the northwest portion of Palm Springs, Desert Hot Springs, and Cabazon, and 5,513 sales from 1996 to 2002. The view shed portion of northwest Palm Springs corresponds very closely to the boundaries of Palm Springs zip code 92262.

Interviews with State of California Palm Springs Regional Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Assessment District Supervisor Gary Stevenson's opinion, over 80 percent of Cabazon properties can see some wind turbines; over 80 percent of Desert Hot Springs properties can see some wind turbines; almost all of the properties on the outer edge of northwest Palm Springs can see some wind turbines, but due to foliage (mainly palm trees) and tall buildings, only five percent or less of the properties in the interior of Palm Springs can see any wind turbines.

iii. Comparable Selection

The comparable community was selected through interviews with State of California San Gorgonio Regional Assessors Office personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Selection of the comparable in this case was difficult, as the eastern side of the view shed is close to downtown Palm Springs, which is growing fairly quickly, while the western portion of the view shed, including Cabazon, is not growing quickly and has more stable housing sales prices. Tables 1.2 and 1.3 summarize the Census data reviewed. Because Census data by zip code is not available for 1990, we were unable to determine 1990 demographic statistics for the Palm Springs view shed, as it is not separable from the Palm Springs non-view shed area.

Based on his extensive experience in the area, Assessment District Supervisor Gary Stevenson suggested Banning and Beaumont in Riverside County, to the west of the wind farms, and Morongo Valley in San Bernardino County, to the north of the wind farms as appropriate comparables to the view shed area. Banning and Beaumont are visually separated from the wind farm area by a ridge, and Morongo Valley is separated by approximately seven miles distance.

In order to determine the most appropriate comparable community we looked at the demographics of 10 surrounding areas. The 92264 zip code area of Palm Springs to the south of northwest Palm Springs was initially considered as a comparable, but Supervisor Stevenson said that this area was closer to the metropolitan center and had significantly different demographics than the view shed area. Towns adjacent to Banning and Beaumont, including Hemet, San Jacinto, and Cherry Valley, were considered but rejected for use after discussion with Supervisor Stevenson. Upon examination of Census data, sales data availability, and review of Assessor comments, Banning was selected as the comparable, with a total of 3,592 sales from 1996 to 2002.

Table 1.2 Riverside County, California: 1990 Census Data

Year	View shed	Location	Population	Median Household Income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Cabazon CDP	1,588	$13,830	19%	754	$64,000
1990	Y	Palm Springs City*	n/a	n/a	n/a	n/a	n/a
1990	Y	White Water**	n/a	n/a	n/a	n/a	n/a
1990	VIEW SHED DEMOGRAPHICS		n/a	n/a	n/a	n/a	n/a
1990	COMP	Banning City	20,570	$22,514	17%	8,278	$89,300
1990	COMPARABLE DEMOGRAPHICS		20,570	$22,514	17%	8,278	$89,300
1990	N	Beaumont City	9,685	$22,331	23%	3,718	$89,700
1990	N	Cathedral City	30,085	$30,909	13%	15,279	$114,200
1990	N	Cherry Valley CDP	5,945	$29,073	9%	2,530	$127,500
1990	N	Hemet City	36,094	$20,382	14%	19,802	$90,700
1990	N	Idyllwild Pine Cove CDP	2,037	$31,507	4%	3,635	$147,200
1990	N	Morongo Valley CDP***	1,554	$38,125	23%	827	$74,100
1990	N	Rancho Mirage City	9,778	$45,064	7%	9,360	$252,400
1990	N	San Jacinto City	16,210	$20,810	16%	6,845	$90,200
1990	N	Valle Vista CDP	8,751	$22,138	8%	4,444	$125,500

*Census data by zip code not available for 1990. Unable to determine demographics of view shed as the Palm Springs view shed area is not separable from the Palm Springs non-view shed area.
**White Water not listed in 1990 U.S. Census.
***San Bernardino County.

Table 1.3 Riverside County, California: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Cabazon - Zip Code 92230	2,442	$22,524	32%	884	$48,200
2000	Y	Palm Springs - Zip Code 92262	24,774	$32,844	18%	15,723	$133,100
2000	Y	White Water - Zip Code 92282	903	$35,982	23%	380	$62,400
2000	VIEW SHED DEMOGRAPHICS		[illegible]	$30,150	[illegible]	[illegible]	$87,900
2000	COMP	Banning City - Zip Code 92220	23,443	$32,076	20%	9,739	$97,300
2000	COMPARABLE DEMOGRAPHICS		23,443	$32,076	20%	9,739	$97,300
2000	N	Beaumont City	11,315	$29,721	20%	4,258	$93,400
2000	N	Cathedral City	42,919	$38,887	14%	17,813	$113,600
2000	N	Cherry Valley CDP	5,857	$39,199	6%	2,633	$121,700
2000	N	Hemet City	58,770	$26,839	16%	29,454	$69,900
2000	N	Idyllwild-Pine Cove CDP	3,563	$35,625	13%	4,019	$164,700
2000	N	Morongo Valley CDP*	2,035	$36,357	19%	972	$73,300
2000	N	Rancho Mirage City	12,973	$59,826	6%	11,643	$251,700
2000	N	San Jacinto City	23,923	$30,027	20%	9,435	$78,500
2000	N	Valle Vista CDP	10,812	$32,455	12%	4,941	$76,500

*San Bernardino County.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values. For Cases II and III, the on-line date is defined as the month the first wind project came on line during the study period, May 1999.

In Case I, the monthly sales price change in the view shed is twice the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over 80 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 86 percent greater after the on-line date than before the on-line date. The Case II model provides a good fit to the data, with over two-thirds of the variance in the data explained by the linear regression. In Case III, the monthly sales price change in the view shed after the on-line date is 63 percent greater than the monthly sales price change of the comparable after the on-line date. The data for the full study period is graphed in Figure 1.4, and regression results for all cases are summarized in Table 1.4 below.

Table 1.4 Riverside County, California: Regression Results

Projects: Cabazon, Enron, Energy Unlimited, Mountain View Power Partners I & II, Westwind

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Nov 02 Jan 96 - Nov 02	$1,719.65 $814.17	0.92 0.81	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Nov 02	$1,062.03 $1,978.88	0.68 0.81	The rate of change in average view shed sales price is 86% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Nov 02 May 99 - Nov 02	$1,978.88 $1,212.14	0.81 0.74	The rate of change in average view shed sales price after the on-line date is 63% greater than the rate of change of the comparable after the on-line date.

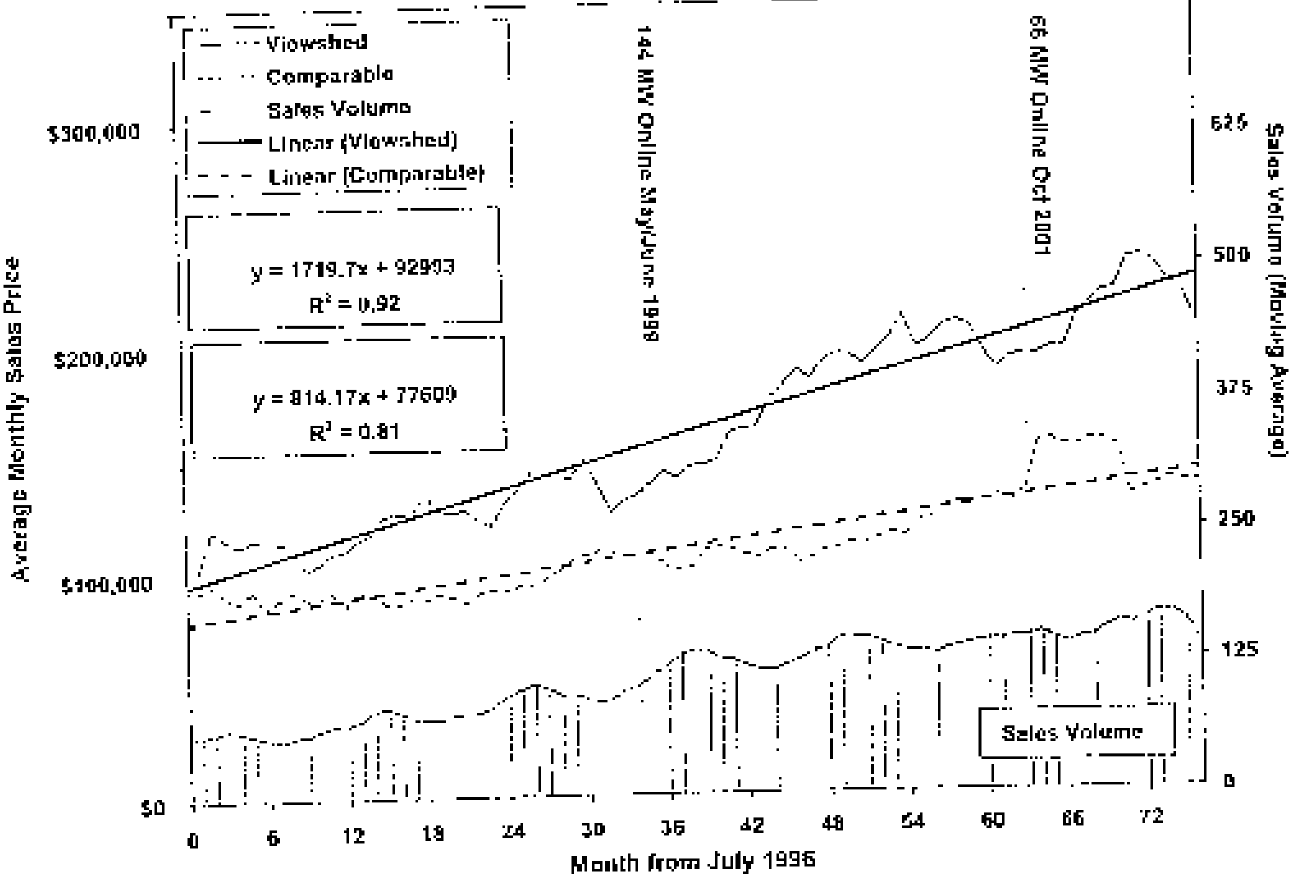


Figure 1.4 Average Residential Housing Sales Price
Riverside County, California 1996-2002

D. Additional Interviewee Comments

Jack Norie of Desert Hot Springs, who provides tours of the wind projects, said that since 1998 there has been a discernable sense that more turbines were in the area. Norie felt that the 41 new turbines built high up along the nearest peaks facing Palm Springs near the intersection of Highway 111 and Interstate 10 on the north side, contributed to this impression. (These are possibly the Mountain View Power Partners II project with 37 turbines). Mr. Norie's descriptions of project locations and aerial photographs available from Microsoft's Terraserver and Mapquest, allowed us to determine project locations.

Site Reports 2.1 and 2.2: Madison County, New York

A. Project Description

Madison County has two wind farms meeting the criteria for analysis, Madison and Fenner. Because they are separated by distance, and have different on-line dates, each wind farm is analyzed separately. However, since they are in the same county and share the same comparable region, both analyses are presented in this section.

The Fenner turbines are seated in a primarily agricultural region southeast of Syracuse and southwest of Utica, with 20 turbines at 100 meters (328 feet). The Madison project is about 15 miles southeast of Fenner, and 2.5 miles east of Madison town with seven turbines standing 67 meters (220 feet).

Madison County is classified as a "county in a metro area with 250,000 to 1 million population." See Appendix 1 for a definition of rural urban continuum codes. The view shed areas have a population less than 8,000.

Figure 2.1 View of Fenner wind farm.

Photo Courtesy, New York State Energy Research and Development Authority (NYSERDA)

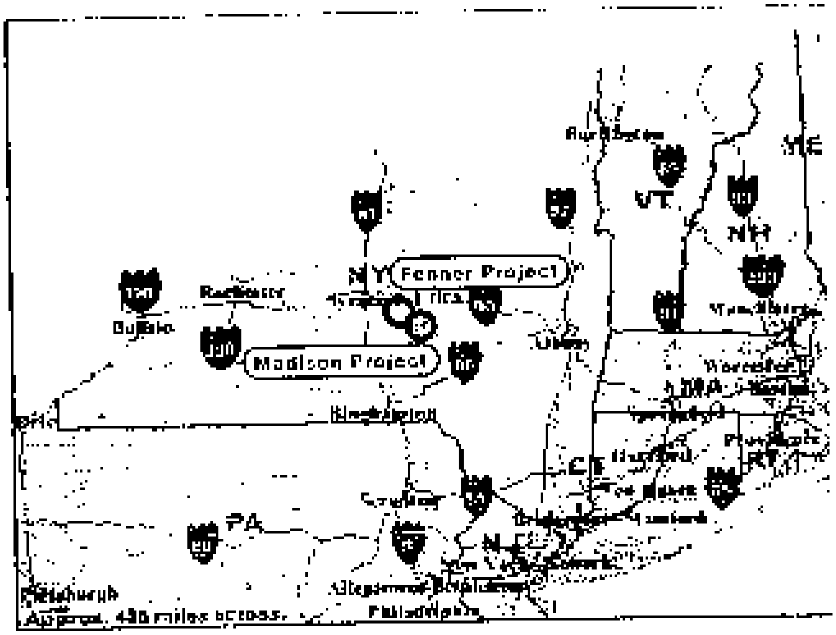


Figure 2.2. Regional Wind Project Location

(Dots approximate wind farm locations)

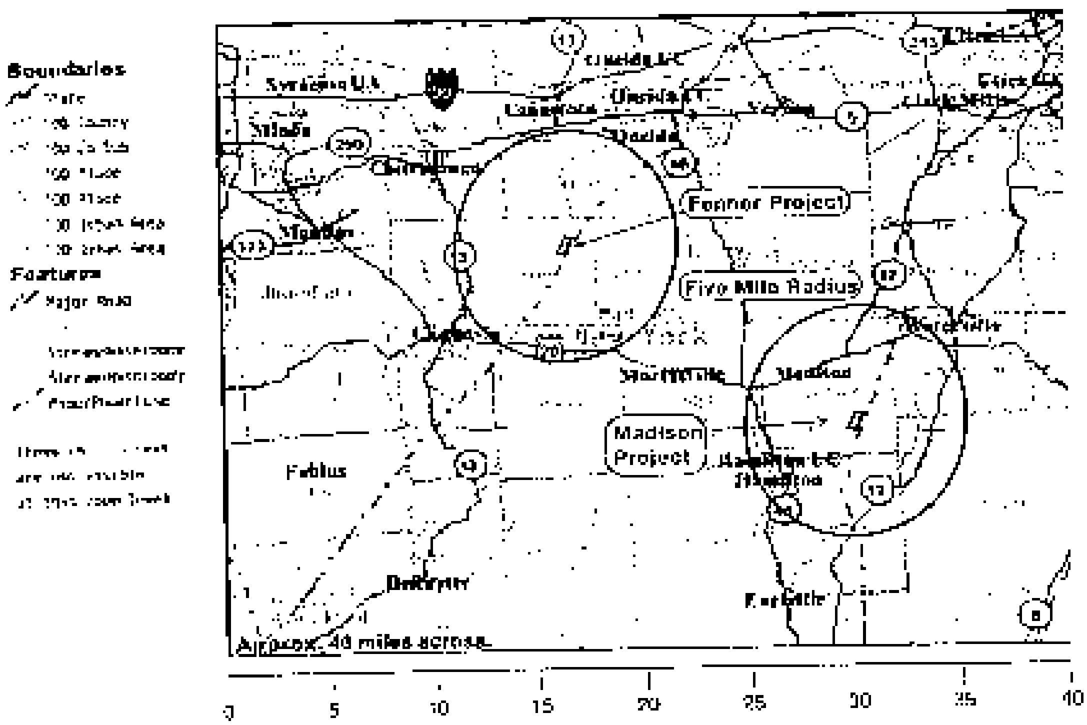


Figure 2.3 Location of Wind Projects in Madison County

Site Locations Source, Madison Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 3.1 Wind Project History, Madison County, NY

Project Name	Completion Date	Capacity (MW)
Fenner Wind Power Project	2001	30.0
Madison Windpower	2000	11.6

C. Analysis

i. Data

Real property sales data for 1997 to 2002 was purchased on CD-ROM from Madison County Real Property Tax Services in Wampsville, NY. The sales data was purchased for the townships and cities encompassing the wind farm areas and surrounding communities. The unit of analysis for this dataset is defined by either township or incorporated city boundaries. Though street addresses are included in the dataset, this analysis lacked the resources to identify the location of properties by street address.

In addition to basic sales data, the dataset included property attributes such as building style, housing quality grade, and neighborhood ratings. The CD-ROMs contained four files that required merging on a common field to create the composite database of all sales. A significant number of redundant, incomplete, and blank entries were deleted prior to analysis. Sales for the following residential property types were included in the analysis: one-, two-, and three-family homes, rural residences on 10+ acres, and mobile homes.

Upon initial analysis, of the 1,263 data points analyzed, approximately six sales in the Madison view shed had unusually high prices. Conversations with the Assessors Office confirmed four of these were valid sales, but that two were not. The invalid sales were eliminated from the analysis.

Projects that went on-line during the study period are the Madison wind farm, which went on-line September 2000 with a capacity of 11.6 MW, and the Fenner wind farm, which went on line December 2001 with a capacity of 30 MW. The wind farms are approximately 15 miles apart.

ii. View Shed Definition

Two separate view sheds are defined for Madison County, one for each wind farm. A five-mile radius around the Madison wind farm encompasses the town of Madison and over 95 percent of Madison Township. The view shed also encompasses portions of three townships in Oneida County. However, due to lack of resources to identify the location of individual properties within townships, the Oneida townships were excluded from the analysis. The Madison view shed is defined as Madison town and all of Madison Township. The Fenner view shed is defined as all of Fenner, Lincoln, and Smithfield Townships, which are fully within a five-mile radius around the Fenner wind farm, with the exception of a small corner of Smithfield Township. The Madison and Fenner view sheds accounts for 219 and 453 sales over the study period, respectively.

Interviews with the State of New York Madison County Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Fenner Assessment District Supervisor Russell Cary's opinion, over 80 to 85 percent of Fenner properties can see some wind turbines, over 85 percent of Lincoln properties can see some wind turbines, over 75 percent of Madison properties can see some wind turbines, and approximately 60 percent of Smithfield properties can see some wind turbines. Cary said that in his opinion, only a few properties in Fenner Township, near Route 13, could not see some wind turbines.

iii. Comparable Selection

The comparable community was selected through interviews with State of New York Madison County Assessors Office personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 2.2 and 2.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of 13 surrounding areas. Based on his experience in the area, Assessment District Supervisor Russell Cary suggested Lebanon, Deruyter and Stockbridge Townships along with villages of Deruyter, Munnsville and Hamilton, all in Madison County, as appropriate comparables for both view sheds. However, Cary added that Hamilton has higher property values than Madison because it is home to Colgate University. Upon examination of Census data, sales data availability, and review of Assessor comments, Lebanon, Deruyter, Hamilton, Stockbridge Townships, and the Villages of Deruyter and Munnsville were selected as the comparable for both view sheds, with a total of 591 sales from 1997 to 2002.

Table 2.2 Madison County, New York: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value - owner-occupied housing unit
1990	Y	Fenner town	1,694	$31,875	13%	609	$73,700
1990	Y	Lincoln town	1,669	$32,073	8%	587	$63,900
1990	Y	Smithfield town	1,053	$23,355	13%	380	$52,200
FENNER DEMOGRAPHICS			4,416	$29,101	11%	1,576	[illegible]
1990	Y	Madison town	2,774	$29,779	10%	1,239	$65,200
1990	Y	Madison village	316	$26,250	12%	135	$50,000
MADISON DEMOGRAPHICS			3,090	$28,015	11%	1,374	$57,600
1990	COMP	DeRuyter town	1,450	$26,187	11%	611	$51,800
1990	COMP	DeRuyter village	568	$24,125	10%	218	$52,200
1990	COMP	Hamilton town	6,221	$28,594	17%	1,820	$60,900
1990	COMP	Lebanon town	1,265	$26,359	12%	581	$49,600
1990	COMP	Munnsville village	438	$23,154	15%	174	$54,700
1990	COMP	Stockbridge town	1,968	$24,489	11%	723	$53,600
COMPARABLE DEMOGRAPHICS			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1990	N	Cazenovia town	6,514	$39,943	4%	2,372	$122,300
1990	N	Cazenovia village	3,007	$31,622	6%	995	$101,100
1990	N	Chittenango village	4,734	$34,459	7%	1,715	$72,400
1990	N	Earlville village	883	$28,839	6%	362	$44,300
1990	N	Georgetown town	932	$25,000	10%	287	$42,700
1990	N	Hamilton village	3,790	$31,960	16%	869	$88,000
1990	N	Morrisville village	2,732	$26,875	30%	443	$55,500

Table 2.3 Madison County, New York: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value - owner occupied housing unit
2000	Y	Fenner town	1,680	$43,846	7%	651	$84,400
2000	Y	Lincoln town	1,818	$46,023	5%	700	$85,000
2000	Y	Smithfield town	1,205	$35,109	16%	446	$61,900
FENNER DEMOGRAPHICS			4,703	$41,659	9%	1,797	$77,100
2000	Y	Madison town	2,801	$35,889	13%	1,325	$77,100
2000	Y	Madison village	315	$27,250	13%	151	$68,400
MADISON DEMOGRAPHICS			3,116	$31,570	13%	1,476	$72,750
2000	COMP	DeRuyter town	1,532	$34,911	12%	867	$68,200
2000	COMP	DeRuyter village	531	$31,420	12%	231	$70,300
2000	COMP	Hamilton town	5,733	$38,917	14%	1,725	$79,300
2000	COMP	Lebanon town	1,329	$34,043	14%	531	$62,900
2000	COMP	Munnsville village	437	$35,000	15%	176	$66,400
2000	COMP	Stockbridge town	2,080	$37,700	13%	802	$67,900
COMPARABLE DEMOGRAPHICS			11,642	$35,432	13%	4,132	$69,167
2000	N	Cazenovia town	6,481	$57,232	4%	2,567	$142,900
2000	N	Cazenovia village	2,614	$43,611	7%	1,031	$115,200
2000	N	Chittenango village	4,855	$43,750	6%	1,968	$75,700
2000	N	Earlville village	791	$32,500	12%	329	$51,400
2000	N	Georgetown town	946	$37,963	11%	315	$54,600
2000	N	Hamilton village	3,509	$36,563	19%	785	$104,600
2000	N	Morrisville village	2,148	$34,375	20%	398	$73,900

iv. Analytical Results and Discussion

In five of the six regression models, monthly average sales prices grew faster or declined slower in the view shed than in the comparable area. However, in the case of the underperformance of the view shed, the explanatory power of the model is very poor. Thus, there is no significant evidence in these cases that the presence of the wind farms had a negative effect on residential property values.

Madison View shed

In Case I, the monthly sales price change in the view shed is 2.5 times the monthly sales price change of the comparable over the study period. However, the Case I model provides a poor fit to the data, with approximately 30 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 10.5 times greater after the on-line date than before the on-line date. However, the Case II model provides a poor fit to the data, with less than 30 percent of the variance in the data after the on-line date, and only 1 percent of the variance before the on-line date explained by the linear regression. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date. The Case III model describes less than 30 percent of the variance in the view shed, but almost 40 percent of the variance in the comparable. The poor fit of the models, at least for the view shed, is partly due to a handful of property sales that were significantly higher than the typical view shed property sale. The data for the full study period is graphed in Figure 2.4, and regression results for all cases are summarized in Table 2.4 below.

Table 2.4 Madison County, New York: Regression Results
Project: Madison

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R^2)	Result
Case 1	View shed, all data	Jan 97 Jan 03	$576.22	0.29	The rate of change in average view shed sales price is 2.3 times greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 97 Jan 03	$245.51	0.34	
Case 2	View shed, before	Jan 97 - Aug 00	$129.32	0.01	The rate of change in average view shed sales price after the on-line date is 10.3 times greater than the rate of change before the on-line date.
	View shed, after	Sep 00 - Jan 03	$1,332.24	0.28	
Case 3	View shed, after	Sep 00 - Jan 03	$1,332.24	0.28	The rate of change in average view shed sales price after the on-line date increased at 3.2 times the rate of decrease in the comparable after the on-line date.
	Comparable, after	Sep 00 - Jan 03	-$418.71	0.39	

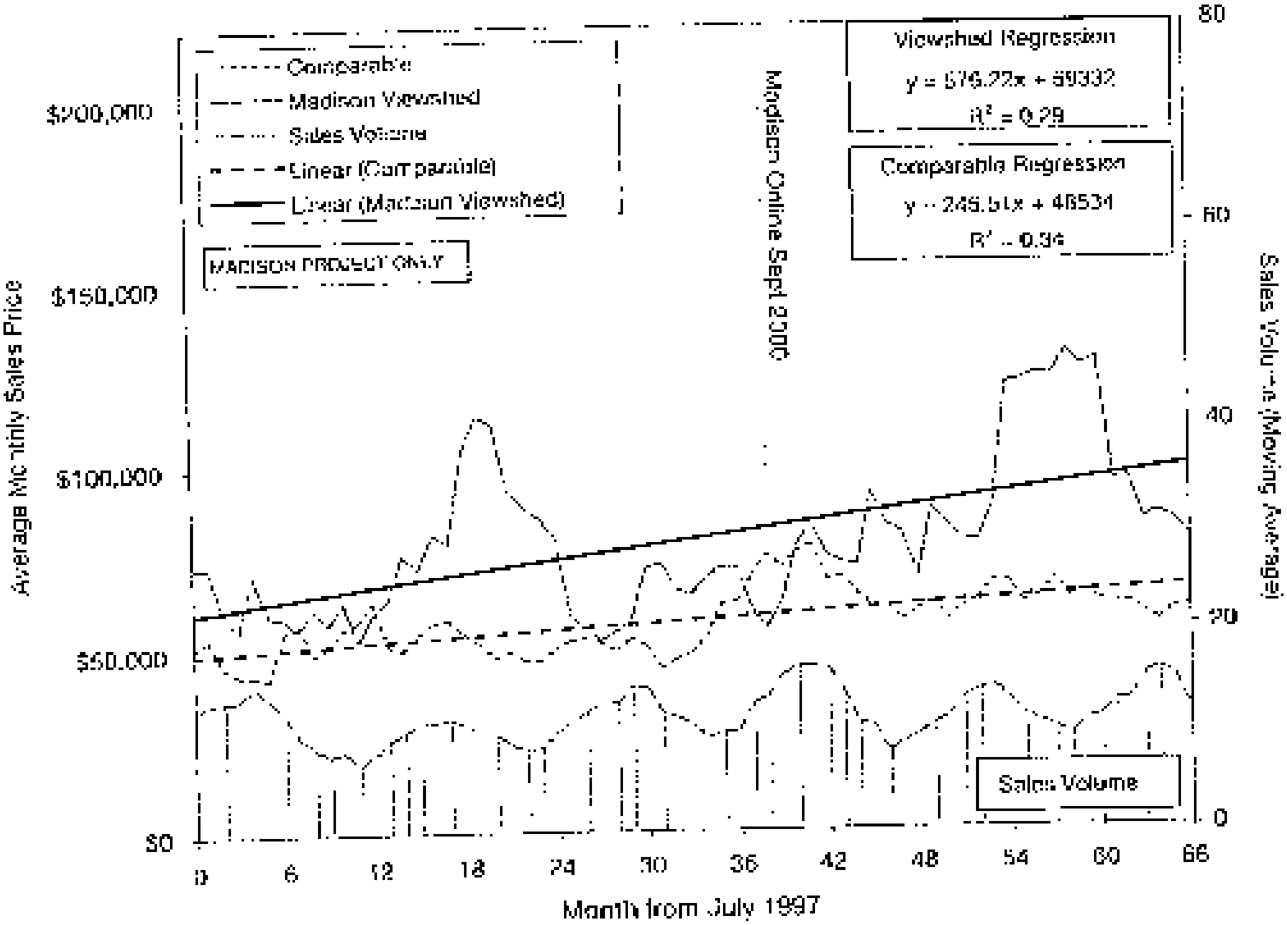


Figure 2.4 Average Residential Housing Sales Price For Madison Project
Madison County, New York 1997-2002

Fenner View shed

In Case I, the monthly sales price change in the view shed is 50 percent greater than the monthly sales price change of the comparable over the study period. The Case I model explains approximately one-third of the variance in the data. In Case II, average monthly sales prices increase in the view shed prior to the on-line date, but decrease after the on-line date. The average view shed sales price after the on-line date decreased at 29 percent of the rate of increase before the on-line date. The Case II model provides a fair fit to the data before the on-line date, with half of the variance in the data explained by the linear regression, but a poor fit after the on-line date, explaining only 4 percent of the variance in the data. The poor fit is partly due to having only 14 months of data after the on-line date, which may not be enough data establish clear price trends in a housing market that exhibits significant price fluctuations over time. In Case III, average monthly sales prices decrease in both the view shed and comparable after the on-line date, with the view shed decreasing less quickly. The decrease in average view shed sales price after the on-line date is 37 percent less than the decrease of the comparable after the on-line date. The Case III model again describes only 4 percent of the variance in the view shed, but over 60 percent of the variance in the comparable. The data for the full study period is graphed in Figure 2.5, and the regression results are summarized in Table 2.5.

Table 2.5 Madison County, New York: Regression Results
Project: Fenner

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 97 - Jan 03	$368.47	0.35	The rate of change in average view shed sales price is 50% greater than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 97 - Jan 03	$245.51	0.34	
Case 2	View shed, before	Jan 97 - Nov 01	$557.05	0.50	The rate of decrease in average view shed sales price after the on-line date is 29% lower than the rate of sales price increase before the on-line date.
	View shed, after	Dec 01 - Jan 03	-$416.98	0.04	
Case 3	View shed, after	Dec 01 - Jan 03	-$416.98	0.04	The rate of decrease in average view shed sales price after the on-line date is 37% less than the rate of decrease of the comparable after the on-line date.
	Comparable, after	Dec 01 - Jan 03	-$655.38	0.63	

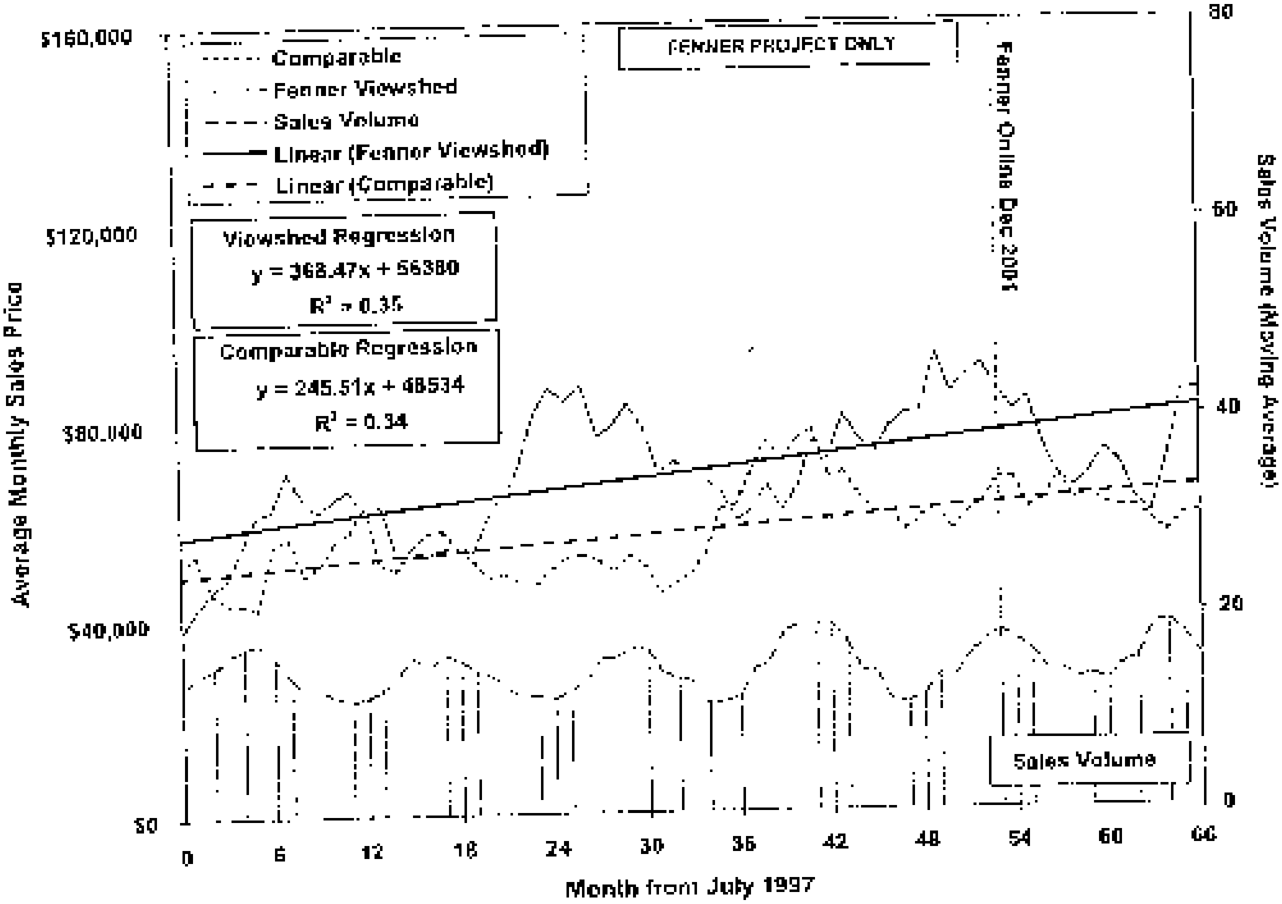


Figure 7-5 Average Residential Housing Sales Price For Fenner Project

Madison County, New York 1997-2002

D. Additional Interviewee Comments

Madison County assessors Carol Brophy and Priscilla Suits said they have not seen any impact of the turbines on property values, and Suits added, "There's been no talk of any impact on values." Assessor Russell Cary noted that there were worries about views of the turbines, and that the project siting was designed such that the town of Cazenovia could not see the project -- it rests just outside the five-mile perimeter viewshed this study designated.

Site Report 3: Carson County, Texas

A. Project Description

Situated in the middle of the Texas panhandle among large agricultural farms and small herds of cattle on fallow, 80 turbines stand at 70 meters (230 feet) high. Southwest of the project by 2.5 miles is White Deer town, which is 4[illegible] miles northeast of Amarillo.

The area is just about dead flat since Carson is right on the edge of the Texas High Plains. The general classification of the county is "completely rural or less than 2,500 urban population, but adjacent to a metro area." See Appendix 1 for a definition of rural urban continuum codes. The view shed represents fewer than 1,200 people.

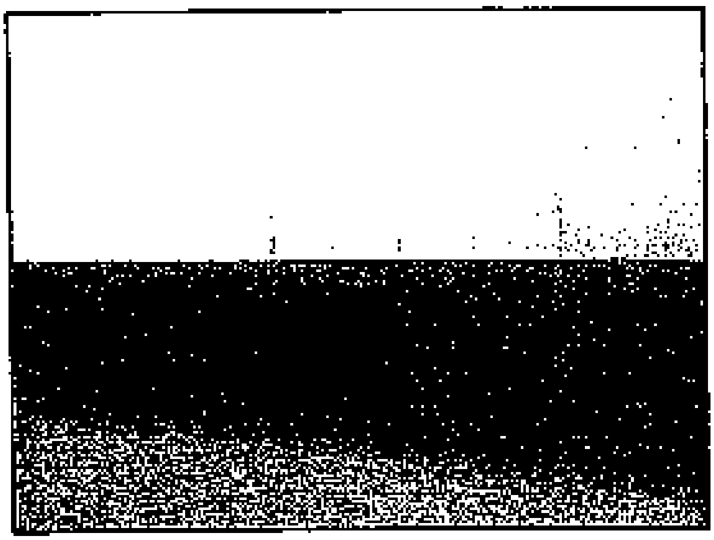


Figure 3.1: White Deer Wind Farm
Photo Courtesy Ted Case [illegible]

B. Project Timeline

Table 3.1 Wind Project History, Carson County, TX

Project Name	Completion Date	Capacity (MW)
Llano Estacado Wind Ranch	2001	80

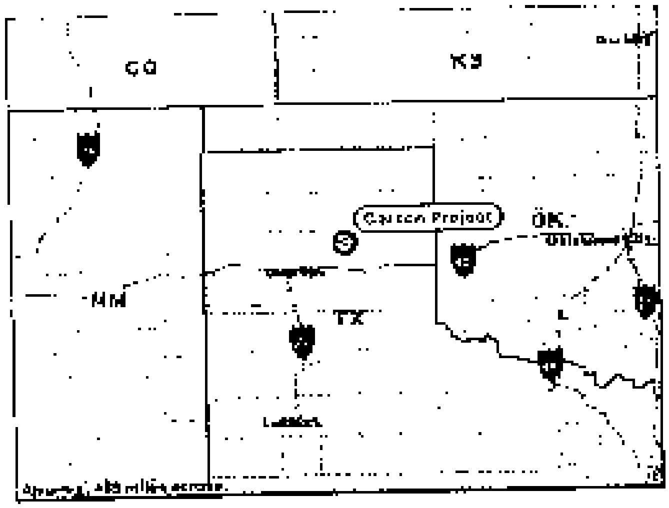


Figure 3.2. Regional Wind Project Location
(Dots approximate wind farm locations)

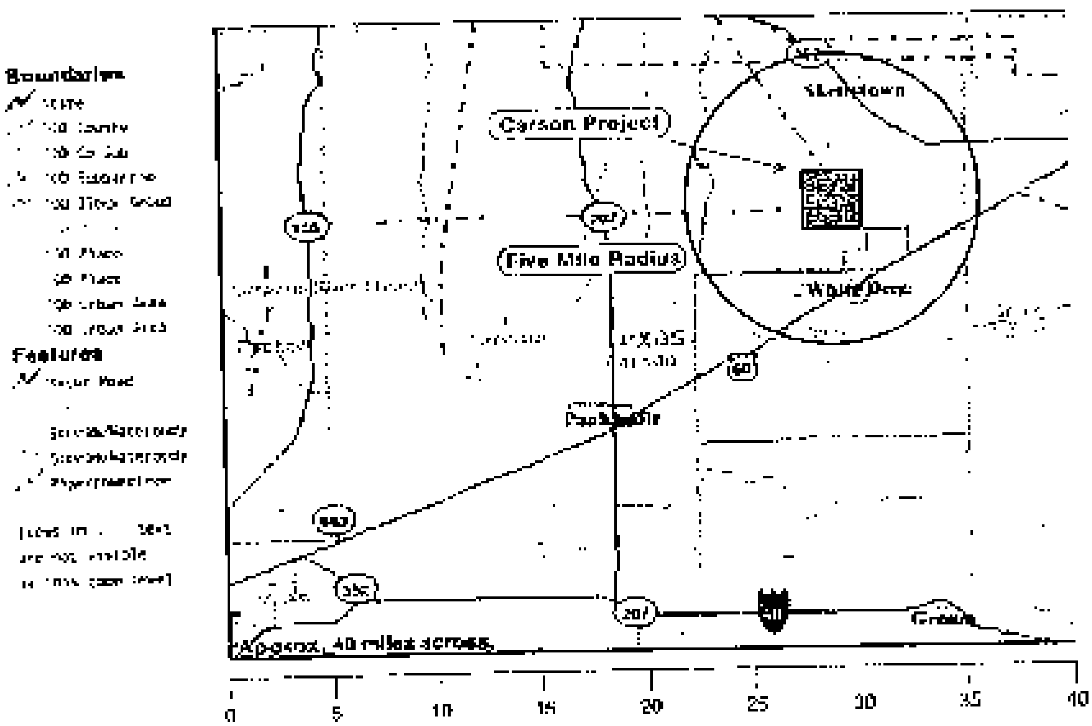


Figure 3.3. Carson County, Texas View Shed
Site Location Source: Carson Appraisal District
Base Map Source: U.S. Census Bureau

C. Analysis

i. Data

Real property sales data for 1998 to 2002 was purchased in paper format from Carson County Appraisal District in Panhandle, TX. The sales data was purchased for the entire county, including the wind farm area and surrounding communities. The unit of analysis for this dataset is defined by census block and section and incorporated city boundaries. A detailed landowners map from for the County that identified every parcel, section, and block in the county was purchased. The Appraiser marked the exact parcel locations of the wind farms on the map, eliminating any estimation of the actual wind farm location.

The dataset included only a few property attributes, such as residence square footage and age of home. While the dataset included all sales of land, commercial property, and residential property, the analysis included only improved lots with residential housing, with a total of 269 sales over the study period. While there were no questions about unusual data points, the view shed had only 45 sales over the five years of data analyzed. This meant that many months had no sales in the view shed. While the six-month trailing average smoothed out most of the gaps, there was a seven-month gap in view shed data from August 2001 through February 2002. As a proxy for the missing data, the average of the two previous months with sales was used to fill in the gap. In addition, a few low value sales and a number of months with no sales contributed to a very low average sale price in the view shed between July 2000 and May 2001.

ii. View Shed Definition

View shed definition using the five-mile radius was straightforward given the land owner map, exact wind farm location, and one-mile reference scale on the map. The town of White Deer lies entirely within the view shed. The region of Skellytown lies just outside the edge of the five-mile radius, too far to be defined as view shed, but too close given the flat land and easily seen wind turbines to be considered as part of the comparable. Thus Skellytown, with a total of 16 sales, was excluded from the analysis. The view shed accounts for 45 sales over the study period.

Interviews with the State of Texas Carson County Appraisal District officers were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Appraiser Mike Darnell's opinion, 90 to 100 percent of White Deer residents can see the project.

iii. Comparable Selection

The comparable community was selected through interviews with State of Texas Carson County Appraisal District personnel, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 3.2 and 3.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community we looked at the demographics of three remaining residential areas in the county that were not part of the view shed and not excluded by being too close to the view shed.

Based on his experience in the area, Appraiser Mike Darnell suggested that Groom would be an appropriate comparable to the view shed area. However, Darnell said that homes in Fritch and Panhandle are more expensive, and have been increasing in value faster over time. Upon examination of Census data, sales data availability, and review of Assessor comments, all three residential areas, Fritch, Groom, and Panhandle were selected as the comparable, with a total of 224 sales from 1998 to 2002.

Table 3.2 Carson County, Texas: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value owner-occupied housing unit
1990	Y	White Deer-Groom division	2,863	$23,683	8%	1,319	$34,700
1990	N	Panhandle division	3,713	$28,569	10%	1,537	$44,100
1990 COUNTY DEMOGRAPHICS			6,576	$26,226	10%	2,856	$38,400

Table 3.3 Carson County, Texas: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value owner-occupied housing unit
2000	Y	White Deer-Groom CCD	2,702	$36,117	9%	1,261	$46,900
2000	N	Panhandle CCD	3,814	$43,349	6%	1,554	$59,400
2000 COUNTY DEMOGRAPHICS			6,516	[illegible]	7%	2,815	$53,150

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 2.1 times the monthly sales price change of the comparable over the study period. The Case I model provides a fair fit to the view shed data, with almost half of the variance in the data explained by the linear regression. However, the model only explains one-third of the variance in the comparable data. In Case II, the monthly sales price change in the view shed is 3.6 times greater after the on-line date than before the on-line date. The Case II model provides a poor fit to the data prior to the on-line date, with a quarter of the variance in the data explained by the linear regression. However, the fit after the on-line date is good, with over 80 percent of the variance explained. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 13.6 times the rate of decrease in the comparable after the on-line date. The Case III model describes over 80 percent of the variance in the view shed, but provides a very poor fit with only 2 percent of the variance explained in the comparable. The data for the full study period is graphed in Figure 3.4, and regression results for all cases are summarized in Table 3.4 below.

Table 3.4 Carson County, Texas: Regression Results
Project: Llano Estacado Wind Ranch

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 98 - Nov 02 Jan 98 - Nov 02	$620.47 $296.54	0.49 0.33	The rate of change in average view shed sales price is 2.1 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 98 - Oct 01 Nov 01 - Nov 02	$553.92 $1,879.76	0.24 0.83	The rate of change in average view shed sales price after the on-line date is 3.4 times greater than the rate of change before the on-line date.
Case* 3	View shed, after Comparable, after	Nov 01 - Nov 02 Nov 01 - Nov 02	$1,879.76 $140.14	0.83 0.02	The rate of change in average view shed sales price after the on- line date increased at 13.4 times the rate of decrease in the comparable after the on- line date.

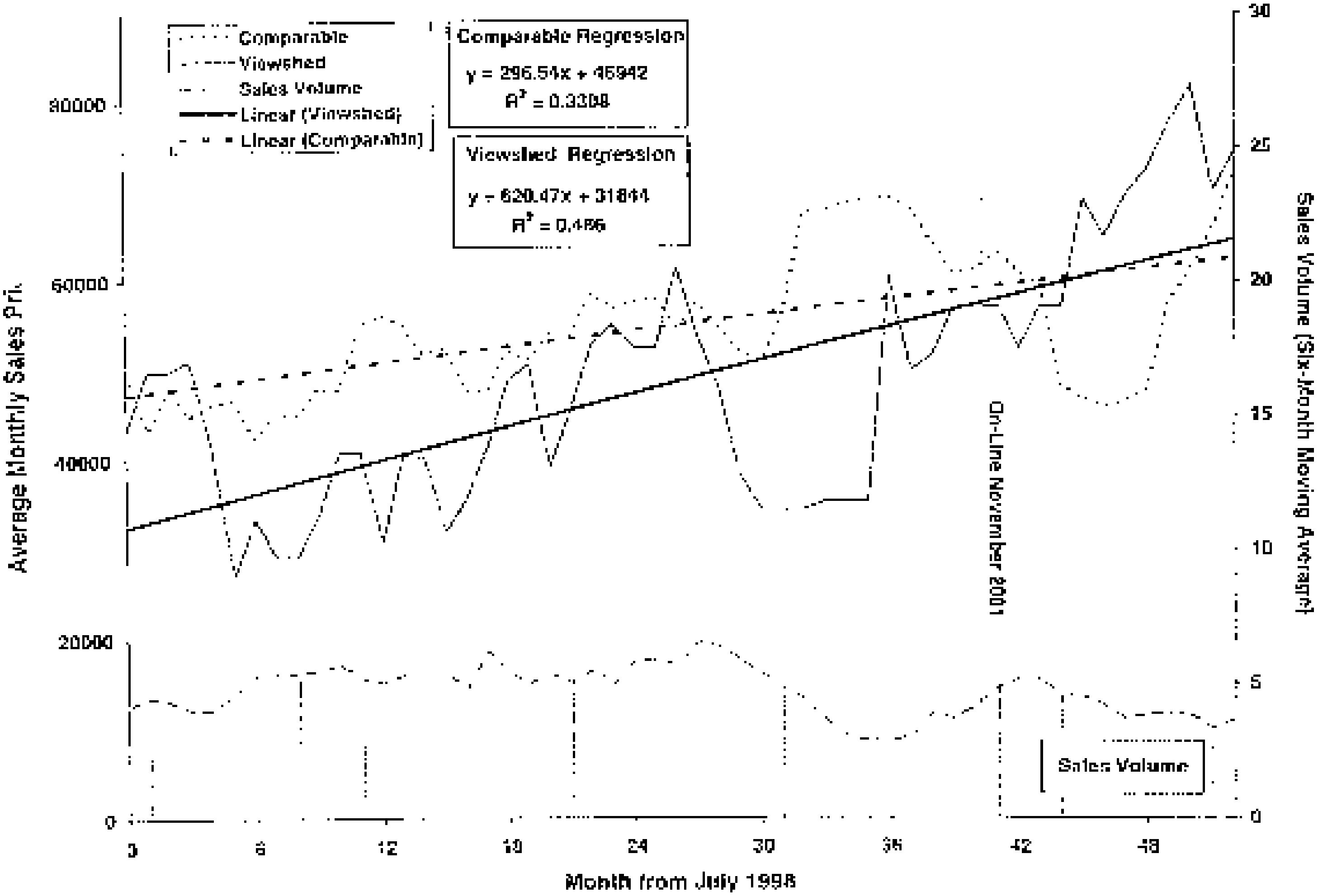


Figure 3.4 Average Residential Housing Sales Price
Carson County, Texas 1998-2002

D. ADDITIONAL INTERVIEWEE COMMENTS

Carson County officers Mike Darnell, appraisal district office, and Barbara Cooper, tax office, said most of the land in the view shed were farms, and that most residents in White Deer worked on the farms. Therefore, White Deer residents' interest in housing values was wholly dependent on their proximity to farms with no concern for the wind towers, she said. Darnell added that most residents in White Deer liked the turbines because they brought new jobs to the area, and there has been no talk of discontent with the turbines.

The county's main claim to fame is it's the home of Pantex; the only nuclear armament production and disassembly facility in the U.S., according to Department of Energy's www.pantex.com website.

Site Report 4: Bennington County, Vermont

A. Project Description

One mile due south of Searsburg, atop a ridge, stand 11 turbines with 40-meter (131 foot) hub heights in a line running north-south. The solid, white, conical towers rise well above dense woods, but the black painted blades are virtually invisible – especially when in motion. The site is in Bennington County less than a mile west of Windham County, and is midway between the two medium-size towns of Bennington and Brattleboro.

The area is defined as a non-metro area adjacent to a metro area, though not completely rural and with a population between 2,500 and 19,999. See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of fewer than 4,000.

Figure 4.1 Searsburg wind project turbines
Photo courtesy Vermont Environmental Research Associates, 2001 www.northeastwind.com

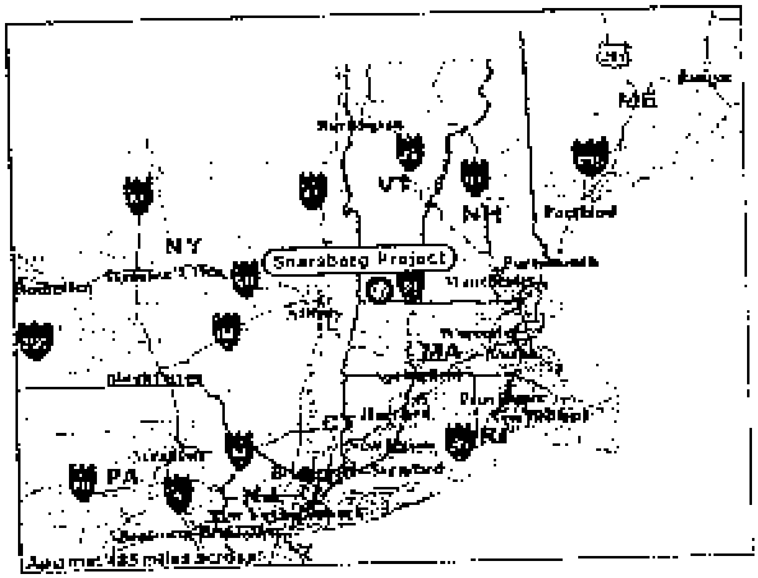


Figure 4.2. The Searsburg wind project is located in Southern Vermont
Base map image source: U.S. Census Bureau

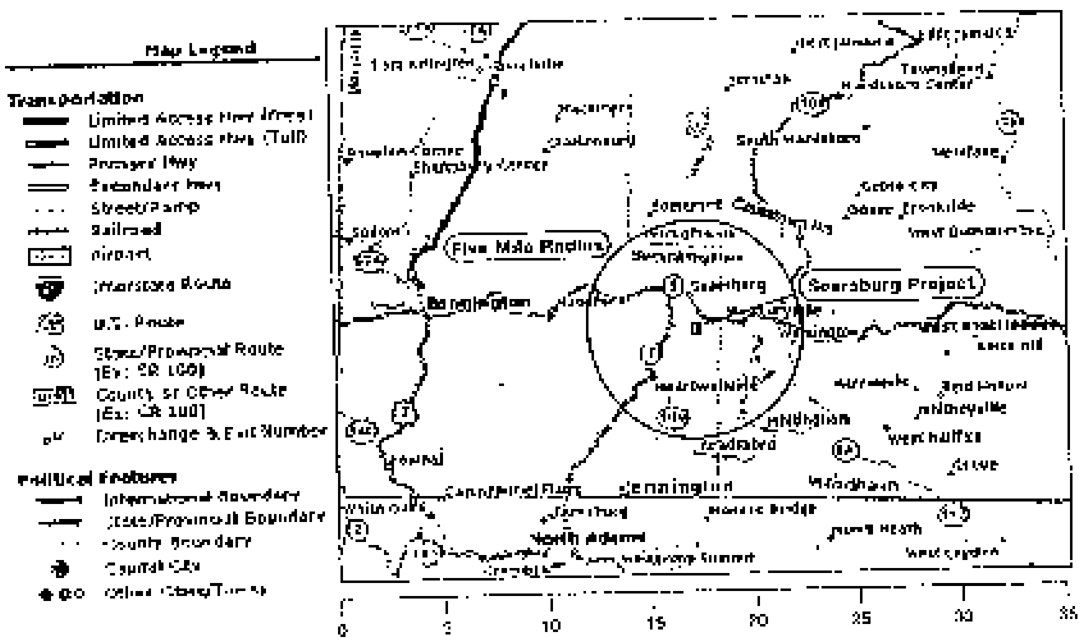


Figure 4.3. Searsburg, Vermont area Viewshed
Location Source: Vermont Environmental Associates
Base Map Source: MapQuest.com

B. Project Timeline

Table 4.1 Wind Project History, Bennington County, VT

Project Name	Completion Date	Capacity (MW)
Searsburg	1997	6

C. Analysis

i. Data

Real property sales data for 1994 to 2002 was purchased in electronic form from Phil Dodd of VermontProperty.com in Montpelier, VT. Sales data was purchased for the townships and cities encompassing the wind farm area and surrounding communities, and was provided in two separate datasets. The first dataset, covering years 1994 through 1998, contained only annual average property sale prices and sales volumes, by town. No other locational data or property attributes were included. Property types from this dataset used in the analysis are primary residences and vacation homes, accounting for 1,584 sales.

The second dataset, contained information on individual property sales from May 1998 through October 2002, and accounted for 2,333 sales. The unit of analysis for the second dataset is towns. Some street addresses were included in the property descriptions, but many of these were only partial addresses. Property types from this dataset used in the analysis are primary homes, primary condominiums, vacation condominiums, and camp or vacation homes. The Searsburg wind farm went on-line in February 1997, with a capacity of 6 MW, during the time when only annually averaged sales data was available.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farm, and encompasses four incorporated towns: Searsburg in Bennington county, and Dover, Somerset, and Wilmington in Windham County. Interviews with the State of Vermont Windham County Listers Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. According to Newfane town Lister Doris Knechtel, approximately 10 percent of the Searsburg homes can see the wind farm. Listers were unable to estimate what percentage of properties could see the wind farms in the other view shed towns. The final view shed dataset contained 1,055 sales from 1994 to 1998 and 1,733 sales for 1999 to 2002, for a total of 2,788 sales.

iii. Comparable Selection

The comparable community was selected through interviews with Phil Dodd of VermontProperty.com, interviews with State of Vermont Listers, as well as analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 4.2 and 4.3 summarize the census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of seven surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments, Newfane and Whitingham in Windham County were selected as the comparable. The final comparable dataset contained 288 sales from 1994 to 1998 and 264 sales for 1999 to 2002, for a total of 552 sales from 1994 to 2002.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

Table 4.2 Bennington and Windham Counties, Vermont: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Searsburg village, Bennington Cty.	85	$26,875	9%	92	$61,500
1990	Y	Dover village, Windham Cty.	904	$30,966	7%	2450	$103,000
1990	Y	Wilmington village, Windham Cty.	1,968	$27,335	6%	2,176	$110,600
1990 VIEW SHED DEMOGRAPHICS			3,017	$28,392	7%	1,718	$91,700
1990	COMP	Newfane town, Windham Cty.	1,555	$31,935	7%	974	$103,000
1990	COMP	Whitingham village, Windham Cty.	1,177	$28,580	8%	737	$88,500
1990 COMPARABLE DEMOGRAPHICS			2,732	$30,258	8%	[illegible]	$95,750
1990	N	Halifax village, Windham Cty.	588	$23,750	15%	473	$81,600
1990	N	Readsboro village, Bennington Cty.	762	$25,913	12%	478	$65,400
1990	N	Stratton village, Windham Cty.	121	$31,369	2%	864	$162,500
1990	N	Woodford village, Bennington Cty.	331	$24,115	28%	257	$75,000
1990	N	Marlboro village, Windham Cty.	924	$29,926	10%	474	$103,300

Table 4.3 Bennington and Windham Counties, Vermont: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Searsburg village, Bennington Cty.	114	$37,500	18%	65	$86,700
2000	Y	Dover village, Windham Cty.	1410	$43,824	10%	2749	$143,300
2000	Y	Wilmington village, Windham Cty.	2,225	$37,396	9%	2,232	$120,100
2000 VIEW SHED DEMOGRAPHICS			[illegible]	$32,907	12%	5,046	$116,700
2000	COMP	Newfane town, Windham Cty.	1,680	$45,735	5%	977	$123,600
2000	COMP	Whitingham village, Windham Cty.	1,298	$37,434	8%	802	$111,200
2000 COMPARABLE DEMOGRAPHICS			2,978	[illegible]	6%	1,779	$117,400
2000	N	Halifax village, Windham Cty.	782	$36,458	16%	493	$98,900
2000	N	Readsboro village, Bennington Cty.	803	$35,000	7%	464	$78,600
2000	N	Stratton village, Windham Cty.	136	$39,588	5%	1,091	$125,000
2000	N	Woodford village, Bennington Cty.	397	$33,029	17%	356	$91,300
2000	N	Marlboro village, Windham Cty.	963	$41,429	4%	495	$150,000

In Case I, the monthly sales price change in the view shed is 62 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a reasonable fit to the view shed data, with 70 percent of the variance in the data for the view shed and 45 percent of the variance in the data for the comparable explained by the linear regression. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 2.6 times the rate of decrease in the view shed before the on-line date. The Case II model provides a good fit to the data, with 71 percent of the variance in the data for the view shed after the on-line date and 88 percent of the variance in the data before the on-line date explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 18 percent greater than in the comparable. The Case III model describes over 70 percent of the variance in the data. The data for the full study period is graphed as Figure 4.4, and regression results for all cases are summarized in Table 4.4 below.

D. Additional Interviewee Comments

Newfane town Lister[1] Doris Knechtel said the area has a wide cross section of home values, styles, and uses (permanent residential and vacation homes). The other primary community in the view shed was Wilmington, which Knechtel said was a resort destination with more turnover than Searsburg.

Table 4.4 Regression Results, Bennington and Windham Counties, VT
Project: Searsburg

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R^2)	Result
Case 1	View shed, all data Comparable, all data	Jan 94 - Oct 02 Jan 94 - Oct 02	$536.41 $330.81	0.70 0.45	The rate of change in average view shed sales price is 62% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 94 - Jan 97 Feb 97 - Oct 02	-$301.52 $771.06	0.88 0.71	The rate of change in average view shed sales price after the on-line date increased at 2.6 times the rate of decrease before the on-line date.
Case 3	View shed, after Comparable, after	Feb 97 - Oct 02 Feb 97 - Oct 02	$771.06 $655.30	0.71 0.78	The rate of change in average view shed sales price after the on-line date is 18% greater than the rate of change of the comparable after the on-line date.

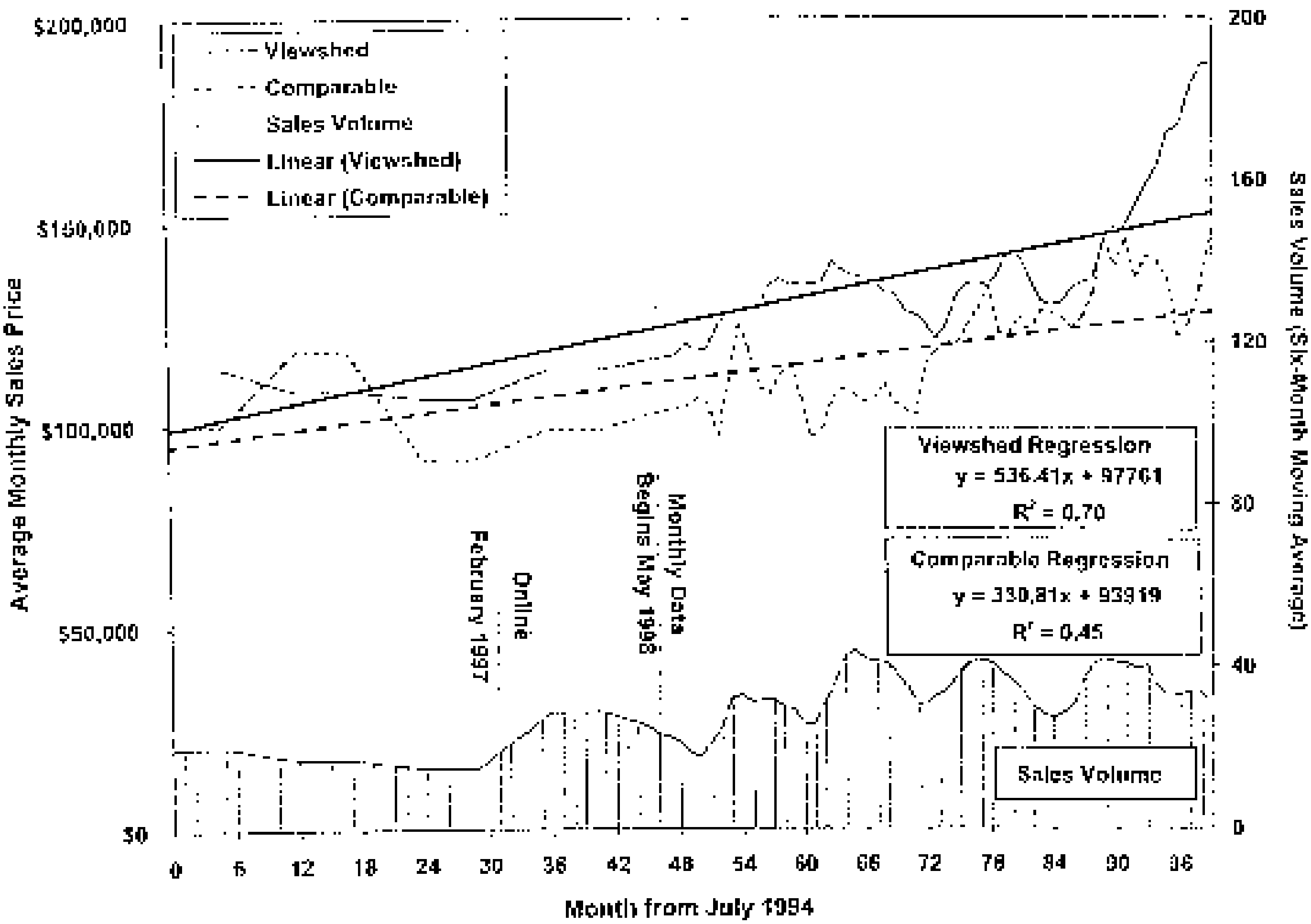


Figure 4.4 Average Residential Housing Sales Price
Bennington and Windham Counties, Vermont 1994-2002

Vermont property records are organized differently than any other state researched for this analysis. [illegible] and operate per town – not on a township or county level. [illegible] local town offices are [illegible] variable, and [illegible] not computerized. The county government office confirmed that many Vermont offices didn't have computers, but were in the process of receiving them as of October 2002.

Site Report 5: Kewaunee County, Wisconsin

A. Project Description

The regional topography has slight elevation changes with some rolling hills, but is mostly cleared agricultural land with intermittent groves. The two major wind farm projects occupy three sites that are all within five miles of each other, two in Lincoln Township and one in Red River Township. There are several small communities in Red River and Lincoln Townships that primarily work the agricultural lands.

The projects, installed in 1999, consist of 31 turbines with hub heights of 65 meters (213 feet). The nearest incorporated towns are Algoma to the east, Kewaunee to the southeast, and Luxemburg to the southwest. The wind farms are roughly 15 miles from the center of the Green Bay metropolitan area, and 10 miles from the outer edges of the city. The area is defined as a non-metro area adjacent to a metro area, though not completely rural and with a population between 2,500 and 19,999. See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of approximately 3,000.

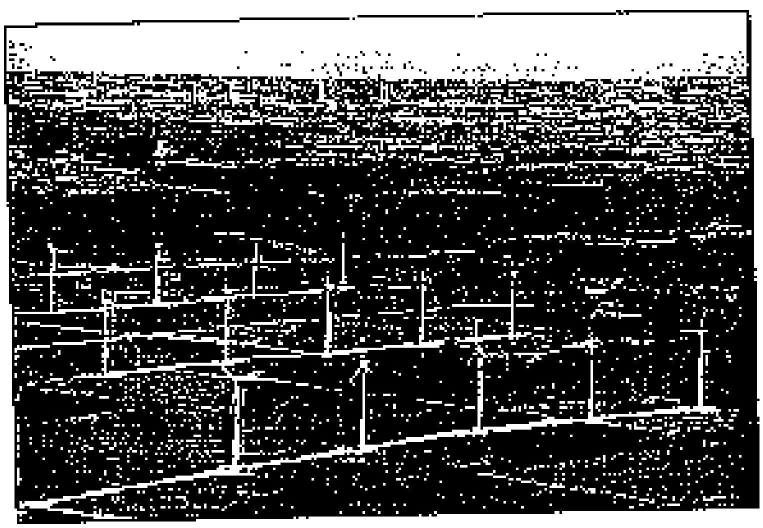


Figure 5.1 Wind Projects in Red River and Lincoln Townships

Photo Courtesy Wisconsin Public Service Corporation

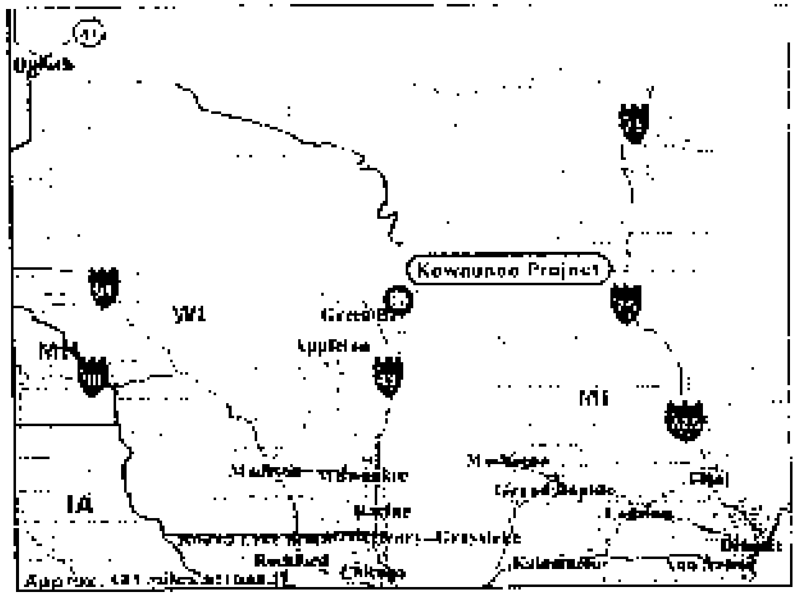


Figure 5.2 Location of Kewaunee County wind projects

Base map image source: U.S. Census Bureau

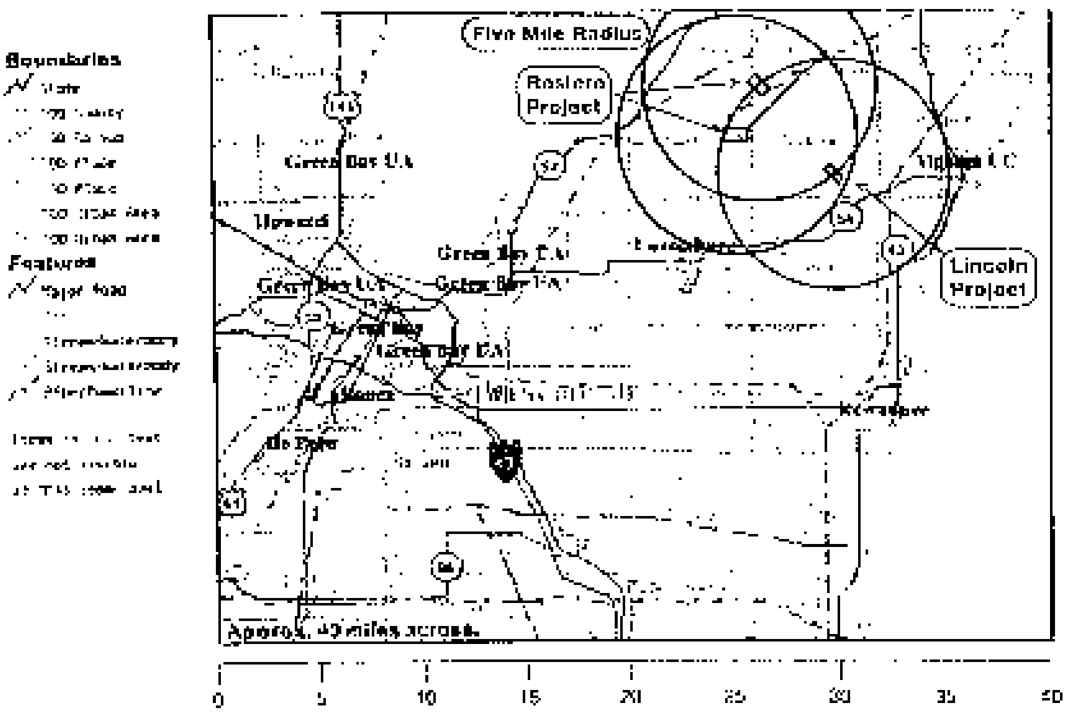


Figure 5.3. Kewaunee County View shed

Location source: Kewaunee County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 5.4 Wind Project History, Kewaunee County, WI

Project Name	Completion Date	Capacity (MW)
Lincoln (Gregorville, Lincoln Township)	1999	9.2
Rosiere (Lincoln and Red River Townships)	1999	11.2

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was purchased in paper and electronic form from the State of Wisconsin Department of Revenue Bureau of Equalization Green Bay Office. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities, and was provided in two separate datasets. The first dataset consisted of paper copy of Detailed Sales Studies for residential properties from 1994 to 1999. These contained individual property sales by month, year, and township or district. Parcel numbers were included, but no other locational data or property attributes were available. The second dataset consisted of electronic files containing residential property sales data for 2000 to 2002. This dataset contained no detailed property attributes, and only partial street addresses. The units of analysis for the combined dataset are townships and villages. After discussion with the Property Assessment Specialist, three unusually high value sales were removed from the view shed dataset. The final dataset included 624 sales from 1996 to 2002.

The Lincoln wind farm near Gregorville and the Rosiere wind farm on the Lincoln/Red River Township Border both went on-line June 1999, with capacities of 9.2 MW and 11.2 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, and because all wind farms went on-line at the same time, a single view shed was defined. It encompasses all of Lincoln and Red River Townships, and the incorporated town of Casco in Casco Township. To assist in the view shed definition, detailed Plat maps for Lincoln and Red River Townships were obtained from the State of Wisconsin Bureau of Equalization Green Bay Office. These maps indicated every block and parcel in each township, and provided a one square mile grid to allow distance measurements. The location of each wind farm was marked on the map by the Bureau, and detailed aerial photos of each wind farm were also provided. This information allowed concise definition of the view shed area. Because only portions of Ahnapee, Luxemborg, and Casco Townships are in the view shed, these townships were excluded from consideration for either the view shed or comparable. The final view shed dataset contained 329 sales from 1996 to 2002.

Interviews with Kewaunee County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. Assessor Dave Dorschner said 20 to 25 percent of Red River Township properties have views of the turbines. No one interviewed was able to estimate the percentage of properties in Lincoln Township or Casco Village with a view of the wind farms.

iii. Comparable Selection

The comparable community was selected through interviews with James W. Green, Bureau of Equalization Property Assessment Specialist, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 5.2 and 5.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of eight surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments. Carlton, Montpelier, and West Kewaunee Townships were selected as the comparable. The final comparable dataset contained 295 sales from 1996 to 2002.

Table 5.2 Kewaunee County, Wisconsin: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Casco village	544	$25,313	6%	223	$54,200
1990	Y	Lincoln town	996	$28,959	7%	338	$44,800
1990	Y	Red River town	1,407	$32,614	3%	552	$60,600
VIEW SHED DEMOGRAPHICS			2,947	$29,962	6%	1,113	$53,200
1990	COMP	Carlton town	1,041	$30,365	8%	393	$42,600
1990	COMP	Montpelier town	1,309	$31,600	6%	457	$61,300
1990	COMP	West Kewaunee town	1,215	$31,034	6%	451	$51,300
COMPARABLE DEMOGRAPHICS			3,625	$31,026	6%	[illegible]	$51,733
1990	N	Ahnapee town	941	$26,850	7%	406	$47,500
1990	N	Algoma City	3,353	$21,393	8%	1,564	$44,000
1990	N	Casco town	1,010	$33,807	4%	344	$57,200
1990	N	Franklin town	990	$32,625	14%	360	$53,300
1990	N	Kewaunee City	2,750	$22,500	14%	1,213	$46,600
1990	N	Luxemburg town	1,387	$35,125	5%	424	$60,600
1990	N	Luxemburg village	1,151	$24,702	6%	460	$58,200
1990	N	Pierce town	724	$25,812	12%	369	$60,400

Table 5.3 Kewaunee County, Wisconsin: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Casco village	572	$44,563	4%	236	$88,700
2000	Y	Lincoln town	957	$42,188	9%	346	$100,000
2000	Y	Red River town	1,476	$47,833	0%	601	$117,900
VIEW SHED DEMOGRAPHICS			3,005	$44,868	4.5%	1,183	$102,200
2000	COMP	Carlton town	1,000	$50,227	3%	383	$98,900
2000	COMP	Montpelier town	1,371	$51,000	4%	492	$112,000
2000	COMP	West Kewaunee town	1,287	$47,059	6%	485	$101,300
COMPARABLE DEMOGRAPHICS			3,658	$49,429	4%	1,360	$104,067
2000	N	Ahnapee town	977	$47,500	3%	426	$95,200
2000	N	Algoma City	3,357	$35,029	5%	1,632	$74,500
2000	N	Casco town	1,153	$46,250	4%	404	$107,800
2000	N	Franklin town	997	$52,019	2%	359	$114,900
2000	N	Kewaunee City	2,806	$35,420	11%	1,237	$79,700
2000	N	Luxemburg town	1,402	$54,875	1%	459	$121,600
2000	N	Luxemburg village	1,935	$45,000	6%	754	$105,100
2000	N	Pierce town	807	$43,000	15%	407	$98,900

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values. However, the fit of the linear regression is poor for all cases analyzed. Very low sales volumes, averaging 3.6 sales per month from 1996 to 1999, lead to large fluctuations in average sales prices from individual property sales. This contributes to the low R2 values.

In Case I, the monthly sales price change in the view shed is 3.7 times the monthly sales price change of the comparable over the study period. However, the Case I model provides a poor fit to the view shed data, with 26 percent and 5 percent of the variance in the data explained by the linear regression in the view shed and comparable, respectively. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 3.5 times the rate of decrease in the view shed before the on-line date. The Case II model provides a poor fit to the data, with 32 percent of the variance in the data for the view shed after the on-line date and 2 percent of the variance in the data before the on-line date explained by the linear regression. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increases 33 percent quicker than the comparable sales price decreases after the on-line date. The Case III model describes approximately a third of the variance in the data. The data for the full study period is graphed in Figure 5.4, and regression results for all cases are summarized in Table 5.4 below.

Table 5.4 Regression Results, Kewaunee County, WI
Projects: Red River (Rosiere), Lincoln (Rosiere), Lincoln (Gregorville)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jun 96 - Sep 02 Jun 96 - Sep 02	$434.18 $118.18	0.26 0.05	The rate of change in average view shed sales price is 3.7 times greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - May 99 Jun 99 - Sep 02	-$238.67 $840.03	0.02 0.32	The increase in average view shed sales price after the on-line date is 3.5 times the decrease in view shed sales price before the on-line date.
Case 3	View shed, after Comparable, after	Jun 99 - Sep 02 Jun 99 - Sep 02	$840.03 -$630.10	0.32 0.37	The average view shed sales price after the on-line date increases 33% quicker than the comparable sales price decreases after the on-line date.

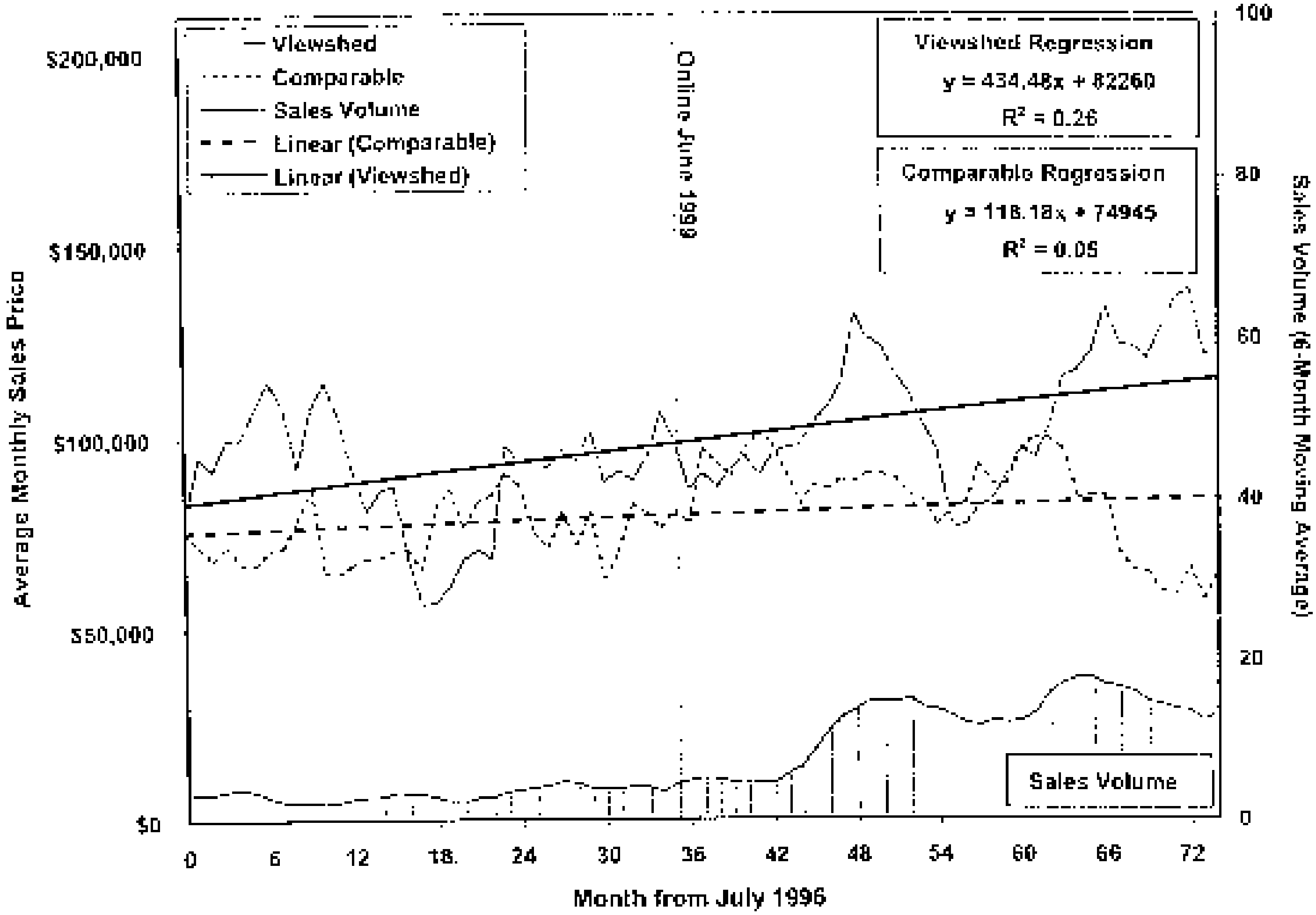


Figure 5.4 Average Residential Housing Sales Price

Kewaunee County, Wisconsin 1996-2002

D. Additional Interviewee Comments

Assessor Dave Dorschner said he has not seen an impact on property values except for those immediately neighboring the project sites. In the cases of neighboring property, he said some homes were sold because of visual and/or auditory distraction, but some of the properties were purchased speculatively in hope that a tower might be built on the property.

James W. Green, Wis. Bureau of Equalization property assessment specialist, also said he has not seen any impact of the turbines on property values. He added that he has seen greater property value increases in the rural areas than in the city because people were moving out of the Green Bay area opting for rural developments or old farmhouses.

Site Report 6: Somerset County, Pennsylvania

A. Project Description

There are two major wind farms in Somerset County, Somerset and Green Mountain. They are about 20 miles due east of the wind farm in Fayette County, PA. The Somerset project has six turbines 64 meters (210 feet) high along a ridge crest east Somerset town. The Green Mountain project has eight turbines at 60 meters (197 feet). They are about 10 miles southwest of the Somerset project, and a mile west of Garret town.

The area is almost the same as Fayette County, but slightly less hilly – dense populations of tall trees, frequent overcast, and primarily rural development. The area is classified as a "county in a metro area with fewer than 250,000." See Appendix 1 for a definition of rural urban continuum codes. The view shed has a population of approximately 19,000.

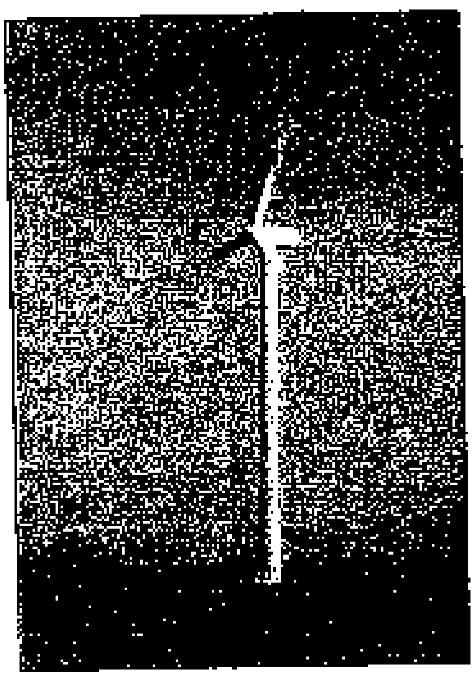


Figure 6.1 Somerset wind tower

Photo courtesy GE Wind Energy © 2001

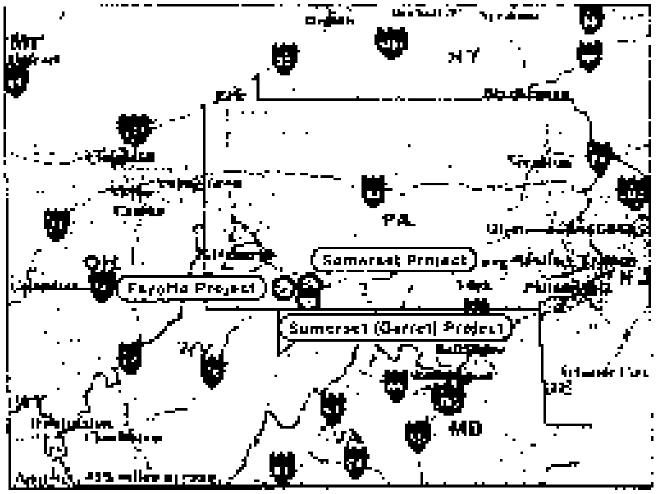


Figure 6.2 General location of Somerset and Fayette County wind projects
Base map image source: U.S. Census Bureau

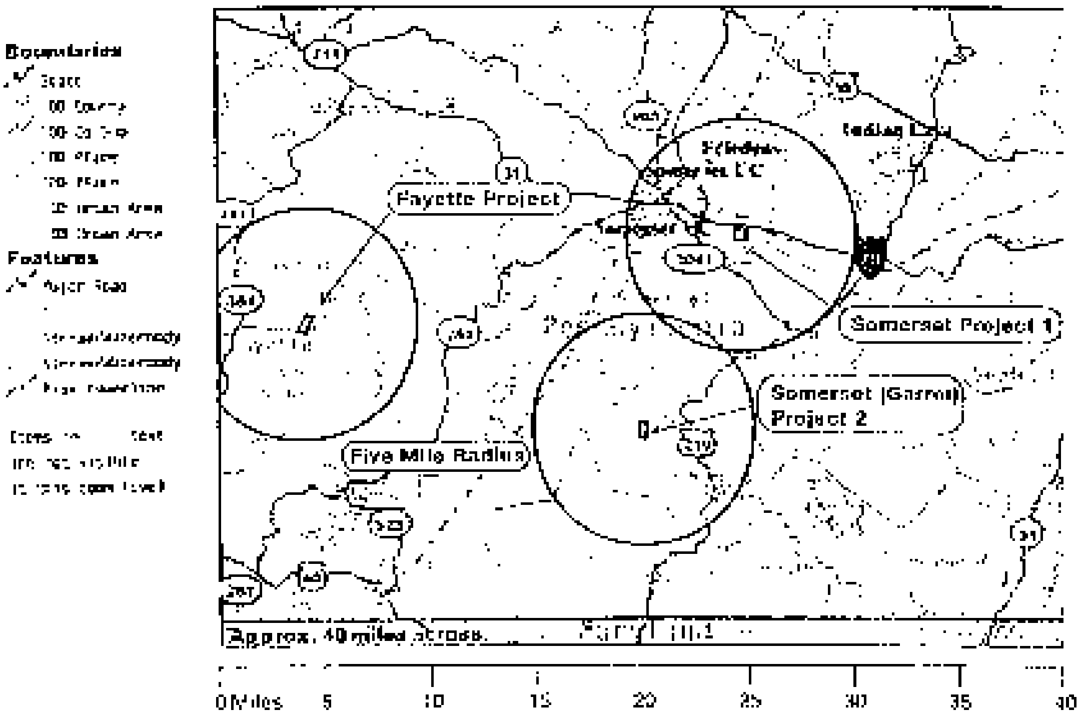


Figure 6.3. Somerset County, Pennsylvania View shed
Location Source: Somerset County Assessors office
Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 6.1 Wind Project History, Somerset County, PA

Project Name	Completion Date	Capacity (MW)
Somerset	2001	9.0
Green Mountain Wind Farm	2000	10.4

C. Analysis

i. Data

Real property sales data for 1997 to 2002 was obtained in electronic form from the State of Pennsylvania Somerset County Assessment Office in Somerset, PA. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities. The electronic files contain residential property sales data for 2000 to 2002. Residential types included in the analysis are homes, homes converted to apartments, mobile homes with land, condominiums, townhouses, and one mobile home on leased land. The dataset contained lot acreages and brief building descriptions, and some, but not all, records provided additional property attributes. As street addresses were not provided, the units of analysis for the dataset are townships and villages. The final dataset included 1,506 residential property sales from 1997 to 2002.

The Somerset wind farm went on-line October 2001 and the Green Mountain wind farm near Garrett went on-line May 2000, with capacities of 9.0 MW and 10.4 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, a single view shed was defined. It encompasses all of Somerset and Summit Townships, and the Garrett and Somerset Boroughs within these townships. Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with maps and interviews with the Somerset County Mapping Department to identify the exact location and extent of the wind farms and view shed. Townships only partially within the view shed were excluded from consideration for either the view shed or comparable. The final view shed dataset contains 962 sales from 1997 to 2002.

Interviews with Somerset County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Assessor Hudack's opinion, 10 percent of Somerset properties can see the turbines, and roughly 20 percent of Garrett properties have a view.

iii. Comparable Selection

The comparable community was selected through interviews with Assessors John Riley and Joe Hudack of the State of Pennsylvania Somerset County Assessment Office, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 6.2 and 6.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community we looked at the demographics of these surrounding areas. Upon examination of Census data, sales data availability, and review of interview comments, Conemaugh Township was selected as the comparable. The final comparable dataset contained 422 sales from 1997 to 2002.

iv. Analytical Results and Discussion

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 90 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a poor fit to the view shed data, with 30 percent of the variance in the data for the view shed and 7 percent of the variance in the data for the comparable explained by the linear regression. In Case II, the monthly sales price change in the view shed is 3.5 times greater after the on-line date than before the on-line date. The Case II model provides a poor fit to the data prior to the on-line date, with 37 percent of the variance in the data explained by the linear regression, but a reasonable fit after the on-line date, with 62 percent of the variance explained. In Case III, average monthly sales prices increase in the view shed after the on-line date, but decrease in the comparable region. The average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date. The Case III model describes 62 percent of the variance in the view shed, but only 23 percent of the variance in the comparable. The data for the full study period is graphed in Figure 6.4, and regression results for all cases are summarized in Table 6.4 below.

Table 6.2 Somerset County, Pennsylvania: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Garrett Borough	520	$16,071	26%	218	$27,100
1990	Y	Somerset Borough	6,454	$19,764	18%	3,100	$58,800
1990	Y	Somerset Twsp	8,732	$25,631	10%	3,296	$57,100
1990	Y	Summit Twsp	2,495	$22,858	17%	942	$40,800
VIEW SHED DEMOGRAPHICS			18,200	$21,004	18%	7,556	$45,950
1990	COMP	Conemaugh Twsp	7,737	$25,025	8%	3,070	$43,100
COMPARABLE DEMOGRAPHICS			7,737	$25,025	8%	3,070	$43,100
1990	N	Boswell Borough	1,485	$16,128	29%	670	$30,700
1990	N	Milford Twsp	1,544	$24,821	9%	666	$47,400

Table 6.3 Somerset County, Pennsylvania: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Garrett Borough	449	$24,609	16%	190	$28,600
2000	Y	Somerset Borough	6,762	$29,050	12%	3,313	$87,200
2000	Y	Somerset Twsp	9,319	$33,391	9%	3,699	$76,300
2000	Y	Summit Twsp	2,368	$32,115	17%	930	$67,700
VIEW SHED DEMOGRAPHICS			18,898	$29,791	13%	8,722	$67,450
2000	COMP	Conemaugh Twsp	7,452	$30,530	7%	3,089	$61,800
COMPARABLE DEMOGRAPHICS			7,452	$30,530	7%	3,089	$61,800
2000	N	Boswell Borough	1,364	$20,875	29%	681	$54,000
2000	N	Milford Twsp	1,561	$34,458	14%	658	$75,300

Table 6.4 Regression Results, Somerset County, PA
Projects: Somerset, Green Mountain

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 97 - Oct 02 Jan 97 - Oct 02	$190.07 $100.06	0.30 0.07	The rate of change in average view shed sales price is 90% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 97 - Apr 00 May 00 - Oct 02	$277.59 $969.59	0.37 0.62	The rate of change in average view shed sales price after the on-line date is 3.5 times greater than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 00 - Oct 02 May 00 - Oct 02	$969.59 $418.73	0.62 0.23	The rate of change in average view shed sales price after the on-line date increased at 2.3 times the rate of decrease in the comparable after the on-line date.

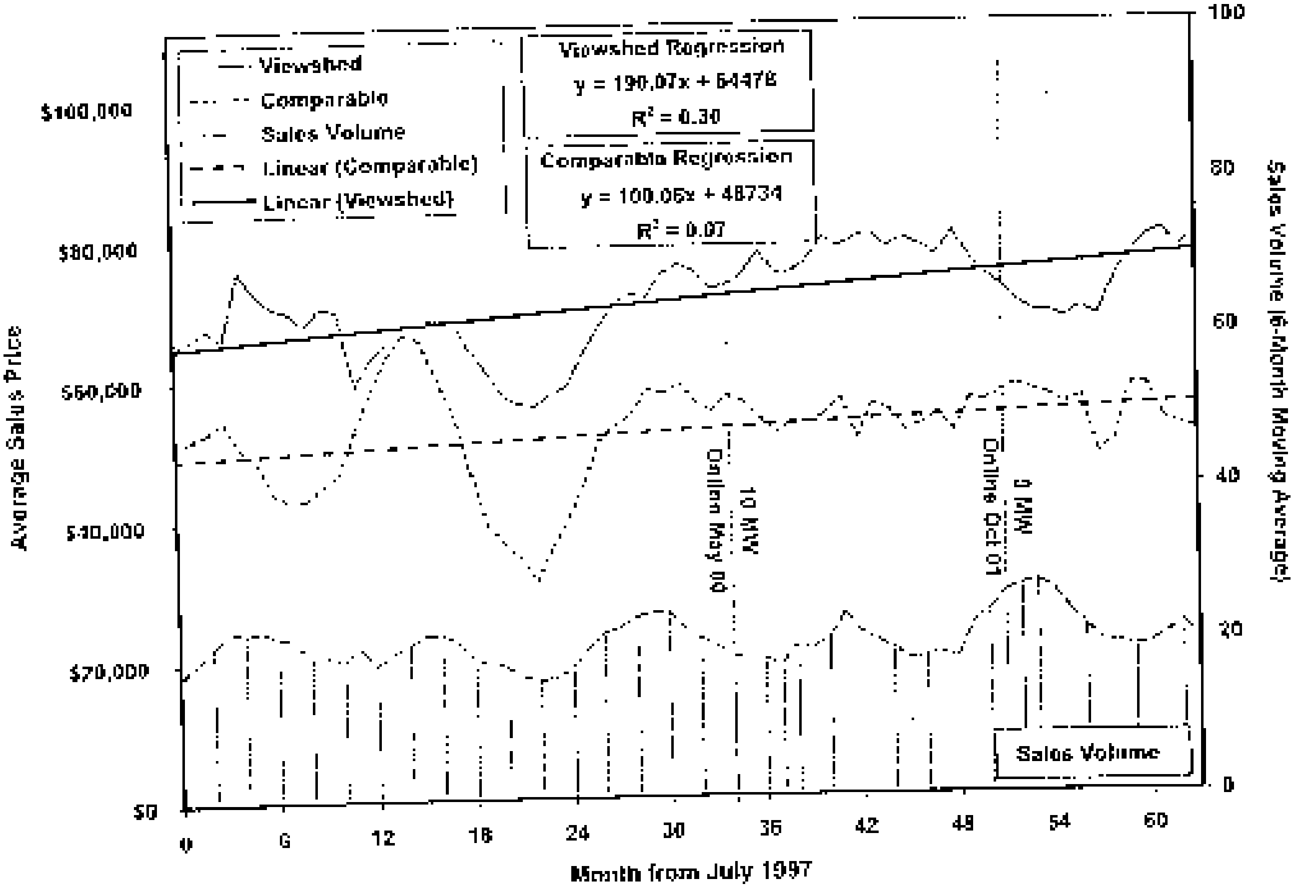


Figure 6.4 Average Residential Housing Sales Price
Somerset County, Pennsylvania 1997-2002

D. Additional Interviewee Comments

Assessor Joe Hudack said he has not seen any impact on property values from wind farms. The turbines outside Somerset were also "not glaring," but could be seen from the PA Turnpike. The Green Mountain turbines outside Garret were noticeable, but because there were so few people residing there, he hasn't seen much housing turnover to base an opinion, he said.

Site Report 7: Buena Vista County, Iowa

A. Project Description

The geography of the view shed and comparable regions is flat with minimal elevation changes. The region is mostly cleared land for agricultural production, with trees along irrigation ditches or planted around homes for shade and wind dampening.

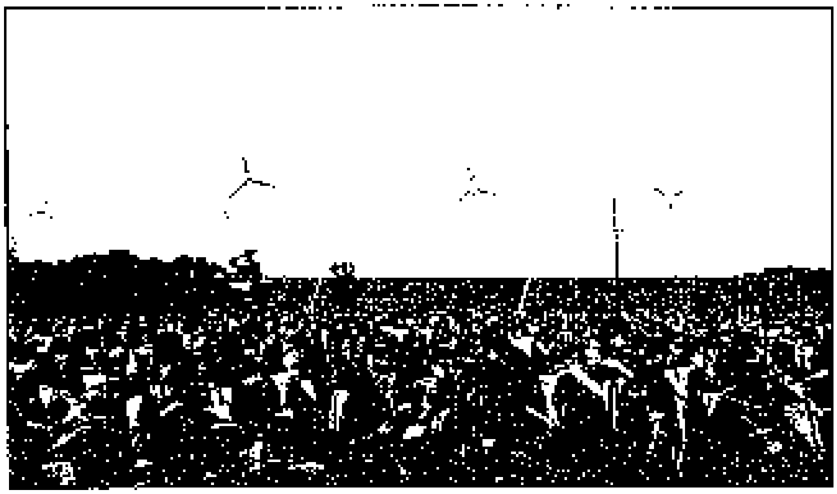


Figure 7.1 – 750 kW Zond wind turbines 1.5 miles east of Alta, Iowa
Photo Courtesy, Waverly Light and Power © 2002

Surrounding Alta, Iowa and west of the town along the Buena Vista and Cherokee counties' border, 257 towers with 63 meter (207 ft) hub heights stand among agricultural farms and scattered homes. Project Storm Lake I comprises 150 towers around Alta extending 1.5-2.5 miles east and west, 1.5 miles south, and five miles north. Throughout the project, the turbines are consistently spaced 3.6 rotor diameters, or about 180 m (590 ft) apart. Project Storm Lake II comprises 107 towers, eight miles northwest of Alta, with several towers over the county border into neighboring Cherokee County. The exact location of all turbines was obtained from the Waverly Power and Light website. All towers have white color blades and hubs with either grey, trussed towers or white solid towers. Solid red lights are required by the FAA on the nacelles of alternate turbines.

Buena Vista County is classified as an "urban population with 2,500 to 19,999 not adjacent to a metro area." See Appendix 1 for a definition of rural urban continuum codes. This analysis defines two possible view sheds, depending on whether Storm Lake City is included in the analysis. Accordingly, the view shed has a population of either 4,000 or 14,000, depending on its definition.

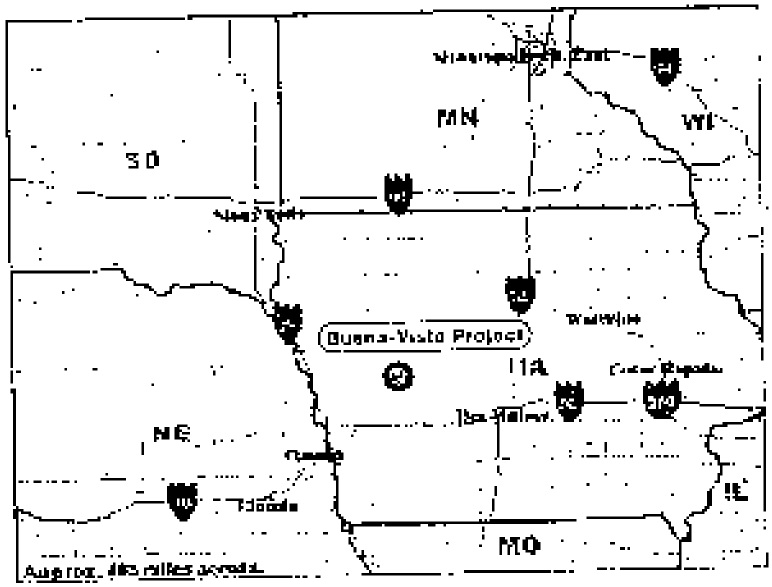


Figure 7.2 Regional Wind Project Location
(Dot approximate wind farm locations)

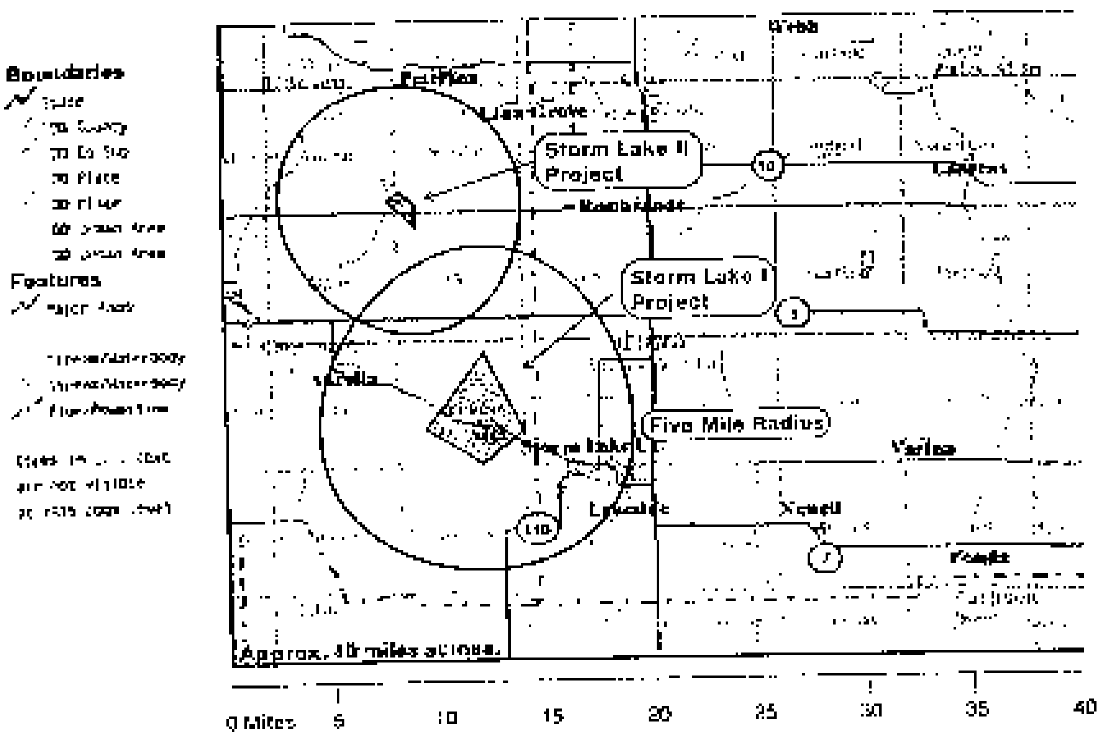


Figure 7.3, Buena-Vista, County, Iowa View shed
Location Source: Buena-Vista County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 7.1 Wind Project History, Somerset County, PA

Project Name	Completion Date	Capacity (MW)
Storm Lake I	1999	112.5
Storm Lake II	1999	80.2

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained in electronic form from the Iowa State Assessors Office Website at www.iowaassessors.com. Sales data was obtained for the townships and cities encompassing the wind farm area and surrounding communities. The electronic data gathered contains residential property sales prices, parcel numbers, street addresses, year built and square footage. The unit of analysis for this dataset is defined by either township or incorporated city boundaries. Though street addresses are included in the dataset, this analysis lacked the resources to identify the location of properties by street address. The final dataset included 3,213 residential property sales from 1996 to 2002.

The Storm Lake II wind farm went on-line June 1999 and the Storm Lake I wind farm went on-line May 1999, with capacities of 112.5 MW and 80.2 MW, respectively.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farms. Because the view sheds of the individual wind farm sites overlap, and the on-line dates are within a month of each other, a single view shed was defined. Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with maps and phone interviews to identify the exact location and extent of the wind farms and view shed. Townships only partially within the view shed were excluded from consideration for either the view shed or comparable.

Interviews with Somerset County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Buena Vista County Assessor Ted Van Grotenst's opinion, 100 percent of the properties in Alta have views of turbines, 75 percent of Nokomis Township have views, and five to 10 percent of Storm Lake City properties have views. However, he estimated that all the waterfront properties on the southeast side of Storm Lake can see turbines when looking northwest. Storm Lake City has a population of approximately 10,000, while Nokomis Township and Alta City have a combined population of approximately 2,000.

This report examines two cases for Buena Vista County.

Analysis #1: Storm Lake City Excluded from View Shed

For the first analysis, the view shed consists only of the village and township in which the wind turbines are located. In this case approximately 75 to 100 percent of the residential properties sold are within view of the wind farm, and are at most 3.5 miles from wind turbines, and in most cases much closer. We believe that if wind farms negatively effect property values, this effect would be strongest in this smaller radius view shed. The Analysis #1 view shed dataset contains 288 sales from 1996 to 2002.

Analysis #2: Storm Lake City Included in View Shed

For the second analysis, the view shed contains Storm Lake City, which is mainly within the five-mile view shed radius, in addition to Alta City and Nokomis Township as included in Analysis #1. Because Storm Lake City's population is five times larger than that of the Alta and Nokomis combined, and because estimates are that roughly 5 percent of Storm Lake City properties can see the wind farms, we believe that any negative property value effects from the wind farms may be overshadowed by economic and demographic trends in Storm Lake City that are distinct from any effect the wind farms may have. The Analysis #2 view shed dataset contains 1,557 sales from 1996 to 2002.

iii. Comparable Selection

The comparable community was selected through interviews with Buena Vista County Assessor Ted Van Grotest, and analysis of demographic data from the 1990 and 2000 U.S. Census for communities near but outside of the view shed. Tables 7.2 and 7.3 summarize the Census data reviewed. In order to determine the most appropriate comparable community, we looked at the demographics of five comparable communities. Upon examination of Census data, sales data availability, and review of interview comments, one city and four townships in Clay County, just to the north of Buena Vista County, were selected as the comparable. The comparables are Spencer City, and Meadow, Riverton, Sioux, and Summit Townships. The final comparable dataset contained 1,656 sales from 1996 to 2002.

Table 7.2 Buena Vista County, Iowa: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	Y	Nokomis Township, Buena Vista County	2,174	$24,915	10%	872	$41,300
1990	Y	Alta City, Buena Vista County	1,824	$23,043	12%	754	$40,400
VIEWSHED DEMOGRAPHICS			[illegible]	$23,979	[illegible]	[illegible]	$40,850
1990	Y	Nokomis Township, Buena Vista County	2,174	$24,915	10%	872	$41,300
1990	Y	Storm Lake City, Buena Vista County	8,769	$23,755	9%	3,557	$47,000
1990	Y	Alta City, Buena Vista County	1,824	$23,043	12%	754	$40,400
VIEWSHED DEMOGRAPHICS			12,767	$23,904	11%	5,183	$42,900
1990	COMP	Meadow Township, Clay County	432	$24,000	12%	142	$60,500
1990	COMP	Riverton Township, Clay County	323	$26,875	19%	115	$47,500
1990	COMP	Sioux Township, Clay County	348	$35,417	2%	134	$42,100
1990	COMP	Spencer City, Clay County	11,066	$24,573	10%	4,824	$45,200
1990	COMP	Summit Township, Clay County	409	$27,266	5%	201	$30,400
COMPARABLE DEMOGRAPHICS			12,578	$27,626	9%	5,416	$45,140

Table 7.3 Buena Vista County, Iowa: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	Y	Nokomis Township, Buena Vista County	2,261	$33,533	11%	922	$69,800
2000	Y	Alta City, Buena Vista County	1,848	$31,941	11%	791	$66,700
VIEWSHED DEMOGRAPHICS #1			4,109	$32,737	11%	1,713	$67,250
2000	Y	Nokomis Township, Buena Vista County	2,261	$33,533	11%	922	$69,800
2000	Y	Storm Lake City, Buena Vista County	10,150	$35,270	12%	3,732	$70,300
2000	Y	Alta City, Buena Vista County	1,848	$31,941	11%	791	$66,700
VIEWSHED DEMOGRAPHICS #2			14,259	$33,58[illegible]	11%	5,445	$68,933
2000	COMP	Meadow Township, Clay County	323	$49,167	2%	129	$82,900
2000	COMP	Riverton Township, Clay County	323	$49,250	3%	110	$124,100
2000	COMP	Sioux Township, Clay County	324	$37,417	0%	144	$107,400
2000	COMP	Spencer City, Clay County	11,420	$32,970	10%	5,177	$80,700
2000	COMP	Summit Township, Clay County	411	$30,500	1%	179	$68,000
COMPARABLE DEMOGRAPHICS			12,80[illegible]	$41,05[illegible]	3%	5,7[illegible]	$92,6[illegible]

iv. Analytical Results and Discussion

Analysis #1: Storm Lake City Excluded from View Shed

In all three of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, indicating that there is no significant evidence that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price change in the view shed is 18 percent greater than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over two-thirds of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 70 percent greater after the on-line date than before the on-line date. The Case II model provides a reasonable fit to the data, with over half of the variance in the data explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 2.7 times greater than in the comparable. The Case III model describes over half of the variance in the data for the view shed, but only 23 percent of the variance for the comparable. The data for the full study period is graphed in Figure 7.4, and regression results for all cases are summarized in Table 7.4 below.

Analysis #2: Storm Lake City Included in View Shed

In all three of the regression models, monthly average sales prices grew slower in the view shed than in the comparable area.

In Case I, the monthly sales price change in the view shed is 34 percent less than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the data, with over 60 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 59 percent less after the on-line date than before the on-line date. The Case II model explains over half of the variance in the data prior to the on-line date explained, but only 27 percent of the variance after the on-line date. In Case III, average view shed sales prices after the on-line date are 22 percent lower than in the comparable.

The Case III model provides a poor fit to the data, explaining less than 30 percent of the variance for the data. The data for the full study period is graphed in Figure 7.5, and regression results for all cases are summarized in Table 7.5 below.

Table 7.4 Regression Results, Buena Vista County, IA Projects: Storm Lake I & II (Without Storm Lake City)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data Comparable, all data	Jan 96 - Oct 02 Jan 96 - Oct 02	$401.86 $341.87	0.67 0.72	The rate of change in average view shed sales price is 18% greater than the rate of change of the comparable over the study period.
Case 2	View shed, before View shed, after	Jan 96 - Apr 99 May 99 - Oct 02	$370.52 $631.12	0.51 0.53	The rate of change in average view shed sales price is 70% greater after the on-line date than the rate of change before the on-line date.
Case 3	View shed, after Comparable, after	May 99 - Oct 02 May 99 - Oct 02	$631.12 $234.84	0.53 0.23	The rate of change in average view shed sales price after the on-line date is 2.7 times greater than the rate of change of the comparable after the on-line date.

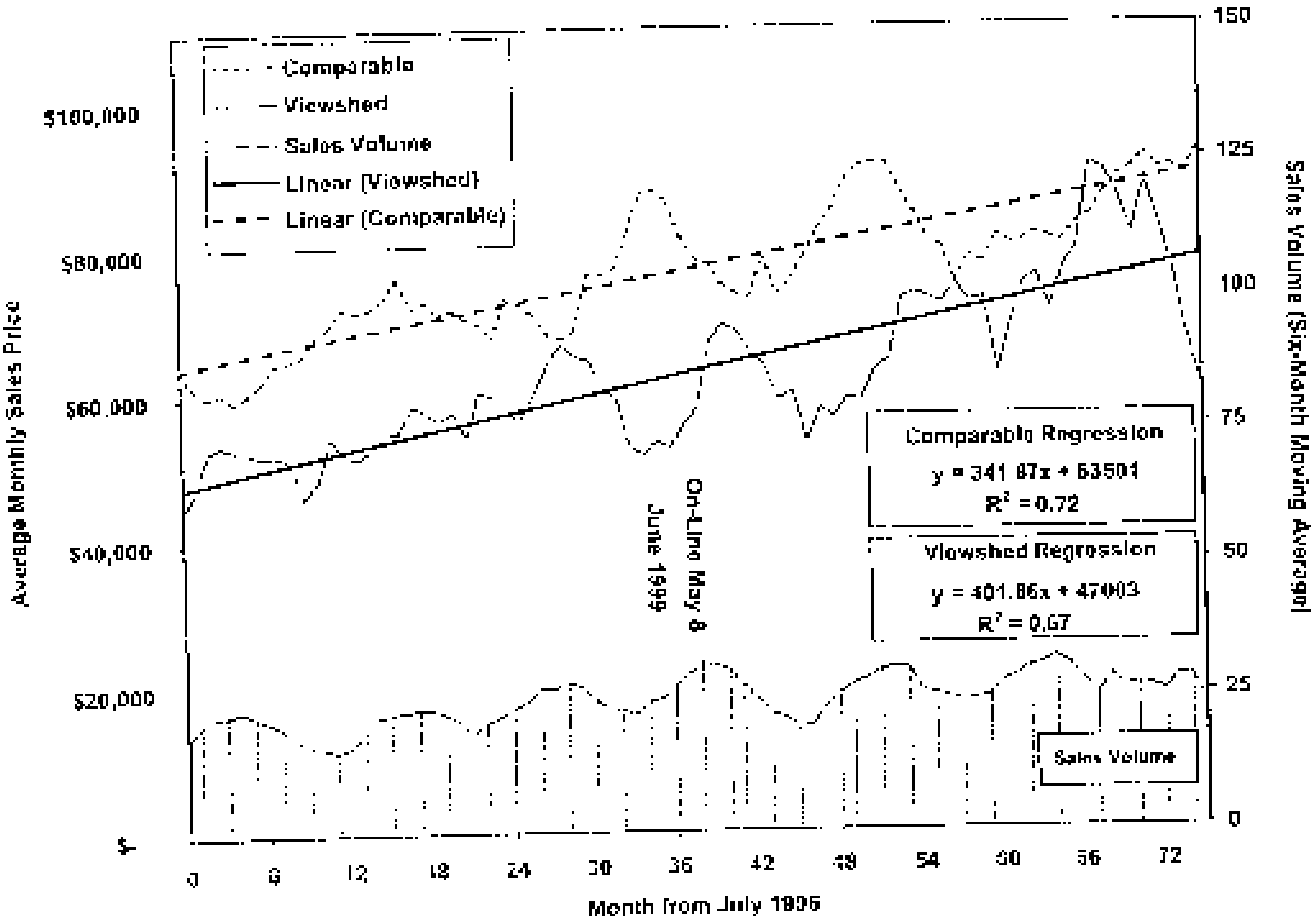


Figure 7.4 Average Residential Housing Sales Price
Analysis #1: Storm Lake City Excluded from View Shed
Buena Vista County, Iowa 1996-2002

Table 7.5 Regression Results, Buena Vista County, IA
Project: Storm Lake I & II (With Storm Lake City)

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Oct 02	225.97	0.60	The rate of change in average view shed sales price is 34% less than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Oct 02	341.87	0.72	
Case 2	View shed, before	Jan 96 - Apr 99	450.11	0.59	The rate of change in average view shed sales price is 59% less after the on-line date than before the on-line date.
	View shed, after	May 99 - Oct 02	183.92	0.27	
Case 3	View shed, after	May 99 - Oct 02	183.92	0.27	The rate of change in average view shed sales price after the on-line date is 22% lower than the rate of change of the comparable after the on-line date.
	Comparable, after	May 99 - Oct 02	234.84	0.23	

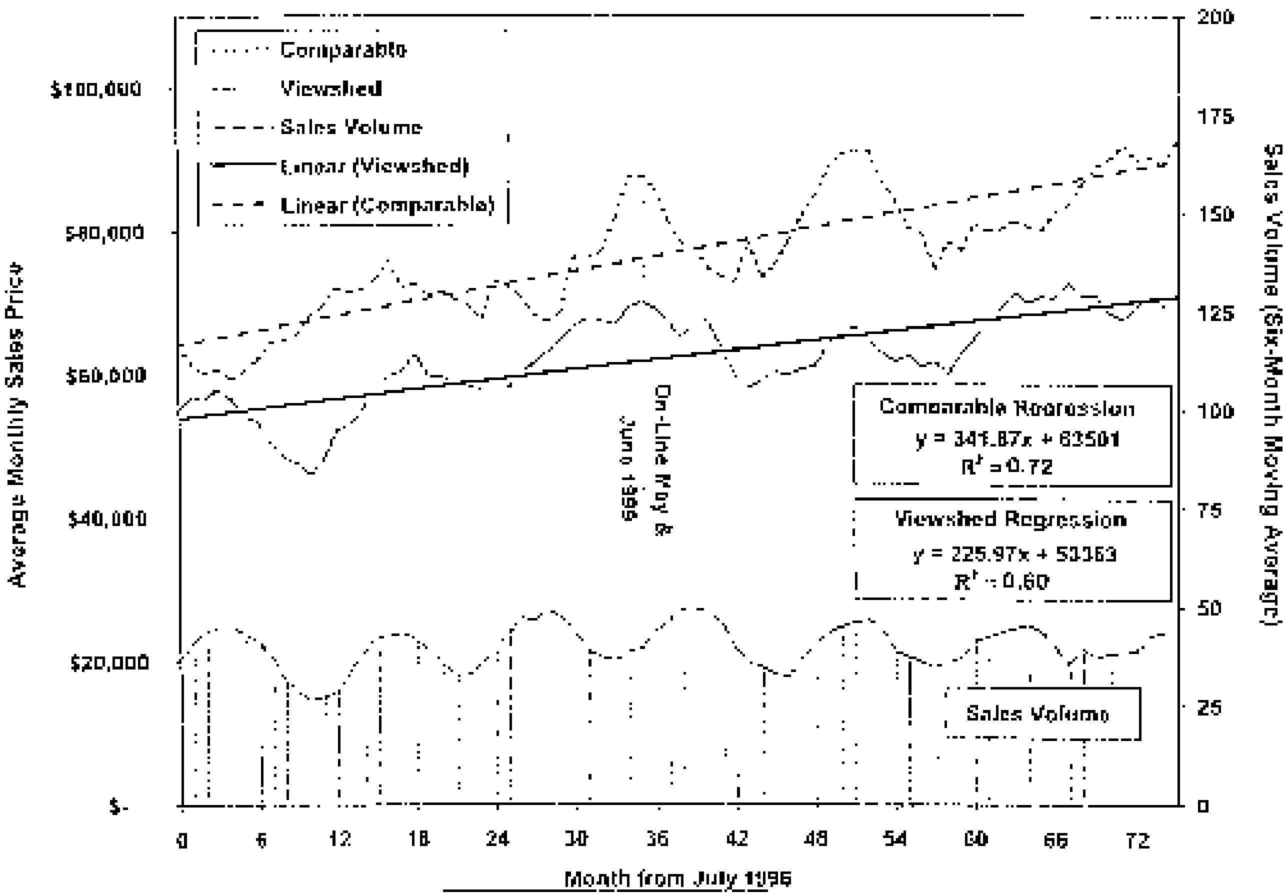


Figure 7.5 Average Residential Housing Sales Price
Analysis #7: Storm Lake City Included in View Shed

Buena Vista County, Iowa 1996–2002

D. Additional Interviewee Comments

Buena Vista County Assessor Ted Van Groterst said the comparable area around Spencer City in the northern neighboring county, Clay, would have higher property values because of its proximity to recreational lakes to the north, but that the two areas' property values rose at equal rates. He added that the predominate business mix was similar, but that the productive value of the land in Clay might be a little higher.

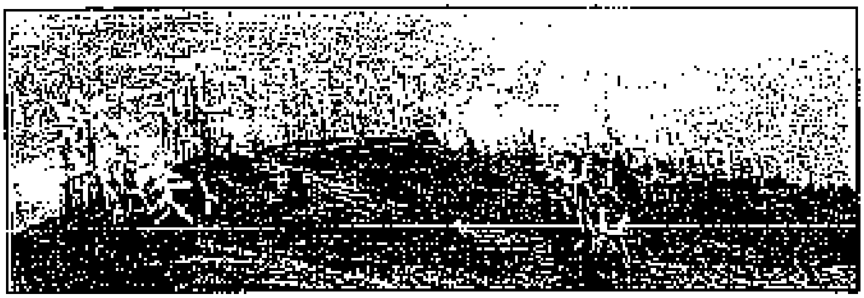
Between October 2002 and March 2003 the following information was obtained through other interviews with Groterst:

- Most of the residences at the Lake Creek Country Club, a golf course community located just west of Storm Lake City (between the city and the wind farms), have views of the towers. Several towers are one-half mile north and southwest of the Country Club. The assessor owns a home at the Country Club.
- In the assessor's opinion, the wind projects have no impact on property values. According to the assessor, the only issue that influences prices is the school district.
- There is also a hog farm on the west side of Storm Lake - the same direction as the wind projects. Groterst said the property values did not change around the hog farm.

Site Report 8: Kern County, California

A. Project Description

The Tehachapi Mountains stretch northeast and southwest with Tehachapi City and neighboring communities seated within a flat valley inside the range. Despite the arid climate, Tehachapi's elevation of 4,000 feet affords it four seasons. This region is known for its extensive wind farm development, which has been ongoing for over two decades



Figures 8.1 – 8.2: Views of the Tehachapi region wind farms
Top Photo Courtesy Jean-Claude Carson © 2000 - Bottom Photo Courtesy Windland Inc. © 2005

Between 1981 and 2002 developers installed 3,569 towers with varied hub heights up to 55 meters (180.5 feet), and repowered six sites with 199 towers between 1997 and2002. The projects nestle within the Tehachapi pass five miles east of Tehachapi City, through the Tehachapi mountains, and scatter along the east-face just as Highway 58 drops sharply southeast toward Mojave and California cities bordering the Mojave Desert. The wind farm locations are shown in the regional area map, Figure 8.3, and view shed map, Figure 8.4, below.

To the east of the mountains are the cities of Mojave, California, and Rosamond. The incorporated limits of these cities are all approximately three to four miles from the base of the range, where the Mojave Desert begins.

Foliage is patchy with many areas covered in wild, dry grasses. Juniper and Cottonwood much like the terrain between Albuquerque and Santa Fe, New Mexico. However, there are some green portions with dense grasses allowing for cattle grazing or equestrian spreads.

Although Kern County is classified as a "county in a metro area with 250,000 to 1 million population," the view shed has a population of less than 15,000. See Appendix 1 for a definition of rural urban continuous codes. Also, Tehachapi is 40 miles to the nearest metro area of Bakersfield, and 115 miles to Los Angeles.

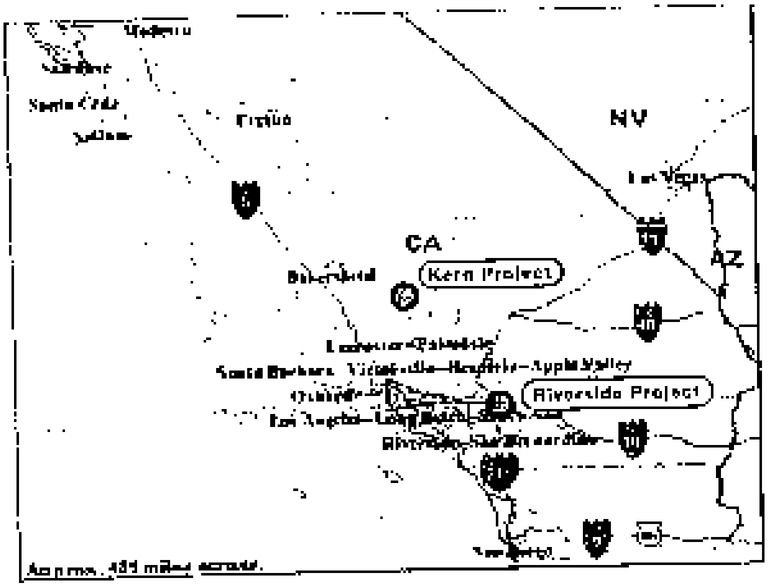


Figure 8.3. Regional Wind Project Location

(Shows approximate wind farm locations)

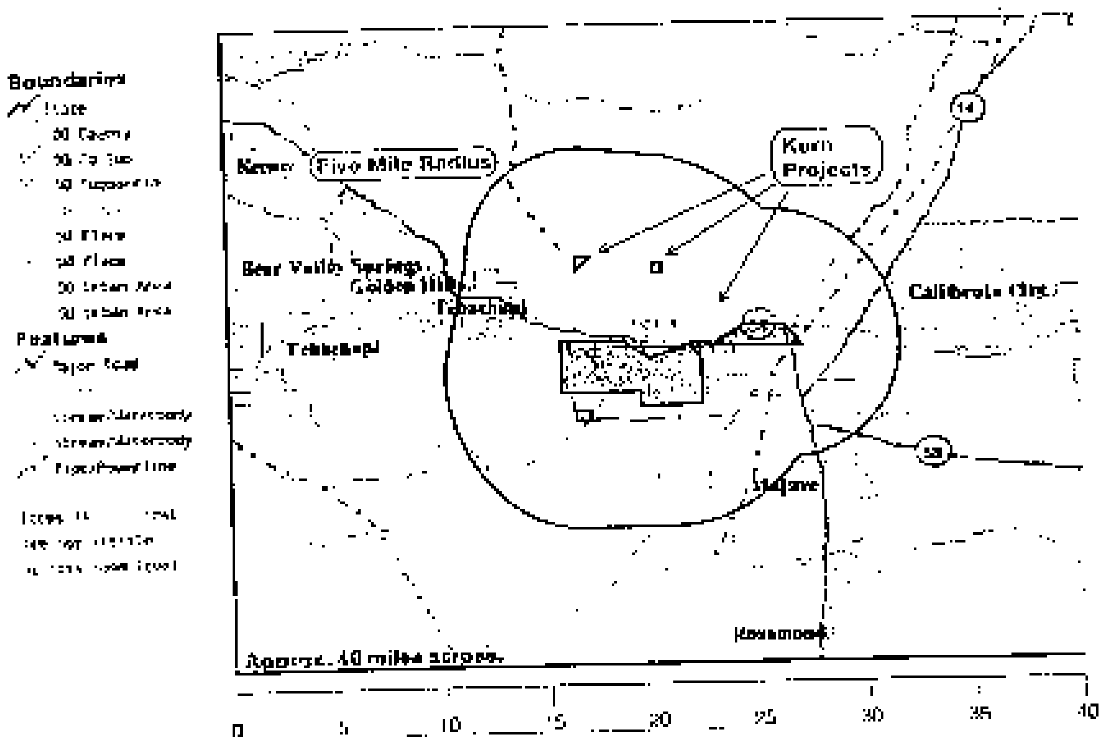


Figure 8.4. Kern County, California View Shed

Project Location Source: Kern County Assessors Office

Base Map Source: U.S. Census Bureau

B. Project Timeline

Table 3.1 Wind Project History, Tehachapi, CA

Project Name	Completion Date	Capacity (MW)	Project Name	Completion Date	Capacity (MW)
Oak Creek	2002	2.5	Coram Energy Group	1981-1995	6.3
Oak Creek-Phase 2A-Repower	1999	0.8	Cannon (various)	1981-1995	4.5
Pacific Crest-Repower	1999	45.5	Mogul Energy	1981-1995	4.0
Cameron Ridge-Repower	1999	56.0	Coram Energy Group	1981-1995	4.0
Oak Creek Phase 2-Repower	1999	23.1	Windridge	1981-1995	2.3
Victory Gardens-Repower	1999	6.7	Coram Energy Group	1981-1995	1.9
Oak Creek Phase 1-Repower	1997	4.2	Victory Gardens I & IV	1981-1995	1.0
Mojave 16, 17 & 18	1981-1995	85.0	Sky River	1993	77.0
Mojave 3, 4 & 5	1981-1995	75.0	Victory Gardens Phase IV	1990	22.0
Ridgetop Energy	1981-1995	32.6	Various Names	1982-87	64.0
Calwind Resources	1981-1995	14.1	Various Names	1982-87	24.0
Cannon	1981-1995	13.5	Various Names	1986	0.2
Calwind Resources	1981-1995	8.7	Windland (Boxcar II)	Mid-1980s	14.3
AB Energy-Tehachapi	1981-1995	7.0			

C. Analysis

i. Data

Real property sales data for 1996 to 2002 was obtained from First American Real Estate Solutions in Anaheim, CA. The dataset is quite detailed and contains many property and locational attributes, among them 9-digit zip code (ZIP+4) locations. Sales data was purchased for two zip codes encompassing the wind farm area and surrounding communities. These zip codes are Mohave (93501) and Tehachapi (93561).

Sales for the following residential property types were included in the analysis: single-family residences, condominiums, apartments, duplexes, mobile homes, quadruplexes, and triplexes. Of 21 apartment sales in the database, five in the view shed had unusually high sales prices. After discussion with the local Assessor, it was determined that these did not represent single sale data points, and they were eliminated from the analysis. A total of 2,867 properties are used in the analysis.

Projects that went on-line during the study period are the Cameron Ridge, Pacific Crest, and Oak Creek Wind Power Phase II sites. All three are repowering projects, with installed capacities of 56, MW, 45 MW, and 23 MW, respectively. Cameron Ridge went on-line March 1999, and the other two came on-line June 1999.

ii. View Shed Definition

All ZIP+4 regions within 5 miles of the wind turbines define the view shed. The location of the ZIP+4 regions were derived from the latitude and longitude of the ZIP+4 areas obtained from the U.S. Census TIGER database. Because the view sheds of the individual wind farm sites overlap, and because all projects went on-line within three months of each other, a single composite view shed is defined. The view shed is approximated by two rectangles that overlap the combined area swept out by a five-mile radius from each wind farm location.

Locational data for the wind farms was obtained from utility and wind industry web sites, and used in conjunction with detailed block maps, wind farm site maps, topographic maps and interviews to identify the exact location and extent of the wind farms and the composite view shed. The final view shed dataset contains 745 sales from 1996 to 2002.

Interviews with Kern County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. Assessor Ron Stout said 50 to 60 percent of residents within Tehachapi City could see the turbines, but the Golden Hills area was too far and had views only if one intentionally tried to see them. He said about 30 percent of residents in the northwest corner of Mojave (north of Purdy Avenue and West of the Airport) could see turbines.

iii. Comparable Selection

The comparable community was selected through extensive interviews with Assessor Ron Stout of the State of California Kern County Assessment Office and analysis of topographic and site maps. Because the U.S. Census does not provide Census data at the resolution of individual ZIP+4 regions, we were unable to use Census data as part of the comparable selection process in this case. Based on review of the Assessor interviews, the ZIP+4 regions in Golden Hills, Bear Valley Springs, Stallion Springs and the central and southeastern portions of Mohave, all within Mohave zip code 93501 and Tehachapi zip code 93561, were selected as the comparable. The final comparable dataset contained 2,122 sales from 1996 to 2002.

iv. Analytical Results and Discussion

In one of the regression models, monthly average sales prices grew faster in the view shed than in the comparable area, and in two of the regression models it did not.

In Case I, the monthly sales price change in the view shed is 28 percent less than the monthly sales price change of the comparable over the study period. The Case I model provides a good fit to the view shed data, with over 70 percent of the variance in the data explained by the linear regression. In Case II, the monthly sales price change in the view shed is 38 percent greater after the on-line date than before the on-line date. The Case II model provides a good fit to the post on-line data, with 75 percent of the variance in the data explained by the linear regression. For the pre-on-line period, the regression explains 44 percent of the variance in the data. In Case III, average view shed sales prices after the on-line date are 29 percent less than in the comparable. The Case III model provides a good fit to the data, with 75 percent of the variance in the view shed data and 95 percent of the variance in the comparable data explained by the regression. The data for the full study period is graphed in Figure 8.4, and regression results for all cases are summarized in Table 8.2 below.

D. Additional Interviewee Comments

Assessor Stout also said that Mojave has not seen any new residential development in eight years. Both Stout and Assessor James Maples said they have not seen any impact of the farms on property values. However, Maples said the area was so agricultural or lightly populated that it would be hard to isolate price changes due to the wind projects. Maples, added that over 30 years of wind project development an industrial cement manufacturer, among other projects, was built close to Tehachapi on the east. The cement plant spewed out dust for 10 years or more until county and federal government inspectors required upgrades 15 years ago, said Stout

Tehachapi is the busiest single-tracked (locomotive) mainline in the world, according to the Tehachapi Chamber of Commerce. It runs through the Tehachapi Mountains between Mojave and Bakersfield. Of other notable businesses, Tehachapi has a manufacturing plant for GE Wind Energy (formerly Zond) wind turbines.

Table 8.x Regression Results, Kern County, CA
Projects: Pacific Crest, Cameron Ridge, Oak Creek Phase II

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R2)	Result
Case 1	View shed, all data	Jan 96 - Dec 02	$492.38	0.72	The rate of change in average view shed sales price is 28% less than the rate of change of the comparable over the study period.
	Comparable, all data	Jan 96 - Dec 02	$684.16	0.74	
Case 2	View shed, before	Jan 96 - Feb 99	$598.15	0.44	The rate of change in average view shed sales price is 33% greater after the on-line date than the rate of change before the on-line date.
	View shed, after	Mar 99 - Dec 02	$786.60	0.75	
Case 3	View shed, after	Mar 99 - Dec 02	$786.60	0.75	The rate of change in average view shed sales price after the on-line date is 29% less than the rate of change of the comparable after the on-line date.
	Comparable, after	Mar 99 - Dec 02	$1,115.10	0.85	

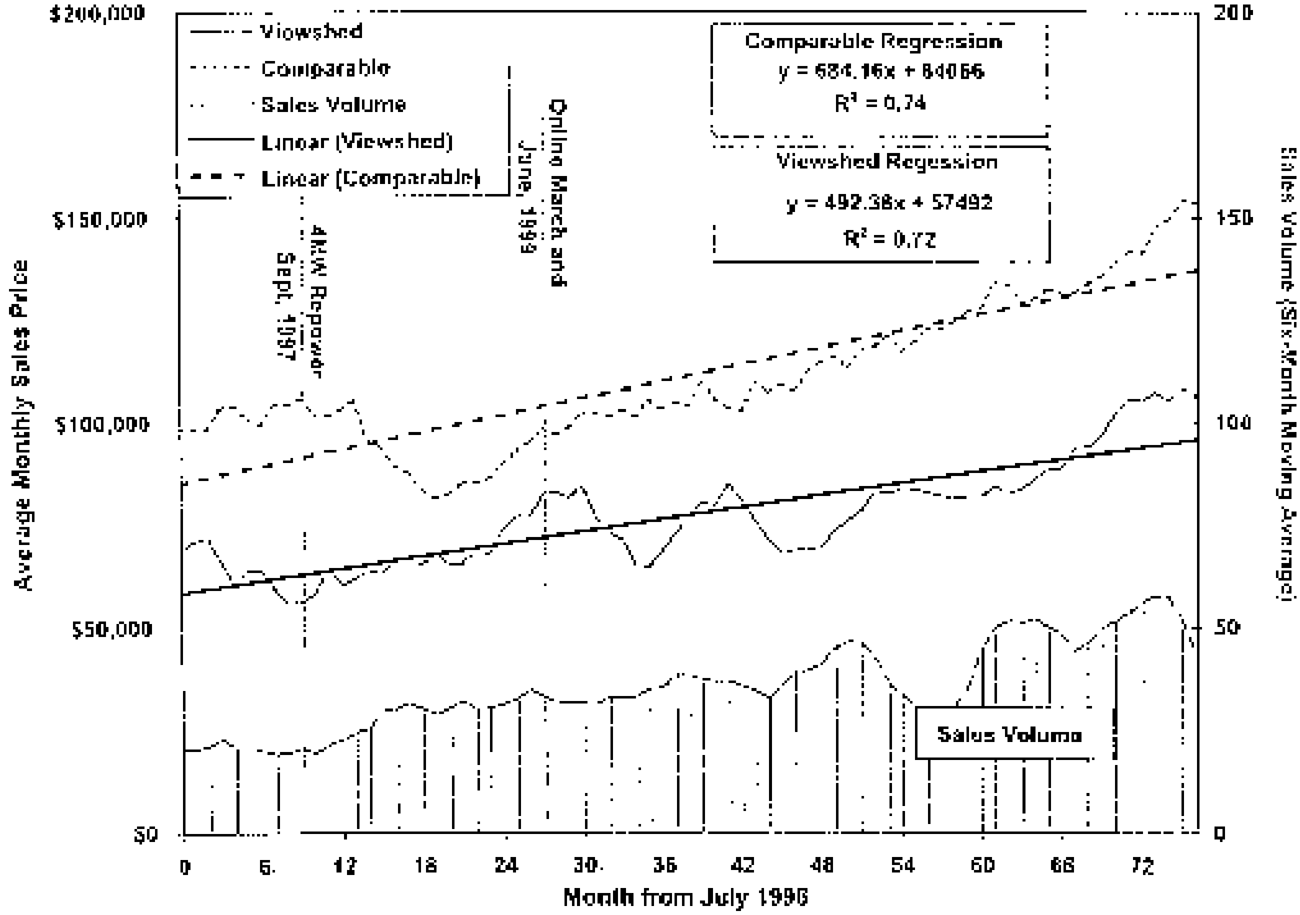


Figure 8.4 Average Residential Housing Sales Price

Kern County, California 1996-2002

Site Report 9: Fayette County, Pennsylvania

A. Project Description

Although the area is famous for being the home of Frank Lloyd Wright's Falling Water House built for a wealthy Pittsburgh family, much of the area is low-income and rural. The 10 turbines rising 70 meters (230 feet) were built along a ridge on the border of Stewart and Springfield Townships, and run north/south against the county border with Somerset. The land is owned primarily by one family who rents some of the acreage to a petroleum pumping company and for the turbines.

The area is very hilly with densely populated tall trees. The project site is approximately 62 miles from Pittsburgh with several ski lodges in the vicinity. The local economy is primarily agricultural or tourism related.

The view shed area of Springfield and Stewart Townships is rural with a combined population less than 2,000 although the county is classified as a "fringe county of a metro area with 1 million population or more." See Appendix 1 for a definition of rural urban continuum codes. This discrepancy is because the southeastern periphery of suburban Pittsburgh creeps a little into northwest Fayette. The view shed is at least 62 miles from downtown Pittsburgh.

Figure 9.1 View of a Mill Run Turbines
Photo Courtesy GE Wind Energy © [illegible]

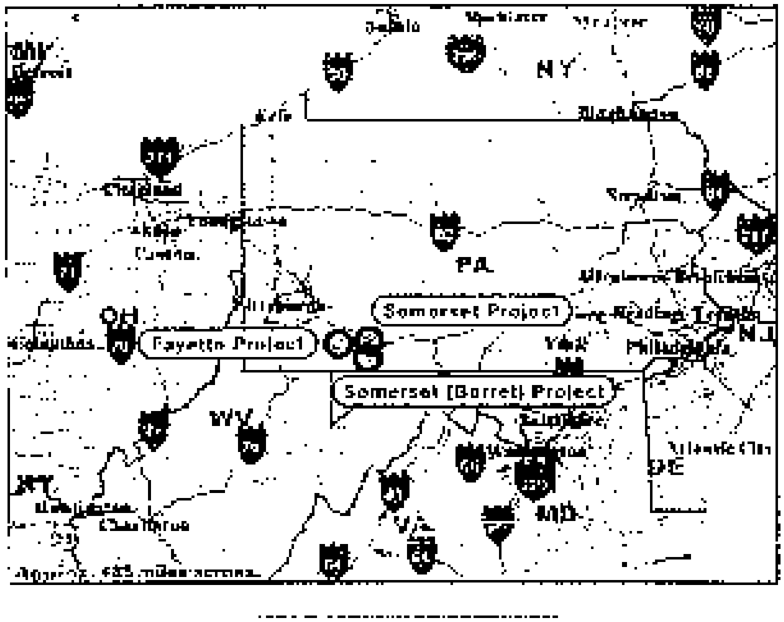


Figure 9.2. Regional Wind Project Location
(Dots approximate wind farm locations)

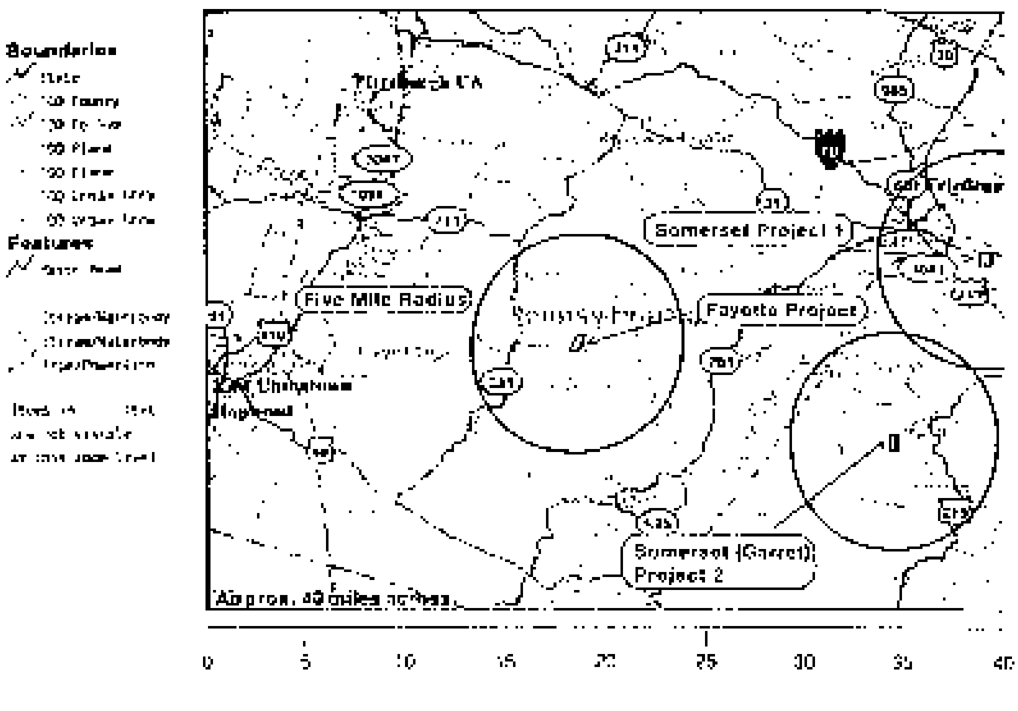


Figure 9.3. Fayette County, Pennsylvania View shed
Project Location Source - Fayette County Assessors Office
Base Map Source - U.S. Census Bureau

B. Project Timeline

Table 9.1 Wind Project History, Fayette County, PA

Project Name	Completion Date	Capacity (MW)
Mill Run Windpower LLC	2001	15.0

C. Analysis

i. Data Source

Real property sales data for 1998 to 2002 was obtained electronically from the Fayette County Assessment Office Website, www.fayettepropertyorg/assessor. The dataset contains all property sales in Stewart and Springfield Townships. The sales volume is the smallest of all sites analyzed, with only 89 sales over the five-year period studied. The wind farm went on-line October 2001, with an installed capacity of 15 MW.

Complete addresses and detailed sales data are available on the website only by clicking on each parcel individually. However, there is no parcel map of the entire township to help identify parcel locations. We combined over 50 local parcel maps into one composite parcel map for the view shed, and used this in combination with street maps to identify the view shed and non-view shed areas.

ii. View Shed Definition

The view shed is defined by a five-mile radius around the wind farm. The view shed covers the eastern portion of both Springfield and Stewart Townships in Fayette County. The five-mile radius also covers portions of Lower Turkey Foot, Upper Turkey Foot, and Middlecreek Townships in Somerset County. Because the Somerset County Townships are only partially in the view shed, and because the Somerset data we obtained is identified primarily by township or city, these areas are not included in the analysis. The view shed is therefore defined as the portions of Springfield and Stewart Townships falling within the five mile radius. The view shed accounts for 39 sales over the study period.

Interviews with the State of Pennsylvania Fayette County Assessors Office were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Fayette County Chief Assessor James A. Hercik's opinion, 10 to 20 percent of residents have views of the turbines.

iii. Comparable Selection

The comparable community was selected based on the availability of parcel-level data and through interviews with Fayette County Chief Assessor James A. Hercik. Assessor James Hercik said properties in the west of the view shed had no views of the wind turbines. Upon examination of sales data availability and review of Assessor comments, the western portions of Springfield and Stewart Townships, outside the five-mile view shed radius, were selected as the comparable, with a total of 50 sales from 1997 to 2002.

Demographic data from the 1990 and 2000 U.S. Census for Springfield and Stewart Townships was gathered, but not used because both the view shed and comparable are in the same township. Tables 9.2 and 9.3 summarize the Census data reviewed.

Table 9.4 Fayette County, Pennsylvania: 1990 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
1990	partial	Springfield Township	2,968	$15,086	28%	1,137	$40,200
1990	partial	Stewart Township	734	$18,236	24%	331	$42,500
VIEW SHED DEMOGRAPHICS			3,702	$15,961	26%	1,468	($41,350)

Table 9.5 Fayette County, Pennsylvania: 2000 Census Data

Year	View shed	Location	Population	Median household income	% Population below poverty level	Number housing units	Median value-owner-occupied housing unit
2000	partial	Springfield Township	3,111	$29,133	22%	1,283	$57,400
2000	partial	Stewart Township	743	$32,917	11%	338	$64,000
VIEW SHED DEMOGRAPHICS			3,854	$31,025	16%	1,621	$60,700

iv. Analytic Results and Discussion

In two of the three regression models, monthly average sales prices grew faster or declined slower in the view shed than in the comparable area. However, in the case of the underperformance of the view shed, the explanatory power of the model is very poor. Thus, there is no significant evidence in these cases that the presence of the wind farms had a negative effect on residential property values.

In Case I, the monthly sales price increase in the view shed is only 24 percent that of the comparable over the study period. However, the Case I model provides a poor fit to the view shed data, with only two percent of the variance in the data for the view shed and 24 percent of the variance in the data for the comparable explained by the linear regression. In Case II, sales prices decreased in the view shed prior to the on-line date, and increased after the on-line date. The average view shed sales price after the on-line date increased at 3.8 times the rate of decrease in the view shed before the on-line date. The Case II model provides a poor fit to the data, with less than one-third of the variance in the data explained by the linear regression. In Case III, average view shed sales prices after the on-line date are 13.5 times greater than in the comparable. However, the Case III model describes only 32 percent of the variance in the view shed data, and none of the variance in the comparable data. The data for the full study period is graphed in Figure 9.4, and regression results for all cases are summarized in Table 9.4 below.

The poor fit of the model, as evidenced by the low R2 values, is partly due to the very small sales volume, on average only 2.1 sales per month in the view shed and comparable combined. As can be seen from Figure 9.4, the small sales volume leads to very high variability in average sale price from month to month. In addition, for regressions fit to data after the on-line date, only 13 months' sales data was available, accounting for 18 sales total, which leads to the caveat that these results should be viewed carefully.

Table 9.4 Fayette County, Pennsylvania: Regression Results
Project: Mill Run

Model	Dataset	Dates	Rate of Change ($/month)	Model Fit (R^2)	Result
Case 1	View shed, all data	Dec 97-Dec 02	$115.96	0.02	The rate of change in average view shed sales price is 24% of the rate of change of the comparable over the study period.
	Comparable, all data	Dec 97-Dec 02	$479.20	0.24	
Case 2	View shed, before	Dec 97 - Nov 01	-$413.68	0.19	The rate of change in average view shed sales price after the on-line date increased at 3.8 times the rate of decrease before the on-line date.
	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	
Case 3	View shed, after	Oct 01-Dec 02	$1,562.79	0.32	The rate of change in average view shed sales price after the on-line date is 13.5 times greater than the rate of change of the comparable after the on-line date.
	Comparable, after	Oct 01-Dec 02	$115.86	0.00	

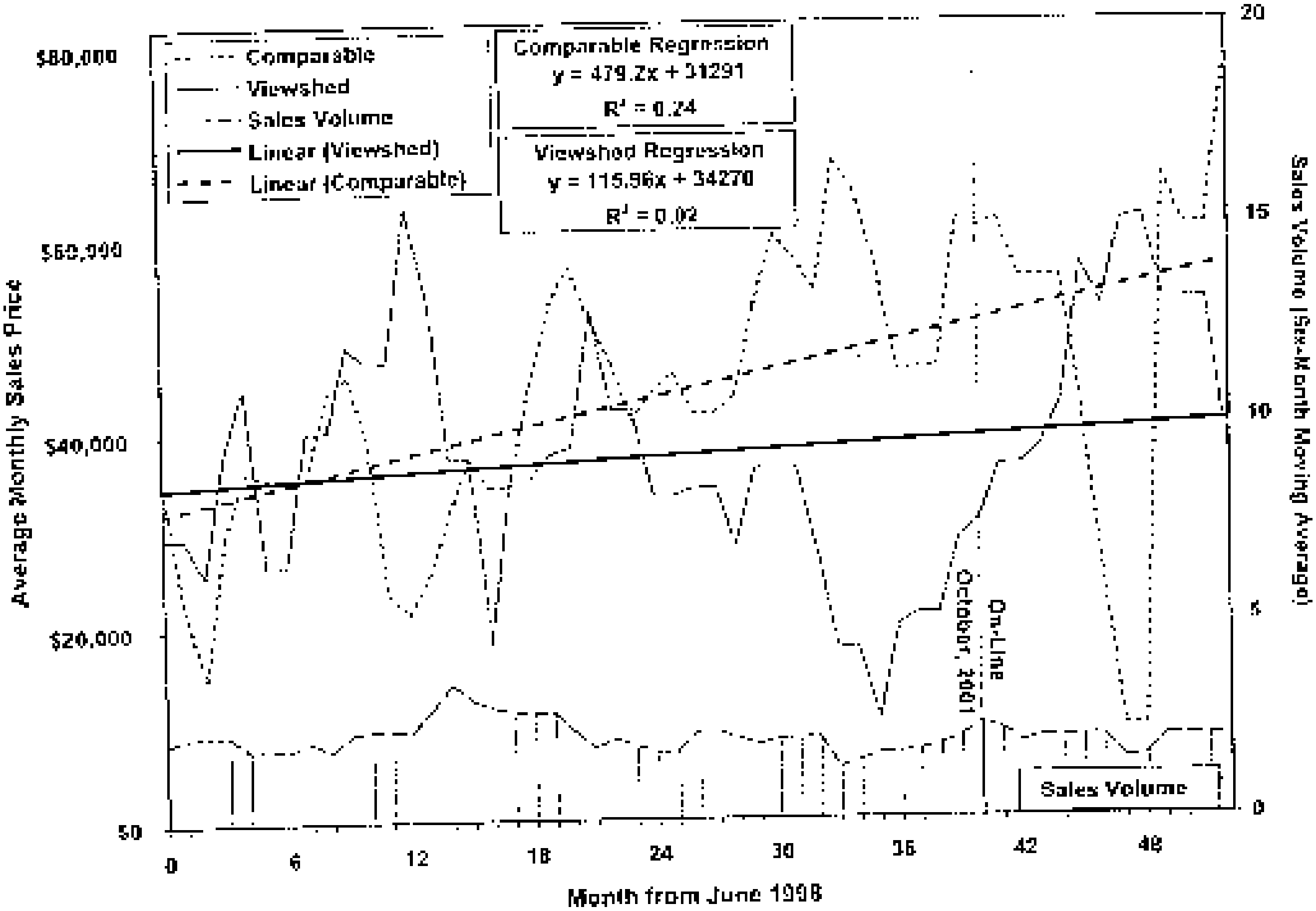


Figure 9.4 Average Residential Housing Sales Price
Fayette County, Pennsylvania 1998-2002

D. Additional Assessor Comments

James A. Hercik, Fayette County chief assessor/director of assessments, said he has not seen any impact of the wind farms on property values, with the exception that the assessed value of properties with turbines went up. He also noted that on the same property as the turbines are on, there are natural gas wells, which additionally impact valuations. Finally, Hercik said that often, sales in the view shed were family-to-family sales that may reflect sales prices lower than assessed value.

Site Report: Projects Excluded From Analyses

Of the 27 projects selected for analysis, five were excluded from analysis because there were not enough sales in the view shed for statistical analysis; one was excluded because comparable data was not available at time of publication of this report; and an additional 12 projects were excluded because property sales data was unavailable, not readily available, or because there were not enough sales in the view shed for statistical analysis. Table 51 below summarizes the reasons for project exclusion from analyses.

Table 51: Summary of Projects Excluded from Analyses

I. Data acquired, but insufficient for analysis

County	State	Reason for Exclusion
Logan	CO	Not enough sales to make a valid judgment (5 Sales)
Worth	IA	Not enough sales to make a valid judgment (38 sales over 7 years)
Umatilla	OR	Not enough sales to make a valid judgment (28 sales)
Howard	TX	Comparable data not acquired at time of publication (1,896 view shed sales)
Upton	TX	Not enough sales to make a valid judgment (7 sales)

II. Data not acquired

County	State	Reason for Exclusion
Weld	CO	Not enough sales to make a valid judgment
Cerro Gordo	IA	No electronic data - accessible in office on paper only
Gray	KS	State law prohibits access to information
Pipestone	MN	No electronic data - accessible in office on paper only - and not enough sales
Lincoln	MN	No electronic data - accessible in office on paper only
Gilliam	OR	No electronic data - accessible in office on paper only
Culberson	TX	No electronic data - accessible in office on paper only
Pecos	TX	No electronic data - accessible in office on paper only - and no sales in view shed
Taylor	TX	No electronic data - accessible in office on paper only
Benton	WA	Not enough sales to make a valid judgment (Project came on-line in 2002)
Walla Walla	WA	No sales in the view shed since project completion
Iowa	WI	No electronic data - accessible in office on paper only
Carbon	WY	State law prohibits access to information

1. Data Acquired, but Insufficient for Analysis

County State Reason for Exclusion

Logan CO **Not enough sales to make a valid judgment** (Five Sales)

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Ann Rogers-Ridnour said her office has seen no impact from the wind project and that it was hard gauge because there are so few sales.

Worth — IA — Not enough sales to make a valid judgment (38 sales over seven years)

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said the project was surrounded only by agricultural land, that it was hard to pinpoint home locations on farms if any because addresses are vague, and that they felt the wind projects have been welcomed.

Umatilla — OR — Not enough sales to make a valid judgment (28 sales)

Years Reviewed: 1995 to 2002

Assessor comments. Assessor Lee Butler said there were only 28 sales in view shed.

Howard — TX — Comparable not available at time of publication

Years Reviewed: 1996 to 2002

The exact location of the Big Spring wind farm in Howard County, TX, and thus definition of the view shed, was elusive. While site maps with individual turbine locations were obtained, they were hand drawn and not to scale. Interviews with county Assessors and on-site operations staff yielded conflicting descriptions of the exact location of the turbines. In the end, the wind farm location was fixed in an interview with one of the original site developers, Mark Haller of Zilkha Inc. According to Mr. Haller, the turbine towers reach out far away from the Big Spring, but the closest one is only 100 yards or so from the third tee of a golf course on the south side of town – close enough for golfers often take chip shots at it.

The view shed covers portions, but not all of, the three school districts in the county: Coahoma, Big Spring, and Forsan. Approximately 70 percent of Big Spring City, all of Coahoma City, and none of Forsan City are within the view shed. Because this project lacks the resources to identify every property by street address, the view shed is defined to include all of Big Spring City, which is equivalent to using a six-mile radius view shed instead of a five-mile radius view shed for this case only. The final view shed dataset contains 1,896 sales from 1996 to 2002.

Interviews with Howard County Assessors were conducted by phone to determine what percentage of residential properties in the view shed can see all or a portion of the wind turbines. In Chief Assessor Keith Toomire's opinion, 30 percent of Big Spring City properties can see the turbines. Mr. Haller added that due to the various plateaus surrounding Big Spring, there are portions of the town that cannot see the turbines.

The selection of an appropriate comparable for Big Spring is difficult because the area has experienced an economic downturn and loss of jobs for a number of years. According to Howard County Chief Assessor Keith Toomire, the two major employment categories in the Big Spring are agriculture and petroleum extraction. Due to a 10-year draught in the region, crop yields are severely reduced, with significant economic impacts for the city. Additionally, depletion of petroleum resources has led to the closing of wells and economic downturn in the local petroleum industry.

Because the view shed for Big Spring was defined very late in the process of producing this report, data for a comparable has not yet been obtained.

Upton — TX — Not enough sales to make a valid judgment (Seven sales)

Years Reviewed: 1996 to 2002

Assessor comments: Chief Appraiser Sheri Stevens said no sales near southwest Mesa, and only seven sales near the King Mountain project.

II. Data Not Acquired

<u>County</u> <u>State</u> <u>Reason for Exclusion</u>

<u>Weld</u> **<u>CO</u>** **<u>Not enough sales to make a valid judgment</u>**

Years Reviewed: 1996 to 2002

Assessor comments: Office staff said there were very few people in the project area and didn't think anybody could see it.

<u>Cerro Gordo</u> **<u>IA</u>** **<u>No electronic data - accessible in office on paper only</u>**

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said we were the third group to call them about the same question and that they've looked into every way they could to parse their data, and could find no proof that there was any impact on county property values.

<u>Gray</u> **<u>KS</u>** **<u>State law prohibits access to information</u>**

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Jerry Dewey said area had only small populations and that most land was agricultural; therefore he said they have seen no impact, primarily because the land is assessed for productive use.

<u>Pipestone</u> **<u>MN</u>** **<u>No electronic data - accessible in office on paper only - and not enough sales</u>**

Years Reviewed: 1991 to 2002

Assessor comments: Interim Assessor "Farley" said he's not seen any impact on property values. Also, he added that there haven't been enough sales to make a judgment call, and all property surrounding the project is agricultural land which is valued on productive use (so unless the turbines were on the property itself, then the property value would not go up).

<u>Lincoln</u> **<u>MN</u>** **<u>No electronic data - accessible in office on paper only</u>**

Years Reviewed: 1991 to 2002

Assessor comments: Assessor "Bruce" (last name unavailable) said the project was a "non-issue" and has not seen any impact on values. Specifically, the projects were welcomed and some people tried to have the turbines built on their land.

<u>Gilliam</u> **<u>OR</u>** **<u>No electronic data - accessible in office on paper only</u>**

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Pat Shaw said area around project had a population less than 700 all living dispersed among agricultural land. Also, he expressed no sense of impact on property values

<u>Culberson</u> **<u>TX</u>** **<u>No electronic data - accessible in office on paper only</u>**

Years Reviewed: 1992 to 2002

Assessor comments: Appraiser Sally Carrasco said they've been very happy with the wind farms. She added that because they have a terrible economy, she wasn't sure if they would even have a town were it not for the revenue from turbines that support the schools.

<u>Pecos</u> **<u>TX</u>** **<u>No electronic data - accessible in office on paper only and no sales in view shed</u>**

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Santa S. Acosta said there were no residences with a view, and that there are so few sales in general that the area wasn't due for re-appraisal until 2003.

Taylor TX No electronic data - accessible in office on paper only

Years Reviewed: 1997 to 2002

Assessor comments: Assessor Ralf Anders said no homes had a view.

Benton WA Not enough sales to make a valid judgment.

(Project came on-line in 2002)

Years Reviewed: 1996 to 2002

Assessor comments: Office clerk "Harriet" said they only have the past three months of data in electronic form; everything else is in paper and a person must go to office to search records.

Walla Walla WA No sales in the view shed since project completion

Years Reviewed: 1996 to 2002

Assessor comments: Walla-Walla County Assessor Larry Shelley said there have been no sales since the wind project was built.

Iowa WI No electronic data - accessible in office on paper only

Years Reviewed: 1996 to 2002

Assessor comments: Assessor said only small village areas had views, but that the wind projects were welcomed. -Assessor specifically made a comment that a bowling alley has built a small tourist attraction around the project.

Carbon WY State law prohibits access to information

Years Reviewed: 1996 to 2002

Assessor comments: Assessor Darrell Stubbs said that although it is illegal to release individual property information, he has seen no impact on values. Specifically, he noted if any impact occurred, property values have risen because the population is so small that the infusion of a few jobs from the project in the area is enough to raise prices.

REFERENCES

AES Calgary ULC. Application comments. 525-MW Natural Gas-Fired Power Plant Application No. 2001113 to Alberta Energy and Utilities Board. 2001.

California Energy Commission. Decision. Application for the Sutter Power Plant Project: Docket No 97-AFC-2. 1999.

Campaign for the Protection of Rural Wales. The "Sinclair-Thomas Matrix" in Evidence to the House of Lords European Communities Committee. Sub-Committee B-Energy and Transport. Appendix 1: The Potential Visual Impact of Wind Turbines in relation to distance. March 1999. Available electronically at http://www.cprw.org.uk/wind/Hlords/hlcont.htm

Damborg, Steffen. Public Attitudes Towards Wind Power. Danish Wind Industry Association. June 2002. Available electronically at www.windpower.org/articles/surveys.htm

Dempsey, William E. The DUPA Technique for Electric Transmission-Line Easement Acquisitions. The Appraisal Journal. July 1981.

Des Rosiers, François. Power Lines, Visual Encumbrance and House Values: A Microspatial Approach to Impact Measurement. Journal of Real Estate Research. 2002.

Grover, Stephen. Economic Impacts of Wind Power in Kittitas County. Phoenix Economic Development Group/ECO Northwest. 2002.

Ignelzi, Patrice and Priestley, Thomas. A Statistical Analysis of Transmission Line Impacts on Residential Property Values in Six Neighborhoods. Edison Electric Institute. 1991.

Ignelzi, Patrice and Priestley, Thomas. A Methodology for Assessing Transmission Line Impacts in Residential Communities. Edison Electric Institute. 1989.

Jorgensen, Jaeden Jordal. Social Assessment of Wind Power: Visual Effect and Noise from Windmills—Quantifying and Evaluation. Institute of Local Government Studies. Denmark. April 1996. Available electronically at www.akf.dk/eng/wind0.htm

Kroll, Cynthia A. and Priestley, Thomas. The Effects of Overhead Transmission Lines on Property Values: A Review and Analysis of the Literature. Prepared for Edison Electric Institute Siting & Environmental Planning Task Force. July 1992.

Kung, Hsiang-te and Seagle, Charles. Impact of Power Transmission Lines on Property Values: A Case Study. The Appraisal Journal. July 1992.

McCann, Richard. A Review of Literature on Property Value Impacts from Industrial Activities. Metcalf Energy Center. 1999.

Priestley, Thomas. Public Perceptions of Electric Facilities: An Advanced Workshop. Edison Electric Institute. 1997.

Sinclair Knight Merz. Social Economics and Tourism. Environmental Effects Statement Supplement for the Pacific Hydro Limited Portland Wind Energy Project, Volume C. 2001. Available electronically at http://www.pacifichydro.com.au/files/PWEP/VolC_SET_Pt6on.pdf

Thomas, Gareth Wyn. An Environmental Assessment of Visual and Cumulative Impacts arising from Wind Farm Developments: A Welsh Planning Policy Perspective. University of Wales, Aberystwyth. March 1996. Available electronically at http://users.aber.ac.uk/zwk/distlearn/wind/theses/thomas/thomas.html

U.S. Department of Agriculture. National Forest Landscape Management, Volume 1. Agriculture Handbook Number 434. 1973.

Appendix I. County Classification Descriptions

U.S. Department of Agriculture, Economic Research Service Rural-Urban Continuum Codes

Metro counties:

0 Central counties of metro areas of 1 million population or more.
1 Fringe counties of metro areas of 1 million population or more.
2 Counties in metro areas of 250,000 to 1 million population.
3 Counties in metro areas of fewer than 250,000 population.

Nonmetro counties:

4 Urban population of 20,000 or more, adjacent to a metro area.
5 Urban population of 20,000 or more, not adjacent to a metro area.
6 Urban population of 2,500 to 19,999, adjacent to a metro area.
7 Urban population of 2,500 to 19,999, not adjacent to a metro area.
8 Completely rural or less than 2,500 urban population, adjacent to a metro area.
9 Completely rural or less than 2,500 urban population, not adjacent to a metro area.

Note: New Rural-Urban Continuum Codes based on the 2000 Census are not expected to be available until 2003. The development of the updated codes requires journey-to-work commuting data from the long form of the 2000 Census and delineation of the new metropolitan area boundaries by the Office of Management and Budget. OMB's work is not scheduled to be completed until 2003. www.ers.usda.gov/briefing/rurality/RuralUrbCon/

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Impacts of Windmill Visibility on Properties Values in

Madison County, New York.

Project Report Submitted to the Faculty of the

Bard Center for Environmental Policy

By Ben Hoen

In partial fulfillment of the requirement for the degree of

Master of Science in Environmental Policy

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Abstract

Potentially adverse effects of windfarm visibility on property values can represent real costs to communities, yet few studies exist on the subject. The studies that are available are contradictory, and suffer from statistical flaws. A clearer understanding of actual effects of existing wind facilities will inform future decisions. To explore this subject this report analyzes 280 arms-length single-family residential sales using a hedonic regression model. The sales took place from 1996 to 2005 and are within 5 miles of a 20 turbines - 30 megawatt (MW) windfarm in Madison County, New York. The report differentiates itself from previous studies by visiting all homes ("ground truthing") in the sample to ascertain the actual level of turbine visibility. The analysis finds an absence of measurable effects of windfarm visibility on property transaction values. This result holds even when concentrating on homes within a mile of the facility and those that sold immediately following the announcement and construction of the windfarm in 2001. These results dispel the proposition that effects, either positive or negative, are universal. The report concludes by making recommendations to stakeholders and outlining possible considerations for further research.

Key Words

Viewshed, view, vista, wind energy, windfarm, turbines, property values, transactions, hedonic, regression, review, GIS, ground cover

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1 Executive Summary

With federal renewable energy tax credits and a number of state incentive packages in place (AWEA, 2005b), U.S. states are increasingly relying on wind energy to mitigate risks related to resource scarcity, increasing costs of fossil fuel extraction, greenhouse gas emissions and other environmental hazards (CRS, 2005). This shift has caused wind energy development to grow at an unprecedented rate. In 2005 new capacity totaling 2,400 megawatts (MW) was installed in the U.S., an increase of 35% over 2004 U.S. capacity (AWEA, 2006).[1] At the same time windmill sizes have become increasingly large in order to capture greater efficiencies per turbine, and the numbers of turbines installed per windfarm has increased to capture economies of scale (AWEA, 2005c). Litigious conflicts between community members and facility developers have occurred (Adams, 2005) and are likely to increase if the industry trends of increasing size and number continue. Community attitudes regarding wind energy are often promoted by small groups of organized opponents or proponents, therefore the sentiments of the entire community on average may be missed. One way to measure the community's disposition is to use property transaction prices (transaction values) as a proxy. If the visibility of a windfarm is believed by the members of the community to adversely affect the view from the home, the transaction value, with all else being equal, will be lower as compared to other homes without a view. Alternatively, if residents find the view acceptable, no change in property values will be discernable.

Many opinions exist on the effects of wind development on surrounding property values. For example, the two largest studies completed in the U.S. reach contradictory

[1] The American Wind Energy Association (AWEA) estimates that 2,400 MW of wind energy will supply energy for 600,000 homes (AWEA, 2006)

results. Haughton (2004) predicts sizable negative effects from windfarm development on property values in Cape Cod, Massachusetts while Sterzinger (2003) concludes from his analysis of 10 communities around the U.S. there are strong positive effects. Despite these contradictory results no studies to date have rigorously analyzed the subject by using a large sample of arms-length home transaction values combined with a verification to what degree each home in the sample can see the wind farm or not. Instead, with each new wind development interested parties are forced to rely on poorly constructed or inconclusive studies (Jordal-Jorgensen, 1996; Grover, 2002; Sterzinger *et al.*, 2003; Poletti, 2005), or comparisons to inappropriately analogous research (Zarem, 2005a). For instance in 2004, the Public Service Commission (PSC) of Wisconsin heard opposing conclusions of studies conducted by experienced economists (Poletti, 2005; Zarem, 2005b). Both cited, in their testimony, their frustration with the lack of available evidence in this subject area.

Compounding the lack of data problem, changes in property values are not likely to be taken into consideration by the developer and the community. These "hidden costs" or "externalities" are not weighed against the benefits of a project. Without proper analysis of these potential costs or externalities and a thorough understanding of when and how they affect property values, facilities may be either needlessly delayed or inappropriately approved. This report studies property values and windfarms with the hope of shedding light on these issues.

First the report reviews the existing literature on property values and windfarms finding in most cases a lack of rigor and insufficient detail to capture the complex relationship between home transaction prices and views, such as those found in research of high voltage transmission lines (HVTL) and property values (e.g. Des-Rosiers, 2002). Then using data from a Madison County, New York community surrounding a 20 turbine windfarm, the report analyses home transaction values in an effort to ascertain if effects exist and to create a potential blueprint for future analysis of other communities. The data contains 280 arms-length single-family residential home sales which took place between 1996 and 2005; 140 occurred after facility construction began in 2001. None of the home sales were on properties that contained turbines, or received compensation from the operation of the turbines. Two methods of measuring the degree to which each home can see the turbines are developed, a simulated method and one involving field visits. Ultimately, as is discussed below, the method involving field visits was used for the regression model. The simulated method uses a geographical information system (GIS) model to predict visibility. Ten meter digital elevation model (DEM)[2] data provided by the United States Geological Survey (USGS) is combined with 10 meter ground-cover data by estimating heights of ground cover types and adding these heights to the surface elevations. The ESRI 3-D analyst viewshed algorithm, which is included in the Arc Map product, is used to analyze visibility. Then, GIS predictions are compared to field collected data. Although it incorporates techniques not previously used and reaches an accuracy rate of 85%, which is higher than the 50% accuracy rate found in the literature (Dean, 1997; Maloy and Dean, 2001), it is deemed an unsatisfactory level of accuracy for this report's hedonic analysis which requires greater than 95% accuracy. Therefore, the second, field visit method is used.

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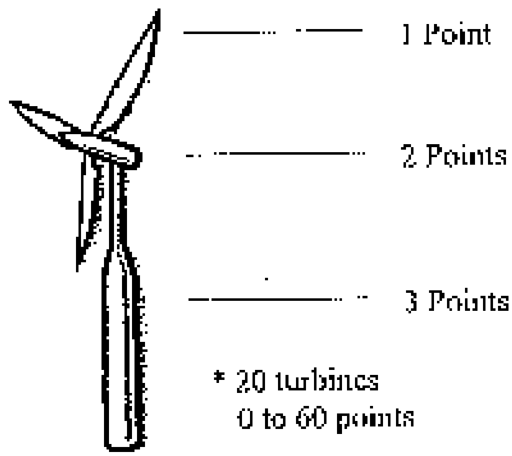
[2] The DEM is a digital representation of the elevation of locations on the land surface. A DEM is often used in reference to a set of elevation values representing the elevations at points in a rectangular grid on the earth's surface.

For this method, each home in the sample is visited and the degree to which each of these homes can see the windfarm is quantified using a scoring method which attempts to minimize bias. From each home each of the twenty turbines is given a 0 (no view) to 3 (full view) score, which are then totaled resulting in a 0 to 60 score specific to that property.[3]

Figure I: Turbine Visibility Scoring Method



As well, a GIS is used to quantify the exact distance from each home to the nearest turbine. These two characteristics, view of and distance from turbines, are combined with a number of house and neighborhood characteristics. The combination of characteristics is then used in a hedonic regression model to investigate the marginal effect that the view of and distance from turbines has on home sale prices. The hedonic pricing model is well established in its usefulness in investigating the effects environmental characteristics have on home values (e.g. Dale *et al.*, 1999).

The report finds that the model significantly predicts home values (f-value 49.56, p-value 0.000, R^2 0.792), and on average that there are no measurable effects on property values based on the view of and distance from turbine characteristics (p-value 0.410 and

[3] The actual range of scores for the sample set used in this report is 0 to 43.

0.679 respectively). This finding holds both temporally and spatially. In other words, homes which sold in the year the project was announced and constructed (2001), and had a clear view of the turbines, are not affected uniquely (p-value 0.742); and no measurable effect is found for homes located within a mile of the facility (p-value 0.656)[4].

Additional tests are run to see if the township of Fenner in which the turbines are located, and to which payments are made by the facility owner, is accordingly perceived to have a positive value in the eyes of home purchasers as compared to the other townships. If the payment to the township is considered to be a distinct advantage by home purchasers, by adding needed dollars to the town budget, for example, it might be found the homes in Fenner are priced at a premium to other townships, all else being equal. In our analysis no measurable premium is found (p-value 0.689).

These results are important to policy makers and other stakeholders because they dispel the supposition that windfarm development has universally negative effects on home values. They support the results previously collected via surveys which find that a majority of residents in communities surrounding other wind facilities not only perceive the turbines to be "acceptable" (Warren *et al.*, 2005), but also "relatively nonexistent," by rarely (< 3.0%) spontaneously mentioning them in descriptions of their surroundings (Braunholtz and MORI-Scotland, 2003).

[4] A p-value is a measure of statistical significance, which can be reported in a number of ways in studies (e.g. margin of error, probability, or significance). They all report the same thing, the degree of confidence that the results were not reached by simple chance. As sample sizes grow, and variation among them becomes more predictable, more confidence can be had that "statistically significant" results from the analysis of the sample set can be transferred to the entire population. Conversely, if sample sizes are small, and variation among them is less predictable, results can not be validated against an average, and therefore present difficulties in being extrapolated to the population. In these cases results should be taken anecdotally or should not be transferred outside of the sample set.

With a paucity of research on the subject of effects of wind facilities on property values and a great deal of speculation regarding the actual effects, policy makers are forced to rely on poorly constructed studies and opinions. This report attempts to move the discussion toward the facts. Its research finds that in this community of 280 homes no effect is found. To the degree that these results are corroborated by further analytical research in other communities, the issue of negative impacts of windfarms on property values might take a lower priority in the decision making process. This report makes policy recommendations to stakeholders based on the results of this study and outlines possible areas for consideration which should be explored in future research.

2 Introduction

With federal renewable energy tax credits and a number of state incentive packages in place (AWEA, 2005b), the States are increasingly relying on wind energy to mitigate risks related to resource scarcity, increasing costs of fossil fuel extraction, green house gas emissions and other environmental hazards (CRS, 2005). Because wind energy, "is one of the lowest-priced renewable energy technologies available today" (USDOE, 2005, p. 1) and its resources are well distributed around the country, it has enjoyed an average annual growth of almost 20% over the last decade (GWEC, 2005) and is expected to continue its growth into the future (EIA, 2006). In the United States, twenty-one states have implemented a Renewable Portfolio Standard (RPS) which requires a percentage of retail sales to be from renewable sources (AWEA, 2005b). The American Wind Energy Association (AWEA) forecasts a 7-fold increase in the use of wind energy in the U.S. by 2020 (AWEA, 2005e). In 2005 alone roughly 2,400 MW (or 1666 turbines[5] in 140 "windfarms"[6]) have come online in the U.S. (AWEA, 2006).

Not only have the amount of windfarms been increasing but the number of turbines in each development has increased to capitalize on economies of scale. Additionally the sizes of the structures over the last 20 years have changed dramatically in order to increase turbine efficiency. As the height and rotor diameter of turbines increase, the power generated from the turbines grows exponentially (AWEA, 2005c). In 1980 when the Altamont Pass wind facility was erected outside of San Francisco in California (CA),

[5] Estimated by using an average turbine size of 1.5 MW and farm size of 100 MW. Using this same estimate, if New York State is to meet its RPS goals of 25% by 2013 (NYSDPS, 2004) 30 new windfarms will have to be sited.

[6] These wind energy production facilities usually contain groupings of 10 or more turbines referred to as a "windfarm," because they are laid out "as a farmer might approach... a field" (Gipe, 2002).

turbines averaged 30 meters in height (Pasqualetti, 2002). Now land based turbines sit on towers as high as 90 meters, and have blade lengths of 45 meters (AWEA, 2005c) totaling 135 meters (442 feet) from base to tip.[7] While increasing efficiency, this difference in heights makes them considerably more visible from long distances.

With the high number of windfarm installations expected to occur in the U.S. to meet RPS goals over the next decade and the ever increasing size of the facilities and the turbines themselves, it is inevitable that there will increasingly be conflicts between developers and members of the communities in which the windfarms are sited. Often these clashes revolve around environmental "aesthetics," or how well the turbines fit into the surrounding environment in the eyes of community members. Findings suggest that respondents prefer smaller turbines over larger ones (e.g. Wolsink, 1989; SEI, 2003) and fewer structures rather than more in each group (e.g. Devine-Wright, 2004). Accordingly, homeowners have often claimed a proposed wind facility will ruin or "mar their view" (e.g. AP, 2006).

How can this claim be tested? When property owners say windmills will "ruin" their view, they are claiming both that there is some intrinsic value of "vista" (or view)[8] from their home, and that if the proposed windmills can be seen from the home this value will be diminished. It follows that if you can analyze home sales that have visual contact with the windmills in comparison with ones that do not, all others things being equal, an average effect can be verified. In other words, community attitudes of a wind development

[7] Offshore turbines can be even bigger ranging up to 165 meters from base to tip.

[8] For this report, a distinction is made between "vista" and view or viewshed. "Vista" will always refer to the value of a home that is derived from a "good view" from the property. "View" or "Viewshed" will refer to the degree to which a property can see the windmills. In other words, "A property not only had a beautiful vista, but had a view of the windmills too."

can be translated into home values, just as, for instance, the perceptions of a safe neighborhood or good quality public schools are translated into sale prices. This correlation of community attitude and property values has been confirmed in studies of other environmental attributes such as open space (e.g. Irwin, 2002), high voltage transmission lines (HVTL) (e.g. Des-Rosiers, 2002) and environmental stigmas (e.g. Dale *et al.*, 1999).

What are the ramifications to the community or society of such potential connections? If the effect of visibility of wind facilities on property values is universally highly negative, these costs might be very high. Haughton (2004), in his study of the proposed Cape Cod windfarm forecasts depreciation of property values in the billions! Yet, often changes in home values are outside the normal transactions of a developer and a community and are thus "hidden costs" or "externalities" of a project. These externalities are often grouped together and termed "environmental impacts" (EMC, 2005). Windfarm developers are often required, depending on the state or local laws, to investigate the nature and magnitude of these externalities by preparing an environmental impact statement (EIS) or something similar[9] often modeled after the Federal requirements as directed by the National Environmental Policy Act (NEPA)[10] regulations. An EIS is a report describing the investigations conducted by the developer of potential effects the facility will have on the surrounding environment. The report has a number of functions. First, it allows interested parties and stakeholders an opportunity to peel back, investigate and in some cases challenge the development's declared environmental impacts. Secondly, it provides a record that can be later challenged if assertions are found to be incorrect. Lastly, it provides

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[9] More often than not, local laws will permit development to take place without a full environmental review (GAO, 2005), but often some type of impact assessment is required.
[10] National Environmental Policy Act (42 U.S.C. & 4321)

a schedule of expected environmental costs that can be compared against the proposed benefits any project will provide. In order for a project to proceed, "it must be demonstrated that the need for the proposal outweighs all adverse impacts" (EMC, 2005, p. 10).

Because of the importance of understanding actual effects on property values as costs to be weighed against benefits, it may be expected that this issue has been widely studied. However, this is not the case. Some studies exist using actual real estate transaction prices, but have made critical errors which weaken the results (e.g. Sterzinger *et al.*, 2003; Poletti, 2005), as explained in section 3. In the absence of actual prices, studies have used surveys of real estate professionals and homeowners as a proxy (e.g. Jordal-Jorgensen, 1996; Grover, 2002; Haughton *et al.*, 2004). Yet none of these studies reported their results accompanied by levels of significance.[11] Accordingly decision makers are forced to make educated guesses as to the predicted effects of a proposed windfarm. One controversy was played out in Wisconsin as two experts argued over the potential effects of the proposed Forward Wind Facility (Zarem, 2005b) and (Poletti, 2005) with each reaching distinctly different conclusions. Without well-designed studies with solid conclusions to work with, planners, developers, and potentially impacted communities will continue to needlessly delay or inappropriately rule on projects that might otherwise be decided differently.

This report examines whether property values were affected by a windfarm installed in Madison County in 2001. 280 home sales, which took place between three quarters and

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[11] Refer to discussion of "significance" in footnote 4 on page vii.

five miles of a 20 turbine windfarm, are analyzed using a hedonic pricing model[12] to establish the degree of impact that a view of windmills might have had on the transaction values of these homes. The report first outlines previous studies on the subject. Next the report presents methodology and results. Lastly the report discusses conclusions and makes policy recommendations to interested parties and research recommendations concerning decisions on siting wind facilities.

[12] A hedonic pricing model, as discussed in section 5.1, is a statistical device which allows market goods to be broken into their component characteristics. It is often used to value individual characteristics of cars, such as the value of a sunroof, and homes, such as the value of a pool.

3 Overview of Previous Studies

The literature on wind energy facilities and surrounding property values can be grouped into three categories of increasing order of relevance for our research: survey-based studies (Jordal-Jorgensen, 1996; Grover, 2002; Haughton *et al.*, 2004; Khatri, 2004), transaction-based studies of analogous high voltage transmission lines (HVTL) structures (e.g. Delaney and Timmons, 1992; Hamilton and Schwann, 1995; Des-Rosiers, 2002), and transaction-based studies of windfarms (Sterzinger *et al.*, 2003; Poletti, 2005).

3.1 *Survey based studies*

When transaction data are not available either because a windfarm has only been proposed or data are not recorded or available for public use,[13] surveys can be used to estimate values of viewshed impacts. Surveys specifically asking questions regarding values can be directed at assessors and real estate agents who have professional knowledge of how values can be impacted by a change in the surrounding environment (Grover, 2002; Haughton *et al.*, 2004; Khatri, 2004) or to residents who can offer their value judgments (Jordal-Jorgensen, 1996; Haughton *et al.*, 2004). Both of these methods can suffer from inflated and unrealistic values (Kroll and Priestley, 1991), and therefore it would be inappropriate to use these values as a replacement for actual economic impacts, as is discussed below. In the absence of other data, and if the surveys are taken using random and unbiased methods, they can be illustrative of community attitudes and indicate areas for further study.

Jordal-Jorgenson (1997) conducts two types of surveys using contingent evaluation methods. Contingent evaluation methods attempt to establish in monetary terms "non-

[13] In the U.K., for example, residential transactional values are not public information.

market" environmental values by asking people how much they are willing to pay for an environmental amenity or to have an environmental nuisance removed.[14] Jordal-Jorgenson surveys 342 homeowners living "near" windmills in Denmark, inquiring if they find the turbines a nuisance and, if so, what they would be willing to pay to have them removed. 13% of the homeowners find them a nuisance and are willing to pay $140 per household per year on average to have them removed.[15] Additionally, Jordal-Jorgensen asks respondents what they would be willing to pay to not live near the windmills. The study finds that people are willing to pay between $2,314 and $13,429 dollars to not live "near" a single or a group of turbines respectively.[16] The term "near" is not defined. The study points out that because the result is an average, a wide variety of impacts could be found among the homes, with individual homes experiencing potentially large impacts. Additionally, the author admits that the small number of houses, 26 out of 342, available for analysis near the turbines did not provide a statistically significant result, and that therefore the results could be "due to coincidental factors" (p. 2).[17] This is a problem, as well, with a number of other studies outlined below. Without a reported level of confidence in the results, readers are recommended to use the findings anecdotally.

Similarly, Grover's (2002) survey results of 13 county tax assessors around Kittitas County, Oregon should also be used anecdotally because he both uses a very small sample size, and implies causality where only correlation has been found. Of the 13 county assessors that are interviewed, 6 state that their county's residential properties have views of

[14] Surveyors use various techniques to improve the predictive power of this method. For further reading on this subject, Bateman (2002) is a good resource.
[15] Converted from Dutch Kroners (DKK) using 1996 exchange rates.
[16] Converted from Dutch Kroners (DKK) using 1996 exchange rates.
[17] Refer to footnote 4, on page vii, for a brief discussion on statistical significance, and how results which are reported without measures of significance should be used anecdotally and not empirically.

turbines, and 5 out of 6 report no complaints from residents. The report declares, "There is no evidence indicating that views of wind turbines decreased property values." (p. 4). Technically this is true, but with only 6 assessors reporting it is not possible to have a great deal of confidence in the results. Additionally, the fact that residents did not complain (correlation) does not mean conclusively that property values are not affected (causation). It is possible other reasons intervened, such as either ignorance of residents that a reduction in assessed values could be requested, that the process would be futile, or perceptions that evidence warranting a decrease would be difficult to collect on their own.[18]

Although previous studies leave much room for criticism, the work by Haughton *et al.* (2004) is more solid because it largely uses accepted rigorous techniques of sampling and survey construction. Yet, predicting actual effects on property values based on these results would be risky because the results are descriptive,[19] not analytic, no significance values are reported, and survey responses might be influenced by other variables. Despite these limitations the results are illustrative of a community searching for solid answers to questions of property value impacts. As part of an economic analysis of the proposed offshore windfarm in Nantucket Sound, Haughton *et al.* (2004) conducts a survey of 546 real estate agents (*n*=45) and residents (*n*=501). It is the first large scale survey concerning wind energy in the U.S. since the late 1980s (Pasqualetti and Butler, 1987; Thayer and Freeman, 1987; Thayer and Hansen, 1988). The report concludes that there is an adverse expectation about the proposed windfarm on property values from both residents (21%) and realtors (49%). Homeowners believe that average values will decrease by 4.0% with losses

[18] Grover (2002, p.5) states that in Lincoln WI, the assessor asked a complaining resident to show that nearby properties had diminished in value. This most likely is outside the abilities of the average homeowner.
[19] Descriptive results describe the distribution of variables without regard for causal or other hypothesis. Analytic studies are designed to examine these associations. (Last, 1995)

of 10.9% expected for waterfront properties. Realtors expect losses to total 4.6% on average. To extrapolate from these results is risky though. In a comparison of survey and hedonic approaches Brookshire *et al.* (1982) caution that, "biases due to lack of experience must be considered" (p. 176). The responder's estimates for anticipated impacts might be higher than those actually experienced. For example, the results of a survey in Scotland of 1,810 adults living near 10 windfarms with 9 or more turbines (Braunholtz and MORI-Scotland, 2003, p. 10) found that:

> "Of those that lived in their homes prior to the construction, concerns about specific problems that might arise as a result of the windfarm do not seem to have materialized in many cases...Furthermore, while around half (54%) anticipated no problems over a range of issues associated with the windfarm development, as many as eight in ten (82%) say that there actually have been no problems."

This is corroborated by Warren (2005), in a study of residents surrounding windfarms in South-West Ireland who stated, "73% of residents across all [spatial] zones feel that their fears have not been realized" (p. 864). Finally, the predicted amount of value degradation as reported by Haughton *et al.* could be confounded by other variables, such as whether the respondent's home has a view of the sound, if they believe wind energy to be necessary, to what degree they believe it might contribute to positive environmental change, or if they had seen an actual windfarm. Yet Haughton does not report these interactions between these variables.

Despite these weaknesses, their results are important in other ways. They illuminate a belief that the brunt of the effects will be felt by residents on the water in full view of the sound. Haughton found that 69% of realtor respondents believed the effects of the windfarm would be felt to a greater extent on ocean front houses, with only 2% expecting the effects to be distributed evenly (29% no opinion). The reasoning for this follows the logic that the "vista" of the sound provide value to the houses (e.g. Rodriguez and Sirmans, 1994; Seiler *et al.*, 2001). Incorporated with the belief that the addition of windmills will decrease the beauty of that "vista," it follows that the values of these homes will be diminished. Further, it might be the case that *ceteris paribus*, home values more dependent on "vista" will experience an effect where others will not. There might be some threshold where an effect begins such as that found with HVTL in Des-Rosiers (2002) study where he found effects (positive and negative!) completely disappear outside of 500 feet from the transmission line. All told, it would be difficult to entirely dismiss the results of Haughton *et al.* as the musings of the inexperienced or the hysterias of those in fear. The proposed windfarm will consist of 130 turbines, and as mentioned above, people have a preference for smaller windfarms over larger ones (Wolsink, 1989; SEI, 2003). It seems likely that house values in that region will react in concert to some degree with resident dislike; the question will be in what amount.

The results of Khatri's (2004) survey, for reasons similar to Haughton (2004) are illustrative of perceptions rather than actual values. Khatri mailed 1,942 surveys to licensed surveyors in Great Britain (U.K.); 405 voluntarily responded, and roughly 80 were surveyors who had experience with residential transactions near windfarms. The report finds that a majority (60%) of surveyors reported that property values will be adversely affected, though closer inspection finds dilutions to the results in three ways. The experienced respondents were concentrated in Wales and Scotland, where 43% of U.K. wind projects are located,[20] yet the percentage of Welsh (45%) and Scottish (55%)

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[20] from www.bwea.org as cited by Khatri (2004)

respondents reporting decreased values is below the survey's national average (60%).[21] This implies that the national average is not appropriate to use as a final result. Secondly, because responses were voluntary, there might be a selection bias as the sample was unlikely to represent the population (Heckman, 1979).[22] Lastly the actual survey is not provided so it is difficult to assess the quality of the research, for example the nature of the questions.[23]

3.1.1 Conclusions drawn from survey studies

The survey studies do not give a clear indication as to whether there is an actual decrease in value. Even Haughton's (2002) study suffers from the likelihood that without actually experiencing what windmills look like in Nantucket Sound, respondents will overestimate the impacts. Haughton does elucidate, though, the possibility of thresholds of sensitivity for price devaluation. The results of these studies reinforce the need for more research and lead us into the next category of studies that are often used as a proxy for windfarm property value analysis: transaction-based studies of analogous HVTL structures.

3.2 Transaction based studies of analogous HVTL structures

With little to go on from existing research of wind energy and property values, interested parties have turned to property value studies of high voltage transmission lines (HVTL) in an attempt to make a benefits transfer from these structures to windfarms. It has been found that HVTL structures are perceived negatively and often adversely affect property values

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[21] A decrease in experienced effects is more recently corroborated by Warren (2005, p.853) "inverse NIMBYism"

[22] It is possible that only those that were bothered by the wind farms responded because they cared the most. If that is the case, than the results are skewed and in actuality less assessors feel there will be a decrease in property values.

[23] The report results "60% agreeing" imply that a leading question was used such as, "Do you agree the windfarms hurt property values?"

(e.g. Kroll and Priestley, 1991; Des-Rosiers, 2002). Because newer windmills are larger, and often more noticeable because of moving parts than HVTL, the temptation is there to assume turbines will have an equal or greater effect on property values (e.g. Zarem, 2005a).

3.2.1 Are HVTL structures and windmills viewed similarly?

Research conducted in 2003 in Ireland, based on a survey of 1,200 people indicated that windfarms were preferred over HVTL towers (as well as cellular towers and fossil fuel stations) (SEI, 2003). Why is this? Thayer and Hansen (1988) found that perceptions of windfarms were based on symbolic aspects in addition to aesthetic ones. Devine-Wright (2004) concurs, stating that symbolic aspects "could include the degree to which turbines are associated with wider environmental concerns such as climate change and feelings of personal responsibility to address such problems" (p. 129). This more complicated view of turbines is echoed in Warren (2005). When respondents living around windfarms were asked to rank the most positive and most negative aspects of the turbines, their presence in the landscape topped both categories (34% and 44% respectively). People either love them or loathe them.[24] It follows that if the U.S. effort in building windfarms is increasingly perceived as a reduction of risks, and therefore a solution to problems of energy scarcity and security, reaction to them will improve. Conversely, it is unlikely that HVTL would ever be perceived as offering a greater good. In fact, however unfounded,[25] electromagnetic radiation from HVTL is still a concern for individuals.[26] Because of these differences in

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[24] This turn of phrase has been used often to describe public sentiment (e.g. Bishop and Proctor, 1994; Ferns, 1998).
[25] Goeters (1997) reports that no study has provided scientific evidence of a relationship between cancer and HVTL proximity.
[26] Delaney (1992) reports that, "Even appraisers who had not appraised such property [near HVTL] believe that power lines contribute negatively to property values [for health reasons]." (p. 315)

perception between windmills and HVTL it would be imprudent to make a one for one comparison between the two.

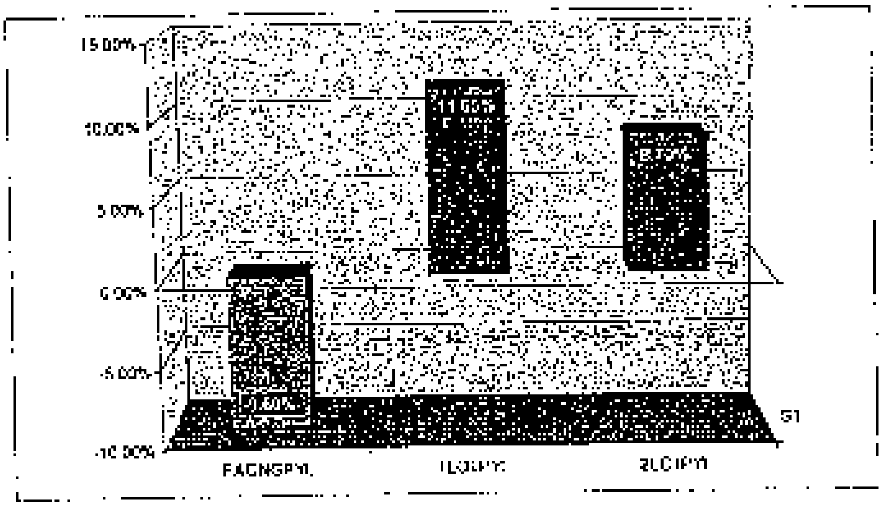
3.2.2 Are spatial property value effects of HVTL similar to windfarms?

Des-Rosiers (2002) found that effects from HVTL and their accompanying easements[27] disappeared outside of 500 ft. Additionally his results show a very sensitive interplay between proximity to the tower structure and proximity to the easement. Des-Rosiers (2002) found both an unambiguous negative effect due to towers and an unambiguous positive effect due to easement of HVTL on house values. In his review of the HVTL literature Des Rosier's (2002) finds that most studies conclude that, "Other physical as well as neighborhood attributes prevail [over proximity to HVTL] in the price determination process." (p. 277). This conclusion is also borne out in his findings that the negative effects of a view of a tower from a house immediately adjacent to it are overwhelmed by the positive effects of living near a HVTL easement just a few doors away (Figure 1).

If HVTL and windmills exhibit similar effects on values, can it be assumed that property value effects of windmills will entirely disappear outside of 500 ft? Perhaps they will disappear, but at what point; one tenth of one mile, a half of one mile, or some other distance? Additionally, what effect will some overriding positive attribute, such as "vista" of sunsets, a bucolic field, or a mountain range, have on the potentially adverse effects of a view of windmills in close proximity?

[27] In the case of HVTL easements are clearings through which transmission lines pass. They have benefits, for example, in that ensure a development free zone and can provide access to green space.

Figure II: Property Value Effects of HVTL and Distance



Source: (Des-Rosiers, 2002, p.293) Effects on houses adjacent to towers (FACNGPYL), are negative (-9.60%). Those on lots 1 or 2 away (1LOTPYL & 2LOTPYL) are positive (11.60% and 8.70 % respectively).

Lastly, it is interesting to consider Warren's (2005) theory "inverse-NIMBYism" that there is an increased appreciation for wind turbines as you move closer to them, and the findings of Braunholtz (2003) which show largely ambivalent and positive reactions of residents to nearby turbines. Braunholtz finds that of the people living within 5 km (3 miles) of turbines 45% had largely positive views (with 6% having negative views and 49% ambivalent/no opinion), which differed significantly from those residents living outside of 10 km (6 miles) of which 17% had positive views (with 6% negative and 77% ambivalent/no opinion). The logical extension of inverse-NIMBYism on property values would have values increasing as distance from turbines decreases! Despite this possibility the report assumes the conventional stance that windmills will either decrease values or not change them at all.

3.2.3 Are temporal property value effects of HVTL similar to windfarms?

Kroll (1991) finds that where newly installed HVTL have effects on property values, they tend to fade away entirely over four to ten years. This is similar to results of some studies conducted near wind energy facilities. Exeter-Enterprises-Ltd (1993) found via its longitudinal study of facilities in the U.K. that negative perceptions diminish over time. "The results show that any change of attitude…is toward thinking that wind power is better." (p. 53) On the other hand, Devine-Wright (2004) believes the opposite. His re-analysis of Krohn's (1999) results show that negative perceptions of development can increase over time. Is this because older turbines are often decommissioned yet are not removed? Thayer (1988) believes so, finding that community sentiment is correlated with the number of turbines in operation, and if turbines are standing idle, negative perceptions increase. Given these contradictory results, a generalization of the similarities of HVTL and windfarm's temporal effects is not appropriate.

3.2.4 Conclusions drawn from analogous HVTL studies

The comparisons of HVTL effects on property values and those of windmills seem unclear. HVTL structures are not viewed the same as windmills, and windmills can even take on positive connotations. Moreover the interplay between HVTL and property values is both tenuous and very sensitive to distance and other neighborhood characteristics. There are spatial and temporal thresholds for HVTL property value effects which also could exist for windmills. As with the survey study analysis above, a careful look at HVTL studies reinforce the need for more research. Possibly other structures, for instance offshore drilling platforms, could be used as a more appropriate proxy as will be discussed further in the recommendations section. The studies conducted using actual property transaction values surrounding wind facilities offer more empirical data, but are also inconclusive as to the effects of windfarms on these values.

3.3 Transaction based studies of windmills

To date only two studies have been conducted using actual transaction values of homes surrounding wind facilities. The results of these are varied. Sterzinger *et al.*, (2003) conclude that property values rise in the area of windfarms, and Poletti (2005) comes to the conclusion that no effect exists.

Sterzinger *et al.*, (2003) analyses roughly 24,000 transactions near 11 windfarms in the U.S., and compared average transaction values for houses in a control area outside the viewshed of the windfarm with transactions occurring within the viewshed (a 5-mile radius). The study comes to the conclusion that, "There is no support for the claim that wind development will harm property values." (p. 9), and even declares, "For the great majority of projects [windfarms] the property values rose more quickly in the viewshed than they did in the comparable community." (p. 2). Although this study is often quoted,[28] its methods have been criticized (e.g. ECW, 2004) for four reasons. First, the authors attempt to calculate a value for the variable "view of windmills," without properly controlling for it. There is no attempt to discern which properties within the ten different 5-mile viewsheds can see the windfarm or not. In effect, the study makes the erroneous assumption that all properties in the 5-mile radii can see the windfarm, when many houses' views in fact are obstructed by geological features, trees, and other houses (RBA, 1998a; Poletti, 2005).[29]

[28] A "Google" internet search using all of the following words, "REPP", "wind" and "property" generates 18,600 results. [tested 2-20-06]

[29] Sterzinger *et al* analyze the community surrounding the Madison County windfarm, which is the subject of this report. We found 66% of the homes sampled in the 5 mile radius could not see the windfarm at all.

Secondly, the analysis does not control for distance to the turbines, thereby making the assumption that the "viewshed" effect is the same, on average, for homes five miles from the windfarm and those in immediate proximity to the turbines. Third, there are problems with how the study validates its results. The report provides readers with only R^2 (or goodness-of-fit) values for its outcomes, and this is problematic, since, by itself, the R^2 statistic is a poor indicator of explanatory power (Halcoussis, 2005). Compounding this problem, the report gives R^2 values which are very low, for instance 0.02 for some models, which is saying in essence the model describes only 2% of the actual movement of property values. Despite this somewhat flagrant disregard for rigor it treats these models as it does models where the statistic is high, for example 0.85. This inconsistency is not addressed by the report. The last reason this research is often criticized is that no attempt is made to sort out inappropriate transactions. Sales that are not arms-length (divorce, sales between family members, estate sales etc.) are included. By doing so the report includes transactions that do not represent the agreement between a willing buyer and a willing seller, a requirement for accurate analysis. Combined, these four omissions in rigor render the results of the report extremely weak, if not entirely misleading.

The analysis by Poletti (2005) improves on that of Sterzinger *et al.* (2003) by culling out transactions that were not arms-length. As well, it excludes sales of homes built before 1960, in an effort to control for house-specific characteristics such as construction quality, amenities and condition. Poletti looks at roughly 300 sales that occurred in and around two windfarms in Wisconsin and Illinois. He comes to the conclusion that there is not sufficient evidence in the data to warrant rejection of the claim that windfarms have an effect on property values. Poletti compares average values of properties surrounding the windfarms, which he entitles "target area" with those in a "control area," which is outside the view of the windfarm. However, Poletti does not attempt to measure to what degree, if any, homes can see the windfarm. The author describes the area surrounding the windfarms as rolling with potentially obscuring features, so the implication is that some of the properties have no view of the windfarm. Further, no effort is made to control for distance. Although statistically sound techniques were used to compare the control area to the target area, by not properly controlling for view and distance, the study results are inconclusive at predicting the effects of the windfarm on property values.

3.3.1 Conclusions drawn from transaction studies

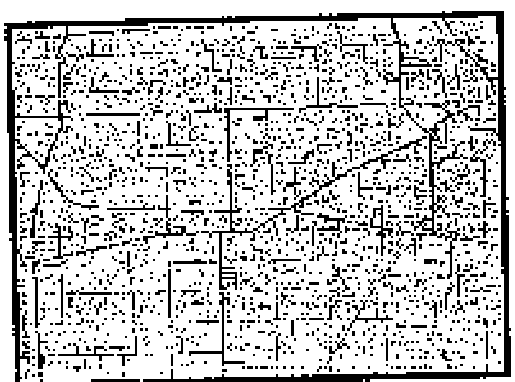
Taken together, the two studies using transaction values still leave open to conjecture the question as to the actual effects of windfarms on property values. By not appropriately sorting out misleading data, empirically establishing the degree to which houses could see the windfarm, and not factoring in distance, these studies most likely miss the potentially subtle interaction between view and value that has been found with other environmental stigmas (Des-Rosiers, 2002).

If results of studies of property values and windfarms can be confidently applied in windfarm siting decision making, the above analysis makes clear the importance of using large samples (>30), of measuring the actual visibility of and distance from turbines from each house, and of testing the results for significance. The following analysis attempts to do this. First there will be a brief discussion of the study area, then methodology, results, conclusions and recommendations.

4 Study Area

The Fenner windfarm was announced near the end of 2000; construction commenced in the spring of 2001 and was completed in the fall of 2001 (Moore, 2005). The 30 megawatt (MW) installation consists of 20 turbines, each 328 feet tall, with a rotor radius of 110 feet, making the top of the turbine blade's sweep roughly 440 feet above the ground. The windfarm sits atop 14 different parcels over 2,000 rolling acres. The Fenner Township receives $150,000 as a payment in lieu of taxes (PILOT) from the project owner which goes to increased road maintenance and schools (Cary, 2005). As is required under the New York State Environmental Quality Review Act (SEQRA) an Environmental Assessment Form (EAF) was prepared and submitted to the lead agency which was the Town of Fenner Board. It issued a Negative Declaration on the project based on the EAF, citing adverse impacts as insignificant. The public was given a number of opportunities to participate in the decision making process at town board and planning board meetings, which were characterized as both numerous and without much opposition (Moore, 2005). Larger maps of the study area are included in Appendix B.

Figure III: Fenner Turbines & Parcels



Source: Madison County Tax Office
(Large dots are windmills, rectangles are parcels, parallel lines are HVTL, and the dark lines are roads.

5 Methodology

The general purpose of this case study is to test if the view of the Fenner windfarm from homes inside of 5 miles from the windfarm has any significant effect on transaction values. "View" is defined using a continuous variable from 0 (no view) to 60 (a full view of all 20 turbines). The study additionally investigates how this effect varies with distance (spatially), time (temporally) and house value. Lastly, the effect and degree of the PILOT payment to Fenner Township is investigated.

The hedonic pricing model is well suited to dissect these issues revolving around windfarm acceptance. The rigor of the instrument in measuring the marginal contribution housing and neighborhood characteristics have on home transaction values is well supported in the literature for assessment purposes (Brookshire *et al.*, 1982; Malpezzi, 2002; Sirmans, G.S. *et al.*, 2005a; Sirmans, G. Stacy *et al.*, 2005b), in establishing effects of HVTL (Kroll and Priestley, 1991; Delaney and Timmons, 1992; Hamilton and Schwann, 1995; Des-Rosiers, 2002), in valuing the contribution "vista" has to value (Rodriguez and Sirmans, 1994; Benson *et al.*, 2000; Seiler *et al.*, 2001; Bond *et al.*, 2002), and in determining the effect of open space (Irwin, 2002) and environmental stigmas (Dale *et al.*, 1999). The model, given enough data, is sensitive enough to allow sales to be grouped temporally (e.g. by year), spatially (e.g. by distance from an amenity such as a body of water), and economically (by the value of the home). Once these divisions are made, variables of interest (e.g. the marginal contribution of fireplaces to homes values) from one group can be compared to other groups, both in terms of significance and the level of contribution.

5.1 The non-linear hedonic model

The non-linear hedonic pricing model in its present form is often attributed to Sherwin Rosen (1974) for his contribution to its utility in deciphering housing prices. A number of reviews (Malpezzi, 2002; Sirmans, G. Stacy *et al.*, 2005b) validate his construction in its ability to rigorously predict changes in residential transaction values based upon characteristics of the homes.

The model takes the form:

Log (Sale_Price) = *f* (Physical Characteristics, Other Factors).

"Physical Characteristics" often used include square footage of the home, lot size, number of bathrooms, number of bedrooms, type of construction, etc. "Other Factors" often include proximity to amenities, school district, local tax rates, and in this case study, "view" of and distance from turbines.

5.2 Variable selection

Although inclusion of the most commonly significant variables as taken from the literature (e.g. Sirmans, G. Stacy *et al.*, 2005b) is important and necessary, often local conditions can direct the proper construction of the model more than convention. Local assessors, realtors, and residents often have considerable insight into how prices are affected by changes in characteristics and other factors. Therefore in constructing the model used for this report Sirman's (2005b) recommendations for variables were included as well as those cited by a survey of two local assessors and two real estate agents. The results of the two inquiries are listed in Table I and Table II.

Sirman's list included all of the variables on the local expert list except School District, the distinction between distance to I90 and distance to State Route 20, local tax rates and building styles. All of the available variables from both the Sirman list and the local expert list were included.

Table I: Sixteen Most Significant Hedonic Variables in Housing Studies

Variable	Appearances	# Times Positive	# Times Negative	% Time Significant
Square Feet (SFLA)	69	62	4	96%
Central Air	37	34	1	95%
Age at Time of Sale	78	7	63	90%
Pool	31	27	0	87%
Acres	52	45	0	87%
# of Full Baths	37	31	1	86%
# of Stories	13	4	7	85%
Deck	12	10	0	83%
# of Fireplaces	57	43	3	81%
# of Garage Spaces	61	48	0	79%
# Rooms	14	10	1	79%
Basement Type	21	15	1	76%
# of Bedrooms	40	21	9	75%
Brick or Stone Extr.	13	9	0	69%
Distance	15	5	5	67%
Time On Market	18	1	8	50%

Source: (Sirmans, G. Stacy et al., 2005b)

3.3 Data collection

The data concerning transaction values and assessor information is collected from Madison County Real Property Tax Office. From January 1, 1996 through June 1, 2005, 452 sales took place that were coded "arms-length" transactions by county assessors, and were within 5 miles of the windfarm. Of these, 152 were removed as land-only sales[19], and upon closer inspection 20 sales (15 land-only and 5 non arms-length) were found to have been coded incorrectly and were removed. For the remaining 280 sales, assessor records from the

[19] "Land Only" sales refer to sales of parcels that did not contain a house at the time of sale.

closest preceding inspection were collected providing information about structural characteristics and location.

Although most of the recommended variables were included in the Madison County records, there were many gaps in the records for the following variables which made them unusable: Pool, deck, number of stories, number of rooms, and garage spaces.[31] Data for time on the market was not available, and therefore was not included.[32]

Table II: Twelve Most Influential Characteristics Recommended by Local Experts

Variable	Percent of the 4 Local Experts Recommending this Variable
# of Full Baths	100%
# of Bedrooms	100%
Overall Condition	100%
Basement Type	75%
# of Fireplace	75%
Acres	75%
Square Feet (SFLA)	75%
Age at Time of Sale	75%
Building Style	50%
Distance to I90	50%
School District & Taxes	50%
Distance to State Route 20	50%

Source: Joel Arsenault, Century 21 Real Estate; Jenny Chapin, Don Kinsley Real Estate; Priscilla Suits, Assessor Fenner & Nelson Townships, Madison County; Tanya Pifer, Assessor Lincoln Township, Madison County

Sale price was adjusted to 1995 dollars by using the Department of Labor's CPI for Rural New York (SALE_PRICE_95) and then converted to its natural log

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31 During field analysis decks and pools were rarely present, and the number of rooms and stories was expected to be highly correlated with the square feet, so their exclusion was not expected to compromise the results. The County is conducting a reassessment of every house in its records, which should be completed in 2006, which is expected to fill in the gaps of these characteristics.

32 Although time on the market generally has the effect of lowering the price it has in some cases produced higher prices. It is assumed that this is because buyers can wait for the price that they want, or that the market slowly appreciates up to their asking price (Sirmans, G. Stacy *et al.*, 2005b).

(LNSALE_PRICE_95).[33] The thoroughness of this adjustment was tested by including a continuous variable (DEED_YEAR) to account for a potential linear escalation in market price which exceeded the CPI inflation rate. Four binary variables (WINTER_SALE, SPRING_SALE, SUMMER_SALE, and FALL_SALE) were included in the model to account for seasonality in the housing market. Descriptive statistics for all non-viewshed variables are given in Appendix A: Tables IX and X.

A geographic information system (GIS) was used to calculate distance from the houses to the nearest turbine (DIS_TO_MILLS). Elevation and spatial location layers were populated using the 10 meter digital elevation model (DEM) provided by the United States Geological Survey (USGS), ortho-imagery was provided by New York's Department of Environmental Conservation (NYDEC), and roads, windmill locations and parcels were provided by the Madison County Planning Department. Parcel shapefiles did not contain actual house location, so a housepoint file was constructed using the ortho images overlaid with the parcel map, for each parcel that sold during the study period.

All layers were projected using the NAD 1983 Coordinate System and the New York State Plane Central projection. Where possible, shapefiles were corroborated with ortho-images, as was the case with the windmills, to ensure locational accuracy. Distances to major roadways (Route 20: DIS_TO_RT20 and U.S. Route 90: DIS_TO_I90) were calculated using linear distance. Although this is not a measurement of actual driving time

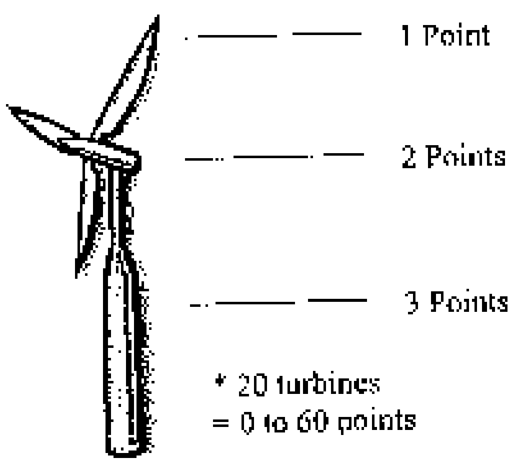
[33] To account for the "bubble" in the housing market binary variables for all years were tested but were found to be insignificant, so the CPI 1995 adjusted prices were used without these variables.

to these arteries, field experience indicated that the high density of roads in this area allowed residents a fairly direct route to the arteries at roughly the same speed.[34]

5.4 Construction of viewshed variables

To populate the variables for windfarm viewshed (VIEW) two methods were developed: a GIS simulated method and one involving field visits, and one method was ultimately used: the field visit method. The GIS method, as discussed in Appendix C, achieved an accuracy rate of 85% which improved on previous studies (Dean, 1997; Maloy and Dean, 2001) but did not meet accuracy requirements for this report's analysis of greater than 95%. Therefore the second method involving field analysis was used to ensure complete accuracy of the "view" variables. Visits were made to each of the 280 homes which sold after Jan 1, 2001 and were within 5 miles of the windfarm (138 homes visited) to assess the degree to which the home could see the windfarm. By standing at or near the house a rating of 1 to 60 was established for each home. This rating was based on the degree to which viewers could see each of the 20 windmills in the Fenner windfarm (Figure III).

Figure IV: Turbine Visibility Scoring Method



[34] A more accurate measurement would be a shortest elapsed time traveled incorporating speed limits of roads, and distance traveled on them. This is similar to the algorithms used by, for instance, Mapquest.

If the viewer could see only the top 1/3 of the turbine blades one point was given for that turbine, visibility of the nacelle (or hub) was a second point and visibility below the sweep of the turbine blades a third. Therefore a total of 3 points per turbine were possible, with a total of 60 points for the 20 turbines. No distinction was made for the direction the house faced because it was assumed purchasers were likely to walk around the house and inspect all views. If the turbines were clearly in view from the property surrounding the house, and the purchasers had a strong reaction to their visibility, it was assumed they were not likely to make a distinction between front, back and side windows at the time of purchase. Inspections were done on October 30 and 31, 2005 when deciduous trees had partially dropped their leaves. A slight distinction between winter (leaves off) or summer (leaves on) sale dates could be made from some properties; therefore visibility was calculated using the appropriate condition. Finally photographs of the house and of the predominant view were taken to corroborate results at a later time if needed.

Table III: Description of Viewshed Variables

DIS_TO_MILLS	The distance from the home to the nearest turbine as calculated by the GIS
VIEW	The view of the turbines as recorded from the field analysis with possible range from 0 to 60. If house sold before Jan 1, 2001 the value is 0.
VIEW1MILE	The VIEW of the home if 0>DIS_TO_MILLS<=1, otherwise 0
VIEW2MILE	The VIEW of the home if 1>DIS_TO_MILLS<=2, otherwise 0
VIEW3MILE	The VIEW of the home if 2>DIS_TO_MILLS<=3, otherwise 0
VIEW4MILE	The VIEW of the home if 3>DIS_TO_MILLS<=4, otherwise 0
VIEW5MILE	The VIEW of the home if 4>DIS_TO_MILLS<=5, otherwise 0
VIEW2001	The VIEW of the home if the year of sale was 2001, otherwise 0
VIEW2002	The VIEW of the home if the year of sale was 2002, otherwise 0
VIEW2003	The VIEW of the home if the year of sale was 2003, otherwise 0
VIEW2004	The VIEW of the home if the year of sale was 2004, otherwise 0
VIEW2005	The VIEW of the home if the year of sale was 2005, otherwise 0

5.5 *Discussion of Descriptive Statistics*

Of the 280 properties in the sample, the mean value of homes was $102,384, the mean number of acres was 8.8 and the mean age of the home at the time of sale was 42 years old. Approximately 28% of all the houses in the sample could see the windfarm; of the 149 sales that took place after January 1, 2001, 43 were from homes which could see the windfarm. A full description of all the variables is included in Appendix A.

5.6 *Testing for violations of OLS assumptions*

After the model had been constructed the data were tested in accordance with the ordinary least squares (OLS) assumptions which govern hedonic regression models. These assumptions include: multicollinearity, the independence of the error term and the independent variables, homoskedasticity and temporal autocorrelation.[35]

5.6.1 Multicollinearity

The assumption of multicollinearity posits that the independent variables are in fact independent and not highly correlated with each other. If one variable is highly dependent on one or a combination of variables, the *p*-values will be inappropriately increased. This assumption can be tested for by regressing each independent variable on the others and then looking at the unadjusted R^2 values. Convention holds that R^2 values less than 0.75 indicate a multicollinearity low enough to allow results to be largely undisturbed (Halcoussis,

[35] A fifth assumption which is commonly considered in OLS models, but rarely in hedonic literature is simultaneity, when the dependent variable affects the independent variables. This was not directly tested for, but its effect on coefficient significance is to increase it. In the case of this report, this does not alter our results.

2005).[36] In our case all R^2 values were under this threshold, and most (80%) were considerably under it (in the .5 to .2 range).

During initial analysis of the variables, a correlation matrix was generated. It was found that the number of bedrooms (NBR_BEDROOMS) was highly correlated (0.746) with square feet (SFLA), but the number of bathrooms (NBR_BATHROOMS) (0.474) and the number of half baths (NBR_HALF_BATHS) (0.361) were acceptably correlated with square feet and each other (0.044), so bedrooms was dropped from the model and half baths was added. Additionally it was found that distance to I90 (DIS_TO_I90) was highly negatively correlated to distance to Route 20 (DIS_TO_RT20) (-0.977) because they run roughly parallel to each other. Therefore, I90 was dropped from the model.

5.6.2 Independence of Error Term and Independent Variables

Independence of the error term and the independent variables is important in assuring that the variables are the best predictor of the dependent variable. To test this assumption, the residuals were regressed on the independent variables. None of the independent variables were significant (*p*-value range from 0.138 – 0.913) and the model itself is non- significant (*f*-value 0.258, *p*-value 0.999, adjusted R^2 -0.059).

5.6.3 Homoskedasticity

Homoskedasticity of the variables assumes that the error terms of any range of values of a continuous variable are similar. The values of the variables are ordered in ascending or descending order and divided into thirds. The Levine test statistic compares the variances

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[36] Actually the measure used is the Variance Inflection Factor (VIF) which is calculated as follows: $1/(1 - R^2)$. A VIF of 4 or below is appropriate to reject the claim of a high degree of Multicollinearity. An R^2 more than 0.75 will result in a VIF more than 4.

of the thirds. If that statistic falls outside the acceptable range (p-value > 0.05) the assumption holds. In our case all continuous variables returned values exceeding 0.05 therefore the OLS assumption of homoskedasticity was met.

5.6.4 Temporal Autocorrelation

The existence of temporal autocorrelation violates the OLS requirement that the residuals are independent of each other. If temporal autocorrelation exists, the values of the dependent variable, and therefore their residuals, are affected by the value in the previous temporal term. By arraying the residuals in chronological order and testing the correlation of any residual against its preceding residual their autocorrelation can be determined. The Durbin Watson test statistic ranges from 0 to 4. Within a range of 1.5 to 2.5 there is considered to be no autocorrelation. A statistic either more or less than that range is considered to have either a positive or a negative autocorrelation respectively. All of the models had a Durbin Watson test statistic between 1.798 and 2.047, therefore no autocorrelation was detected.[37]

[37] Spatial autocorrelation was not tested for, yet it is possible that it would exist within the data, following the logic that a neighbor's transaction value affects the surrounding transactional values both on the sellers and buyers side of the transaction.

6 Analysis

Results of the six models that were run are reported in Appendix F. Initially, the model was run with all potentially significant variables (Model #1), as recommended by the literature (Table I) and the local experts (Table II). Many building styles and school districts did not meet initial significance criteria (p-value < 0.75). As well, the variable for air conditioning (CENTRAL_AIR) was found to be insignificant. These variables were removed. As expected these changes improved the model's overall significance (Model #2). Model #3 is further refined with all non-significant (p-value > 0.1) variables removed except those for seasonality (e.g. FALL_SALE). This model (Model #3) had an F-value (63.764) considerably higher than that of Model #2 (39.185) indicating the removed variables created undue "noise" in the model. All variables had the expected sign except for the Fenner Township binary variable, which is discussed below. Model #3 was then used to test the significance of the viewshed variables.

Initially the variables for distance to the windmills (DIS_TO_MILLS) and view of the windmills (VIEW) were added to the model (Model #4). The coefficients for these variables were both positive yet non-significant at both the 95% or 90% levels of confidence (0.679 and 0.410 respectively). Models #5 and #6 explore the potential micro-spatial and temporal effects of view in 1 miles bands (VIEW1MILE thru VIEW5MILE) and subsequent years (VIEW2001 thru VIEW2005) respectively. Although both models are significant in general, all 10 variables did not meet the significance criteria (p-value < 0.10), therefore interpretation of the coefficient value or sign is not appropriate.

As mentioned above the sign (coeff. -0.083) and significance (p-value 0.018) of the binary variable for the Fenner Township (FENNER) is surprising. This variable measures the marginal change in value for homes in Fenner Township as compared to all other townships. We included this variable to explore if the payment the township receives in lieu of taxes from windfarm operations (PILOT) has had an effect on the values of homes in the township all else being equal. The assumption is that if the payments, which largely go to the school system in the township, are considered to have significantly improved conditions in the township in the eyes of home purchasers, this variable would be both positive and significant. But, in our model the coefficient was negative and quite large (the coefficient -0.083 corresponds roughly to a decrease of 8%). Therefore, to further explore we added binary variables for all townships including Fenner (Smithfield was the omitted township). The results of this test indicated that none of the townships had a significant influence on price when taken together. This indicated that the influence of Fenner was being spread among the townships. Therefore, finally we omitted the Fenner variable and included all of the other township variables and found both Cazenovia (coeff. 0.106, *p*-value 0.095) and Nelson (coeff. 0.105, *p*-value 0.081) were significant and positive. Results for these variables are in Table IV. The positive sign implies that in relation to Fenner *ceteris paribus* the placement of the house in Cazenovia and Nelson adds value. We explored whether this had to do with the wind energy facility by adding view variables to the model. Because distance to turbines can be largely explained by the township variables[38] we only included the variable VIEW [of turbines]. We found that neither the magnitude nor the significance for the township variables changed when we took view into account. This implies that the decreased value of homes in Fenner is not related to the wind facility. To investigate the effects of township further we contacted a local realtor (Arsenault, 2006).

[38] Regressing distance on the township variables produced adj. R^2 of 0.579 and a *p*-value of 0.000.

He believed there was a correlation between the township (Fenner) and the value of homes, in that homes of higher values were not being built in the Township. He attributed this to the windmills, and believed that there was a correlation between values of home and the

Table IV: Testing for the Influence of Township on Home Value

	Coeff.	p-vlu	Coeff.	p-vlu	Coeff.	p-vlu	Coeff.	p-vlu	Coeff.	p-vlu
CAZENOVIA	0.077	0.201	0.106	0.095	0.117	0.141	0.113	0.077	0.118	0.076
LINCOLN	0.009	0.880	0.056	0.505	0.073	0.404	0.072	0.405	0.067	0.456
NELSON	0.095	0.153	0.105	0.031	0.109	0.147	0.105	0.079	0.109	0.071
SULLIVAN	0.038	0.564	0.079	0.290	0.100	0.244	0.097	0.215	0.092	0.250
SMITHFIELD			0.029	0.628	0.036	0.567	0.033	0.566	0.032	0.616
FENNER	-0.023	0.689								
DIS_TO_MILLS					-0.002	0.930				
VIEW					0.001	0.428	0.001	0.441		
VIEW1MILE									0.001	0.716
VIEW2MILE									0.000	0.913
VIEW3MILE									0.006	0.113
VIEW4MILE									0.002	0.676
VIEW5MILE									-0.002	0.711
Model R^2		0.791		0.806		0.790		0.790		0.789
F/Significance	53.921	0.000	51.184	0.000	46.524	0.000	48.827	0.000	41.132	0.000

Note: Non viewshed variables were included in the model but were not shown above. Coefficients roughly correspond to percentages (e.g. 0.100 = 10% increase), and p values correspond to the likelihood that this result was reached by chance (e.g. 0.100 = 10%).

affect "view of the turbines" had on them. He said, "Higher priced homes were not being built in the Fenner area because of the view of the turbines." To analyze this claim we broke sample set of home sales into thirds and investigated whether the variable for view was affected. In so doing we tested the claim that homeowners of higher priced homes care more about the view than those of lower value. Table V contains the results. We found that view did not have a significant effect at any price range. We also found that although splitting the groups did not affect the significance of the overall model, it did dramatically decrease the R^2 statistic as compared to previous models (roughly 0.80 to 0.23). A portion of this decrease can be explained by the decrease in the number of cases in each group (*n*),

Table V: Testing for Significance of View among 3 Price Levels

Price Level	Lower 3rd		Middle 3rd		Upper 3rd	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
DIS_TO_MILLS	-0.009	0.773	0.023	0.132	-0.022	0.285
VIEW	0.003	0.313	0.002	0.341	0.000	0.918
n/Adjusted R^2	92	0.472	93	0.226	92	0.627
F/Significance	6.13	0.000	2.507	0.003	9.605	0.000

Note: All non-viewshed variables were included in the model but are not shown above. Coefficients roughly correspond to percentages (e.g. 0.100 = 10% increase), and p-values correspond to the likelihood that this result was reached by chance (e.g. 0.100 = 10%)

but not all. It could reflect the variance between the income levels, and indicates a need for further research into how each income level makes home buying decisions, based on the non-viewshed variables that were included in the model (i.e. number of bathrooms, square feet, and number of acres).

7 Conclusions

Our analysis of 280 home sales within 5 miles of the Fenner windfarm, in Madison County, New York failed to uncover any statistically significant relationship between either proximity to or visibility of the windfarm and the sale price of homes. Additionally, the analysis in this report failed to uncover a relationship even when concentrating on homes within a mile or that sold immediately following the announcement and construction of the windfarm. Therefore it is safe to conclude, in this community, a view of the windfarm does not produce either a universal or localized effect, adverse or not. To the degree that other communities emulate the Fenner rural farming community, these results should be transferable. But, to be safe in these conclusions, let us first consider the possibility that: 1) effects exists, but the instruments which were used in this study were not effective in measuring them, and 2) effects exists but because those effects are situated outside the sample area our analysis did not discover them.

First we investigate the possibility: whether the instruments were not effective in measuring an effect. The instruments in question are 1) the hedonic pricing model and 2) the methods used to calculate turbine visibility. The hedonic model is appropriate as it has been well tested in various applications including, but not limited to, assessments, in valuing nearby open spaces and in valuing the effects of HVTL and environmental stigmas. It is particularly effective at discerning universal influences, and the question of effects on property values is not whether one or two houses are affected but rather if groups of houses are affected in a predictable universal way. The construction of the model, used in this report, follows the convention described as "test, test, test" (Kennedy, 2003), which refers to a model construction method that, "discovers which models of the economy are tenable, and to test rival views." (p. 83) By carefully testing the assumptions behind the model, as were described in section 5.8, the model that was ultimately chosen can be considered to be, "the best estimated regression line" (Halcoussis, 2005).

In regards to the tests of "visibility" from each of the homes, the method chosen was intended to reduce bias and allow for a robust set of measurements (0 to 60). View was measured not in a subjective way, but rather by counting the numbers of points seen from the house. The distance was measured by linear calculations produced by a GIS. Because the range of the two measurements is relatively large, a small miscalculation of "view" (0-60 scale) or distance (0.00 to 5.99 miles) will not adversely affect the ability of the model to explain variations in sale price. It is therefore safe to say that the instruments this report used are both appropriate.

The second possibility of error concerns whether effects exist outside the sample area and therefore were not measured by our analysis. In other words, is it possible that a house inside of 0.76 miles, outside of 5 miles or that will sell after June 2005 will be affected differently than what our sample describes? The possibility should be investigated in other studies, but in the case of Fenner it is unlikely unless the situation on the ground changes.[39] Our sample set includes *all* arms-length transactions of single family homes which occurred from January, 1996 to June, 2005 within 5 miles of (and as close to 0.76 miles from) the windfarm. If one is to attempt to address the question of whether effects exist, a sample set containing all transactions cannot be improved upon.[40] If houses were

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[39] For example, if the turbines are taken out of operation yet are not decommissioned or removed. Thayer (1987) found a strong negative reaction to just such a situation in California in the 1980s.

[40] The sample data is normally distributed as would be expected of 280 transactions. See Appendix F.

measurably affected outside the sample set, it seems unlikely that concurrently no effect, weak or strong, would be found inside the sample set.

If the potential inadequacy of the instruments has largely been ruled out, and we are confident that the study area represents an adequate sample we can conclude no effect exists for this community, or, if they do, the effects are random and therefore, by definition, unpredictable. The result of "no effect" has been corroborated by peer-reviewed large sample survey studies. Warren (2005) found, on average, windfarms were of little concern to residents stating, "The data reveal a clear pattern of public attitudes becoming significantly more positive following personal experience of operational windfarms" (p. 866). Further, Braunholtz (2003) finds,

> "It is extremely rare for people to spontaneously mention their local windfarm as either a positive [<3.0% of sample] or negative [0.3% of sample] aspect of their area. This fact that suggests that, for most at least, [the windfarm] is not foremost in their minds when thinking of, and describing, the area" (p. 5).

A rural setting with a history of farming, these townships might accept harvesting wind energy as an extension of the use of their land. The wind farm does not seem to have been in contest with the sense of place that is mentioned in Devine-Wright's (2004) discussion. Possibly the non-linear layout is desirable. It is rather undulating as is the landscape itself. There are many opportunities for hide and reveal[41] in this landscape, which might allow viewers to keep an emotional distance from the turbines if they are in opposition to them, or to look at them more affectionately if they are in favor of them.

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[41] "Hide and reveal" or "miegakure" (jap.) is a phrase used in landscaping where even in small spaces portions screening of features (the "hide") encourages viewers to see what lies just around that bend (the "reveal").

Thayer (1987) found that public sentiment was strongly tied to the bureaucracy behind the decision to erect the windfarm (local officials, developer). This is echoed by Wolsink (1989) and Krohn (1999), who states "decision making over the heads of local people is the direct route to protest" (p.959). In the case of Fenner the developer was required to prepare and submit for public review an EAF. And the Town of Fenner was the lead agency overseeing the approval of permits. Therefore, to the degree that the EAF process effectively addressed and corrected negative concerns, the community might not have retained much negative sentiment toward the project going into construction. Possibly the research of Devine-Wright (2004) offers an explanation. He states, "the opinions of significant others such as friends and family living in the local area are important in determining public perceptions of wind farms" (p.130). In Fenner, one civically involved couple who leased their land to the developer is not only a proponent of wind energy, but also talks with great pride of the Fenner Township and surrounding area. They host tours and offer t-shirts and hats for wind farm visitors. They might have influenced the community positively. In fact an imminent windfarm expansion in Fenner from 20 to 29 turbines has been met with no opposition. This matches with Warren's (2005) results. He samples residents both with and without experience living near windfarms and found those with experience are much more likely to favor expansion of them.

To the degree that other similar communities exist in the US, in that they have similar land uses, median home prices, and homeowner profiles, these results should be transferable. Extrapolation of these results to communities which do not fit this description, without careful consideration, is not recommended until more research is conducted. Specific recommendations for further research are outlined below.

8 Policy Implications and Recommendations

Contrary to the notion that adverse effects are universal, this report did not produce any significant relationship between distance from, or visibility of the windfarm and the sale prices of homes. These results fit with those reported in other empirical studies that surveyed public attitudes, which found that people living near turbines find them "acceptable" and, in fact, rarely spontaneously mention them (Braunholtz and MORI-Scotland, 2003). Together these studies suggest that in communities similar to the one surrounding the Fenner windfarm, the question of property value effects should be lessened in importance in the decision making process. Further, if these results are substantiated in further research as discussed below, the implications for stakeholders are significant.

Specific recommendations for many of the stakeholders in the windfarm planning process are as follows:

- Town Officials/Planners: Town planners should realize that the methods for facility approval can greatly contribute to placating community concerns. A transparent process which allows residents to address siting concerns such as the size of the project, the placement of the turbines as it relates to dwellings, and the provisions for dealing with maintenance and decommissioning are very important. If steps such as these are followed, local decision makers should be able to enjoy favorable community sentiment and avoid property devaluation.
- Community Members: This research should provide some confidence to community members that a windfarm siting does not guarantee a devaluation of property values, and that assertions to that effect should be thoroughly investigated. In fact, if more studies corroborate these findings devaluation might be considered unlikely. If residents

believe their community is similar to Fenner's, factors other than property devaluation should be concentrated on. These could include the level of payments in lieu of taxes (PILOT), the quality of decommissioning assurances and the level of transparency in the planning process. Based on the findings of this study these factors could play a more important role than potential property devaluation in a community's proposed windfarm evaluation process. Additionally, urging local, state and federal policy makers to promote continuing research into public attitudes surrounding other wind energy facilities will allow for greater understanding of upcoming development proposals, and a larger area of transferability of results.

- State lawmakers: This report's findings of "no effect" might indicate that the planning process used for the Fenner windfarm should be used as a model. Currently some state laws allow the review process to be entirely avoided (GAO, 2005), yet an environmental review and subsequent community involvement can help ensure that appropriate decisions are made and development is accepted by the community going forward. State regulations should require all wind developments to participate in the EIS process, to ensure that the planning process is transparent, and that community involvement is encouraged. Additionally, through an intense effort to research and disseminate findings, such as reactions of other communities to wind development in the U.S., lawmakers can give local officials the tools needed to weigh real costs and benefits. In so doing, decision makers can avoid having to rely on insufficient information and speculation.
- Wind industry representatives: Although these findings seem to show that property devaluation did not occur in the community surrounding the Fenner windfarm, it should

be clear that property value effects are strongly tied to public attitudes, a cooperative planning process, and might be influenced by characteristics not present in the Fenner community. These are discussed below and include the number of second homes, the proximity to the wind turbines, and the percentage of "vista" included in the home value. Accordingly, encouraging further empirical research of public attitudes and property transaction values surrounding wind developments might provide decision makers with the information needed to make appropriate decisions regarding development proposals going forward.

8.1 Future research considerations

For communities, especially ones that are not similar to Fenner, there is an intense need for more research. With this, policy makers and other stakeholders will have better answers to this contentious issue. More information is needed regarding the following categories:

- Other windfarm communities: Roughly 90 sites in the U.S. are larger than the Fenner site (AWEA, 2005d), and many of them would be appropriate for study. Sites should be chosen with a variety of socio-economic characteristics, windfarm sizes, and population densities. Studies should analyze homes closer than 4000 feet, and include variables for "vista,"[42] level of community cooperation in approval process, degree that farming matches sense of place (such as the percentage of large tract vs. small), and whether homes are the primary or secondary residences.
    - Distance: This study contains homes only as close as 0.75 miles or 4000 feet to the turbines. HVTL studies have found effects exist only inside 500 feet

[42] As discussed in footnote 8 on page 2

(Des-Rosiers, 2002). Future studies should find communities with homes closer than 0.75 miles, and preferably as close as 500 feet if they exist.[43]

- Vista: This study does not include a separate measurement for "vista" (or good view) in its analysis. For example, Haughton (2004) finds that homes with a high percentage of "vista" represented in their value (such as might be found in homes on the coast) might be affected differently by wind development.
- Cooperative Process: The community studied in this report was at least partially involved in the planning process, in so far as they were invited to attend and submit comments at a number of meetings (Moore, 2005). The degree to which the project developer includes the community in the planning process of other communities might influence results (Warren *et al.*, 2005) and should be studied.
- Sense of Place: Anecdotal evidence implies that this community still largely embraces the farming nature of its past. How well wind energy "harvesting" fits with other community's sense of appropriate land use might also alter outcomes (Devine-Wright, 2004). Using an average tract size for a sample might be a proxy for this variable.
- Size of Project: The Fenner windfarm is 20 turbines. Because there is evidence that community's prefer smaller windfarms over larger ones

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[43] Homes within 500 feet of the turbines, in this study area, were situated on the same parcels that had turbines, and therefore the homeowners received income from the windfarm owners. This coincidence could present complications in analysis of sale prices. Additionally, none were sold during the study period.

(Wolsink, 1989; SEI, 2003) studies conducted using homes surrounding facilities larger than 20 might reach different results.

- Primary Residence: This study does not include a separate variable describing if homes are primary residences or not. It is possible that homeowners of non-primary residences might be more sensitive to changes in their viewshed. Future studies should include this variable.

- Other potentially analogous structures: Although the research from HVTL is helpful in establishing potential effects of windfarms on property values, research concerning other infrastructures might be more applicable. For instance, investigating transaction value effects on coastal homes having views of offshore drilling platforms could shed light on the property value effects when a high "vista" value is present.

- Comparisons of hedonic and survey results: Because survey results are often used as a proxy for actual effects, studies to determine the appropriateness of these methods as it applies to windfarms would be very fruitful for policy makers. If combined hedonic and survey studies were conducted in communities with existing windfarms, which started before announcement and continued well after construction, policy makers and stakeholders could determine the applicability of using surveys to determine present and future property value effects.

- GIS visibility determinations: By continuing research into this area, and using the most up to date data, such as that being newly collected by light detecting and ranging (LIDAR) radar techniques, policy makers and stakeholders may find a very inexpensive method for determining visibility and therefore conducting analysis on communities.

By conducting and disseminating further research, policy makers and other stakeholders can more fully understand the subtle interaction between a view of windfarms and property values. As a result, they will have more appropriate tools to make well informed decisions regarding wind energy siting proposals. For now, it is safe to say property value effects are not guaranteed, and in fact, in the case of Fenner, do not seem to exist at all.

Appendix A: Definitions and Descriptions of Variables

Table VI: Definitions of Non-Viewshed Variables

ACRES	The number of acres in parcel
AGE_AT_SALE	The age of home at time of sale. Calculated by subtracting year built from Deed_Year.
BLDSTYL-AFRM	Building style binary variable equal to 1 for A Frame houses and 0 otherwise
BLDSTYL-CAPE	Building style binary variable equal to 1 for Cape houses and 0 otherwise
BLDSTYL-CNTMP	Building style binary variable equal to 1 for Contemporary houses and 0 otherwise
BLDSTYL-COLNL	Building style binary variable equal to 1 for Colonial houses and 0 otherwise
BLDSTYL-CTTG	Building style binary variable equal to 1 for Cottage houses and 0 otherwise
BLDSTYL-LOG	Building style binary variable equal to 1 for Log Cabin houses and 0 otherwise
BLDSTYL-OLDSTYL	Building style binary variable equal to 1 for Old Style houses and 0 otherwise
BLDSTYL-RANCH	Building style binary variable equal to 1 for Ranch houses and 0 otherwise
BLDSTYL-RSRNCH	Building style binary variable equal to 1 for Raised Ranch houses and 0 otherwise
BLDSTYL-SPLIT	Building style binary variable equal to 1 for Split Level houses and 0 otherwise
CAZENOVIA	Binary variable equal to 1 if township is Fenner, otherwise 0.
CENTRAL_AIR	House has central air conditioning
DIS_TO_I90	Distance from home to Interstate I 90 in miles
DIS_TO_RT_20	Distance from home to State Route 20 in miles
DIS_TO_TOWN	Distance from home to nearest town center in miles
DEED_YEAR	Year of sale as recorded on the deed.
DEED_YEAR_SQRD	Year of sale as recorded on the deed - Squared
FALL_SALE	Binary variable equal to 1 for transactions in quarter 4 and 0 otherwise
FENNER	Binary variable equal to 1 if township is Fenner, otherwise 0.
LINCOLN	Binary variable equal to 1 if township is Lincoln, otherwise 0.
LNSALE_PRICE_95	Natural Log of Sale Price in 1995 dollars
NBR_BEDROOMS	Number of bedrooms house contains
NBR_FIREPLACES	Number of fireplaces house contains
NBR_FULL_BATHS	Number of full bathrooms house contains
NBR_HALF_BATHS	Number of half bathrooms house contains
NELSON	Binary variable equal to 1 if township is Nelson, otherwise 0.
OVERALL_COND	Overall condition of home at time of last assessment
RBSMNT_TYP_DLM	Binary variable equal to 1 for full or finished basement and 0 otherwise
SALE_PRICE_95	Sale price converted to 1995 dollars
SCHDIS-CAZ	School district binary variable equal to 1 for Cazenovia school district and 0 otherwise
SCHDIS-CHTNGO	School district binary variable equal to 1 for Chittenango school district and 0 otherwise
SCHDIS-CNSTO	School district binary variable equal to 1 for Canastota school district and 0 otherwise
SCHDIS-MORS	School district binary variable equal to 1 for Morrisville school district and 0 otherwise
SCHDIS-ONIEDA	School district binary variable equal to 1 for Oneida school district and 0 otherwise
SCHDIS-STKBRDG	School district binary variable equal to 1 for Stockbridge school district and 0 otherwise
SFLA	Number of square feet in the home
SMITHFIELD	Binary variable equal to 1 if township is Smithfield, otherwise 0.
SPRING_SALE	Binary variable equal to 1 for transactions in quarter 2 and 0 otherwise
STONE_WALL_MAT	Binary variable equal to 1 for stone or brick exterior and 0 otherwise
SULLIVAN	Binary variable equal to 1 if township is Sullivan, otherwise 0
SUMMER_SALE	Binary variable equal to 1 for transactions in quarter 3 and 0 otherwise
WINTER_SALE	Binary variable equal to 1 for transactions in quarter 1 and 0 otherwise.

Table VII: Definitions of Viewshed Variables

DIS_TO_MILLS	The distance from the home to the nearest turbine as calculated by the GIS.
VIEW	The view of the turbines as recorded from the field analysis with possible range from 0 to 60. If house sold before Jan 1, 2001 the value is 0.
VIEW1MILE	The VIEW of the home if 0>DIS_TO_MILLS<=1, otherwise 0
VIEW2MILE	The VIEW of the home if 1>DIS_TO_MILLS<=2, otherwise 0
VIEW3MILE	The VIEW of the home if 2>DIS_TO_MILLS<=3, otherwise 0
VIEW4MILE	The VIEW of the home if 3>DIS_TO_MILLS<=4, otherwise 0
VIEW5MILE	The VIEW of the home if 4>DIS_TO_MILLS<=5, otherwise 0
VIEW2001	The VIEW of the home if the year of sale was 2001, otherwise 0
VIEW2002	The VIEW of the home if the year of sale was 2002, otherwise 0
VIEW2003	The VIEW of the home if the year of sale was 2003, otherwise 0
VIEW2004	The VIEW of the home if the year of sale was 2004, otherwise 0
VIEW2005	The VIEW of the home if the year of sale was 2005, otherwise 0

Note: This table also appears in the main text

Table VIII: Description of Viewshed Variables

VIEWSHED VARIABLES	Mean	Minimum	Maximum	Frequency
DIS_TO_WNDMILLS	3.50	0.76	5.98	280
VIEW	3.09	0	46	43
VIEW1MILE	0.60	0	40	5
VIEW2MILE	0.81	0	46	15
VIEW3MILE	0.46	0	46	6
VIEW4MILE	0.84	0	32	11
VIEW5MILE	0.38	0	38	6
VIEW2001	0.60	0	39	11
VIEW2002	0.55	0	40	9
VIEW2003	0.79	0	46	8
VIEW2004	1.03	0	46	12
VIEW2005	0.11	0	17	3

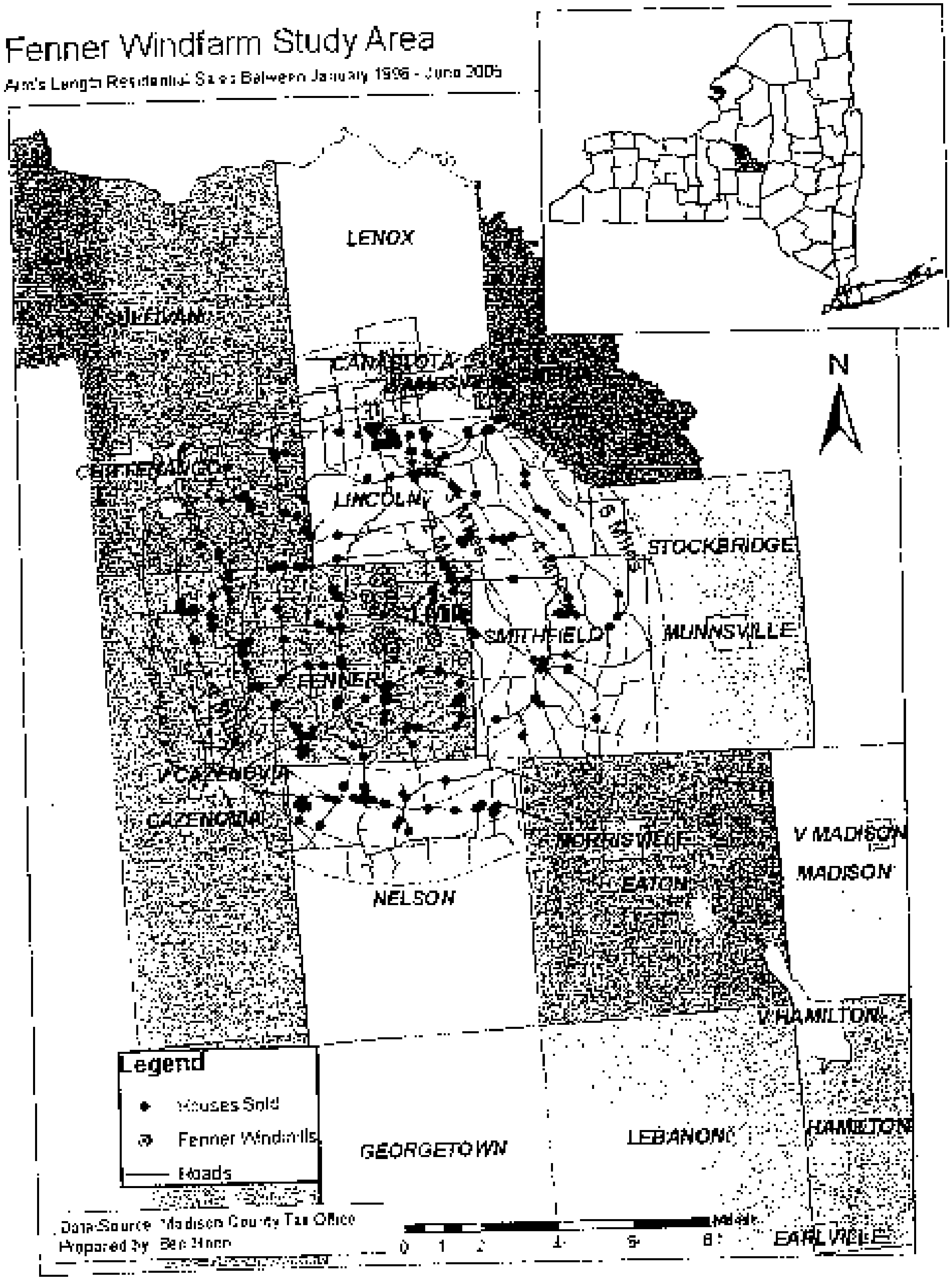
Table IX: Description of Binary Variables

	Median	Mean	Minimum	Maximum	Frequency
BINARY VARIABLES					
BLDSTYL-CAPE	0	0.07	0	1	20
BLDSTYL-CNTMP	0	0.11	0	1	30
BLDSTYL-COLNL	0	0.15	0	1	41
BLDSTYL-CTTG	0	0.01	0	1	2
BLDSTYL-LOG	0	0.04	0	1	10
BLDSTYL-OLDSTYL	0	0.21	0	1	59
BLDSTYL-RANCH	0	0.34	0	1	96
BLDSTYL-RSDRNCH	0	0.04	0	1	11
BLDSTYL-SPLIT	0	0.03	0	1	9
CENTRAL_AIR	0	0.06	0	1	280
FENNER_DUM	0	0.29	0	1	80
RBSMNT_TYP_DUM	1	0.80	0	1	224
STONE_WALL_MAT	0	0.01	0	1	2
SCHDIS-CAZ	0	0.47	0	1	131
SCHDIS-CHTNGO	0	0.14	0	1	39
SCHDIS-CNSTO	0	0.18	0	1	51
SCHDIS-MORS	0	0.15	0	1	43
SCHDIS-ONIEDA	0	0.03	0	1	8
SCHDIS-STKBRDG	0	0.03	0	1	8
SPRING_SALE	0	0.28	0	1	78
SUMMER_SALE	0	0.34	0	1	94
FALL_SALE	0	0.24	0	1	67
WINTER_SALE	0	0.15	0	1	41

Table X: Description of Continuous Variables

CONTINUOUS VARIABLES	Median	Mean	Minimum	Maximum	Frequency
SALE_PRICE_95	$91,293	$102,371	$10,049	$284,935	280
LNSALE_PRICE_95	11.42	11.41	9.215	12.560	280
ACRES	2.26	8.61	0.13	237.26	280
AGE_AT_SALE	20.5	42.36	0	205	280
DEED_YEAR	2001	2001	1995	2005	280
DEED_YEAR_SQRD	49	54.40	1	121	280
DIS_TO_RT20	4.66	4.69	0.01	10.17	280
DIS_TO_TOWN	3.68	3.78	1.51	6.87	280
NBR_FIREPLACES	0	0.51	0	5	116
NBR_FULL_BATHS	2	1.63	0	4	278
NBR_HALF_BATHS	0	0.39	0	1	110
OVERALL_COND	3	3.09	1	5	280
SFLA	1715	1804	420	5194	280

Appendix B: Map of Study Area



Appendix C: Technique for Creating GIS Viewshed Prediction Algorithm

A predicted view from each home was calculated using GIS techniques. The accuracy of the best performing predicted view was 85% as compared to actual view measurements. Since this did not meet confidence requirements, it was not used in the model.

To create a viewshed that effectively mimics the reality of a landscape the ground surface elevations as well the ground cover need to be simulated. In our case the 10 meter USGS DEM was used for surface elevations. The DEM was converted to a 3 dimensional ESRI raster file with the ARCGIS 9 "DEM to RASTER" algorithm using float and no z-value conversion. 10 meter data from the Multi-resolution Land Characterization (MRLC) Consortium[44] depicted the ground cover. Then by estimating heights for each ground cover type in our sample area, and reclassifying the raster fields to these heights, a raster addition was possible between the DEM and the MRLC. Four sets of heights for deciduous, conifer, and mixed forests, shrubs and grass (cultivated land) were tested (See Table IV). All other groundcover types were given a height of 0.

Table XI: Description of Heights for Ground Cover Raster Files (in feet)

Set	Conifer	Deciduous	Mixed	Grass & Shrubs
WINTER	100	0	50	5
80 NO-GRASS	80	70	75	0
80	80	70	75	5
100	100	90	95	10

[44] Partners include the USGS (National Mapping, Biological Resources, and Water Resources divisions), USEPA, the U.S. Forest Service, and the National Oceanic and Atmospheric Administration

Road and turbine location shapefiles were provided by the Madison County Tax Office, and a river shapefile was provided by the USGS National Map. House locations were derived as described in section 5.3. Because MRLC raster cells often spanned roads and covered houses and turbine locations, buffer shapefiles were created around each. 10 foot buffers were created around roads and houses, and 30 foot buffers surrounded turbines. To improve viewshed algorithm performance each raster grid (both DEM alone and DEM/MRCL additions) was converted to a triangulated irregular network (TIN) (Dean, 1997; Reeves, 2004). Z coordinates were not provided for the road, river, turbine, house shapefiles and accompanying buffers so these were derived from the DEM TIN. Buffers were added to the DEM/MRLC TINs using hard replace, and rivers were added using hardline which effectively erased all ground cover in the buffer areas and along the lines of the rivers. A map depicting the landscape is provided in Appendix D.

To calculate the viewsheds that simulated the 3 point score used in field analysis, three values for OFFSETA[45] were used corresponding to the heights on the turbines. The top height was 430 ft, the middle height was 328 ft and the lowest height was 210 ft. Additionally a value for OFFSETB of 10 ft was used.[46] Then the viewshed algorithm was run for the 20 "observation" points of the

[45] OFFSETA is the field name used by ESRI Arc viewshed algorithms of values of vertical distance in surface units that are added to the z-value of each cell as it is considered for visibility.
[46] OFFSETB is the field name used by ESRI Arc viewshed algorithms of values of vertical distance in surface units that are added to the z-value of the observation point.

turbines at each of the three heights (top, middle, lowest). This produced three 10 meter raster grids with values from 0 to 20 possible. All were added together to produce a grid with values from 0 to 60 possible. These raster values were extracted using the house point locations giving a discrete value (from 0 to 60) for each home in our sample set. Of the four sets of heights used to create the ground cover raster values originally (see Table IV) the 80 No-Grass set was best at neither over nor under predicting visibility (See results in Appendix C) but still did not meet confidence threshold of 95% that we had hoped for.

Suggestions for improving GIS viewshed predictions

The reasons we believe our estimates are off is because of inherent errors in the DEM which then transferred to our TIN surface. We test this theory by using 63 geodetic markers from the USGS which were within our study area. Roughly 15% (10/63) of the two elevations differ by more than 1%, which in some cases is more than 5 feet (max = 7 feet). The direction of the errors are 60/40 peaks to pits[47] ("peaks" = 37, "pits" = 26). Errors are smaller for the largest 26 peaks (mean = 1.51 feet) versus the largest 26 pits (mean = -2.76 feet). The errors in the viewshed calculations are well distributed between over predicting the homes' view of the turbines and under predicting it. Therefore, we conclude if the surface of the entire study area is similar in inaccuracies to the test points, predicted

[47] "Peaks" refers to points on the TIN that are at a higher elevation than the geodetic markers, and "pits" refers to the opposite, where the TIN surface is at a lower elevation than the marker.

viewshed inaccuracies could be entirely based on pits and peaks in the DEM. A 5-foot peak in the TIN surface could obscure a large portion of the landscape a few miles away from predicted visibility. Concurrently an observer on a 5-foot peak could be predicted to see a great deal more than actually can be seen. Methods for correcting or smoothing these errors were not investigated, and therefore additional research in this area would be important.

Another contributing factor for viewshed inaccuracies might be ground cover representation. It is observed in field analysis that canopy heights are not similar across all forests of the same type. For instance some deciduous forests have been planted in the last 15 years and have not grown to a mature height, while other forests are in late stage progression with mature heights. We use the same height for all forests of the same type. Further, square raster cells do not accurately depict non-uniform patterns of forest growth, and are particularly bad at depicting lines of trees that cross diagonally to the raster grid. Lastly the depiction of the top of the canopy is flat, but in reality the top is non-uniform. Field analysis proves it was possible to view turbines through the variation of the canopy. Combined these inaccuracies could add to the errors in our visibility prediction results. A smaller grid than 10 meters for the ground cover layer and access to ground cover data that includes z-values would greatly improve depiction and therefore viewshed analysis.

Appendix D: Results of GIS Viewshed Prediction Algorithm

Table XII: Description of Heights for Ground Cover Raster Files (in feet)

Set	Conifer	Deciduous	Mixed	Grass
Winter	100	0	50	5
80 No-Grass	80	70	75	0
80	80	70	75	5
100	100	90	95	10

Table XIII: Results of Viewshed Predictions for 4 Sets of Ground Cover Heights

	Winter	OBSERVED		
		See	No See	Total
PREDICTED	See	42	47	89
	No See	3	37	40
	Total	45	84	129

	Winter	OBSERVED			
		See	No See	Total	Correct
PREDICTED	See	33%	36%	69%	61%
	No See	2%	29%	31%	Incorrect
	Total	35%	65%	100%	39%

	80 No-Grs	OBSERVED		
		See	No See	Total
PREDICTED	See	36	10	89
	No See	9	74	40
	Total	45	84	129

	80 No-Grs	OBSERVED			
		See	No See	Total	Correct
PREDICTED	See	28%	8%	36%	85%
	No See	7%	57%	64%	Incorrect
	Total	35%	65%	100%	15%

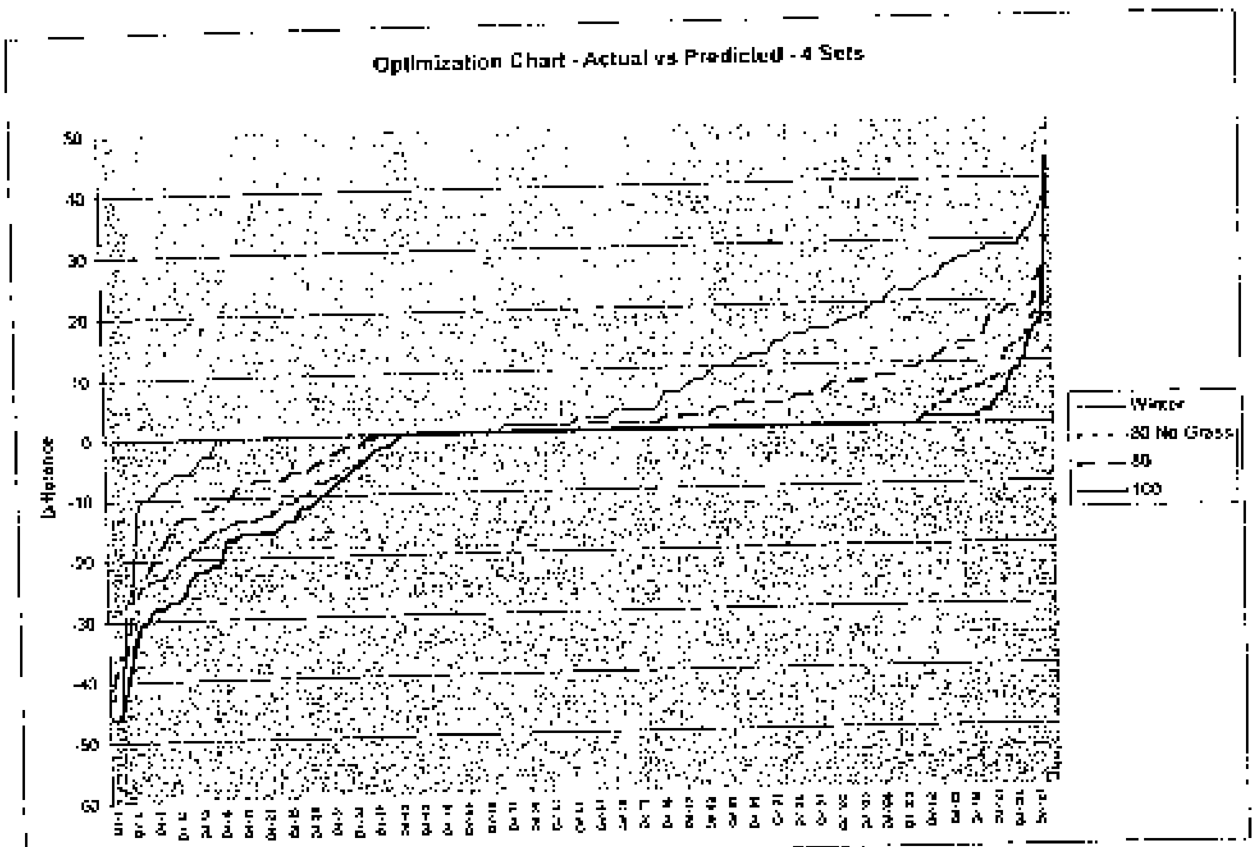
	100	OBSERVED		
		See	No See	Total
PREDICTED	See	26	13	89
	No See	19	71	40
	Total	45	84	129

	100	OBSERVED			
		See	No See	Total	Correct
PREDICTED	See	20%	10%	30%	75%
	No See	15%	55%	70%	Incorrect
	Total	35%	65%	100%	25%

	80	OBSERVED		
		See	No See	Total
PREDICTED	See	42	55	89
	No See	3	29	40
	Total	45	84	129

	800	OBSERVED			
		See	No See	Total	Correct
PREDICTED	See	33%	43%	75%	55%
	No See	2%	22%	25%	Incorrect
	Total	35%	65%	100%	45%

Figure V: Four Sets of Predicted Views versus the Actual Readings



Note: Results for each set are arrayed in ascending order without regard to house location. Therefore the amount of difference for one set for a particular house might not be similar for another set. Results are for 129 separate view readings. It is important to note the relatively even distribution of differences between positive and negative implying that the predicted viewshed models were most likely effected by forces outside the model such as random errors in the DEM

Appendix E: Landscape Constructions for Viewshed Prediction

Figure VI: Depiction of the Study Area without Ground Cover

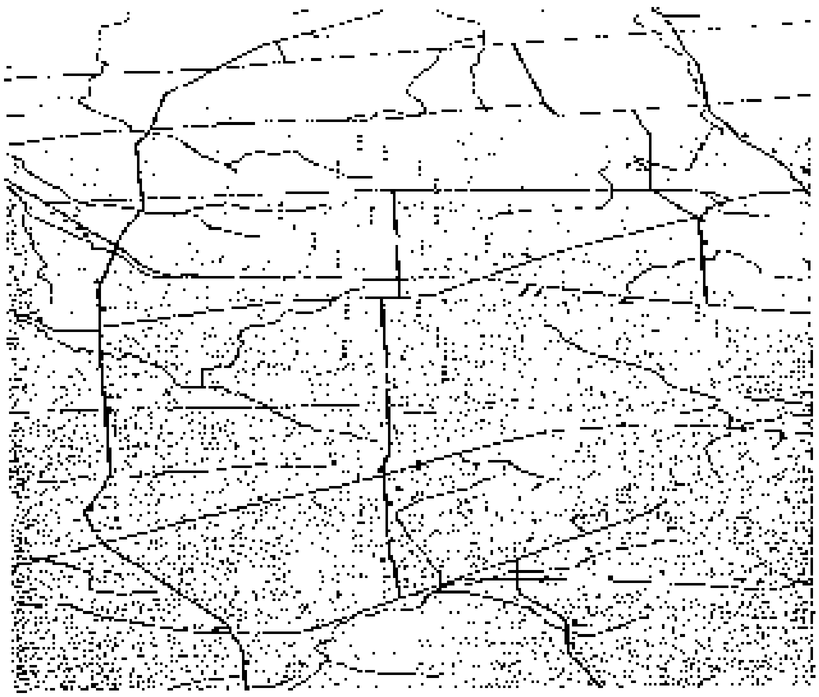


Figure VII: Depiction of the Study Area with Ground Cover

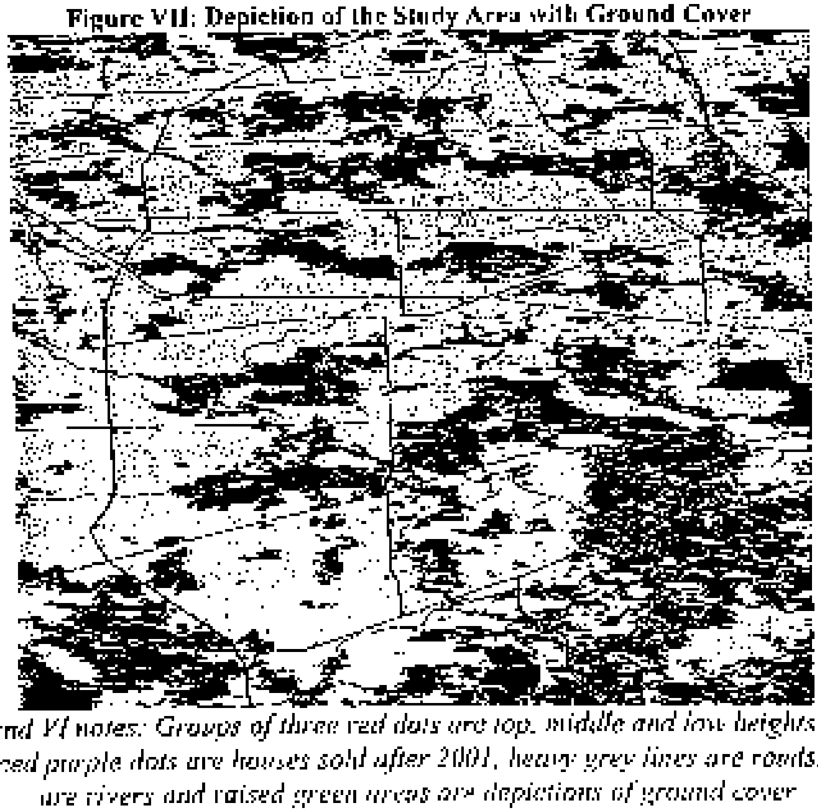
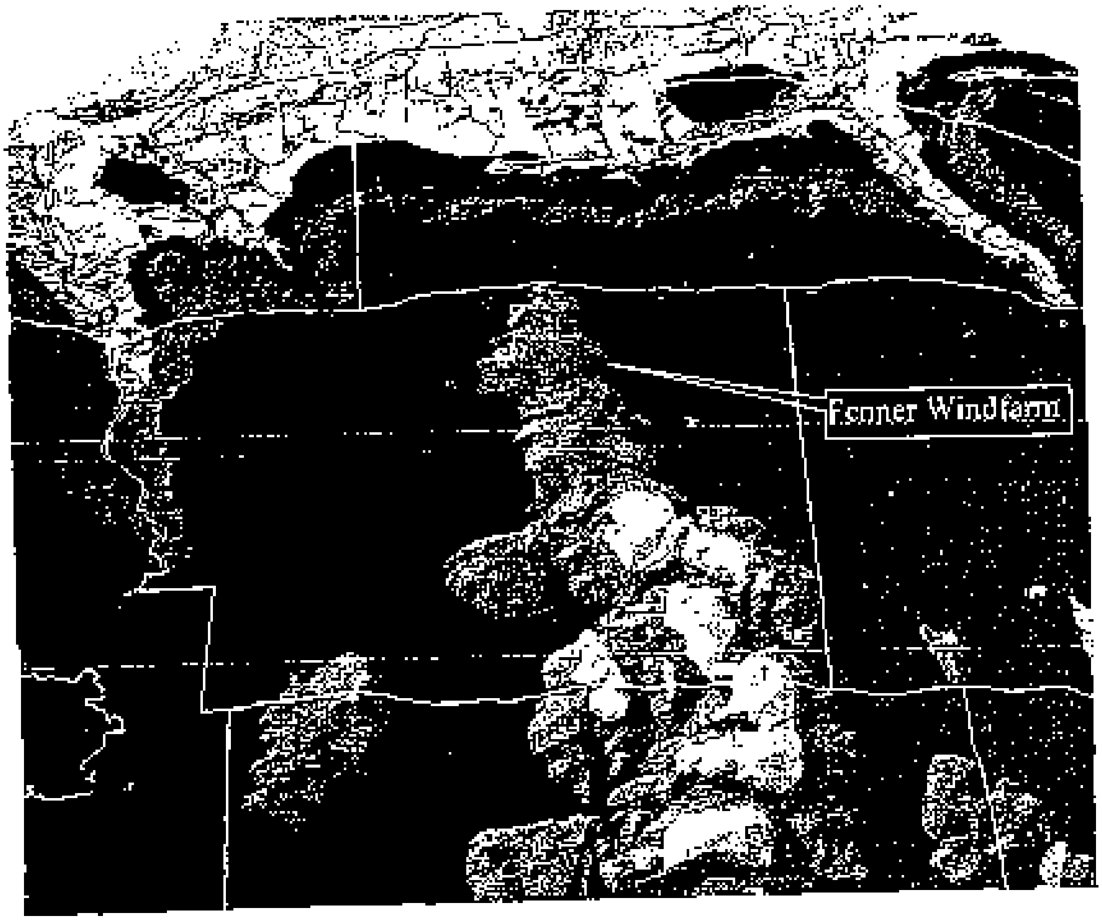


Figure V and VI notes: Groups of three red dots are top, middle and low heights of turbines, randomly spaced purple dots are houses sold after 2001, heavy grey lines are roads, thin blue lines are rivers and raised green areas are depictions of ground cover

Figure VIII: 3D Rendering of Study Area



Note: Depiction has elevation exaggerated 10 times. Except for where indicated dots are houses which sold after 1996, and lines are township borders. If possible rendering should be viewed in color.

Appendix F: Model Results

Table XIV: Results - Models 1-3

	Model # 1		Model # 2		Model # 3	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(CONSTANT)	-32.240	0.632	-30.135	0.647	9.830	0.000
CONTINUOUS VARIABLES						
ACRES	0.005	0.000	0.005	0.000	0.005	0.000
AGE_AT_SALE	-0.001	0.053	-0.001	0.003	-0.002	0.000
SALE_YEAR	0.021	0.532	0.049	0.456		
SALE_YEAR_SQR	-0.002	0.523	0.110	0.090		
DIS_TO_RT_20	-0.012	0.198	-0.013	0.156	-0.009	0.072
DISTOTOWN-MILES	-0.021	0.198	0.000	0.093		
NBR_FIREPLACES	0.051	0.058	0.050	0.059	0.053	0.041
NBR_FULL_BATHS	0.155	0.000	0.152	0.000	0.153	0.000
NBR_HALF_BATHS	0.054	0.170	0.060	0.123	0.088	0.014
OVERALL_COND	0.205	0.000	0.202	0.000	0.197	0.000
SFLA (in 1000s)	0.233	0.000	0.234	0.000	0.261	0.000
BINARY VARIABLES						
BLDSTYL-CAPE	0.101	0.703	0.022	0.688		
BLDSTYL-CNTMP	0.187	0.476	0.199	0.001	0.158	0.003
BLDSTYL-COLNL	0.082	0.752				
BLDSTYL-CTTG	-0.003	0.992	0.004	0.984		
BLDSTYL-LOG	0.287	0.287	0.297	0.000	0.287	0.000
BLDSTYL-OLDSTYL	0.003	0.991	0.052	0.461		
BLDSTYL-OTHR	-0.076	0.836				
BLDSTYL-RANCH	-0.009	0.972	0.020	0.542		
BLDSTYL-RSDRNCH	0.052	0.846	-0.001	0.542		
BLDSTYL-SPLIT	0.089	0.743	-0.020	0.706		
CENTRAL_AIR	0.008	0.915				
FENNER_DUM	0.060	0.129	-0.058	0.142	-0.053	0.018
RBSMNT_TYP_DUM	0.239	0.000	0.241	0.009	0.268	0.000
STONE_WALL_MAT	0.372	0.043	0.377	0.036	0.363	0.037
SCHDIS-CBTNGO	0.050	0.457	-0.143	0.214		
SCHDIS-CNSTO	0.045	0.508	-0.068	0.790		
SCHDIS-MORS	0.024	0.676				
SCHDIS-ONIEDA	-0.151	0.197				
SCHDIS-STKBRDG	0.437	0.000	-0.437	0.000	-0.489	0.000
SPRING_SALE	0.055	0.278	0.054	0.287	0.058	0.239
SUMMER_SALE	0.027	0.596	0.026	0.597	0.026	0.587
FALL_SALE	0.085	0.101	0.086	0.091	0.097	0.052
ADJUSTED R2		0.793		0.793		0.793
F/SIGNIFICANCE	32.857	0.000	39.185	0.000	63.764	0.000

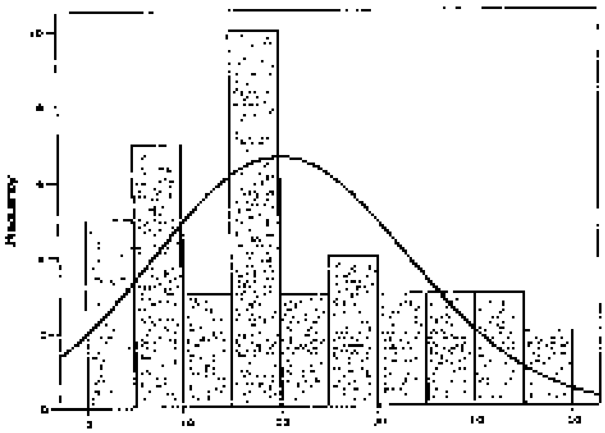
Table XV: Results - Models 4 - 6

	Model # 4		Model # 5		Model # 6	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
(CONSTANT)	9.803	0.000	9.826	0.000	9.840	0.000
CONTINUOUS VARIABLES						
ACRES	0.005	0.000	0.005	0.000	0.005	0.000
AGE_AT_SALE	-0.002	0.000	-0.002	0.000	0.002	0.000
DIS_TO_RT20	-0.009	0.082	-0.009	0.066	-0.010	0.046
NBR_FIREPLACES	0.050	0.053	0.048	0.071	0.051	0.048
NBR_FULL_BATHS	0.153	0.000	0.157	0.000	0.152	0.000
NBR_HALF_BATHS	0.085	0.018	0.091	0.012	0.084	0.022
OVERALL_COND	0.196	0.000	0.196	0.000	0.196	0.000
SFLA (in 1000s)	0.263	0.000	0.262	0.000	0.263	0.000
BINARY VARIABLES						
BLDSTYL-CNTMP	0.154	0.004	0.161	0.003	0.162	0.002
BLDSTYL-LOG	0.286	0.000	0.286	0.000	0.287	0.000
FENNER_DUM	-0.076	0.108	-0.092	0.015	-0.094	0.010
RBSMNT_TYP_DUM	0.271	0.000	0.273	0.000	0.268	0.000
STONE_WALL_MAT	0.359	0.041	0.366	0.037	0.367	0.035
SCHDIS-STKBRDG	-0.491	0.000	-0.485	0.000	0.482	0.000
SPRING_SALE	0.056	0.260	0.058	0.243	0.055	0.270
SUMMER_SALE	0.026	0.592	0.024	0.624	0.029	0.550
FALL_SALE	0.094	0.060	0.093	0.063	0.095	0.061
VIEWSHED VARIABLES						
DIS_TO_WNDMILLS	0.007	0.679				
VIEW	0.001	0.410				
VIEW1MILE			0.001	0.656		
VIEW2MILE			0.000	0.936		
VIEW3MILE			0.006	0.115		
VIEW4MILE			0.001	0.881		
VIEW5MILE			-0.001	0.764		
VIEW2001					-0.001	0.742
VIEW2002					0.006	0.175
VIEW2003					-0.002	0.613
VIEW2004					0.003	0.224
VIEW2005					0.001	0.906
ADJUSTED R2		0.792		0.791		0.792
F/SIGNIFICANCE	56.822	0.000	48.990	0.000	49.210	0.000

(Coefficients roughly correspond to the percentage change of sale price for each unit of change of the underlying variable. For example, adding an additional full bathroom to a house (coeff. = 0.153) adds roughly 15% to the value of the home, for homes that are near the sample mean value of $91,293.)

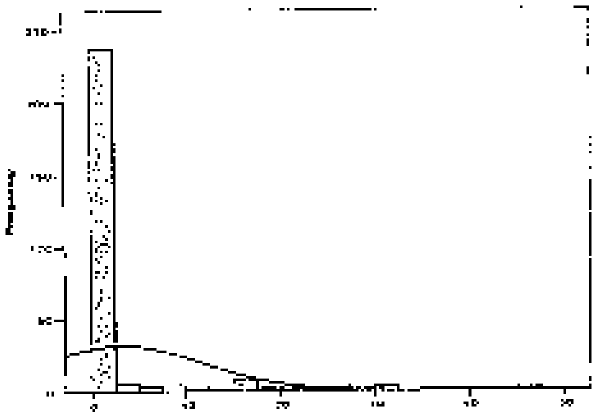
Appendix G: Histograms

Figure IX: Histogram of VIEW >0



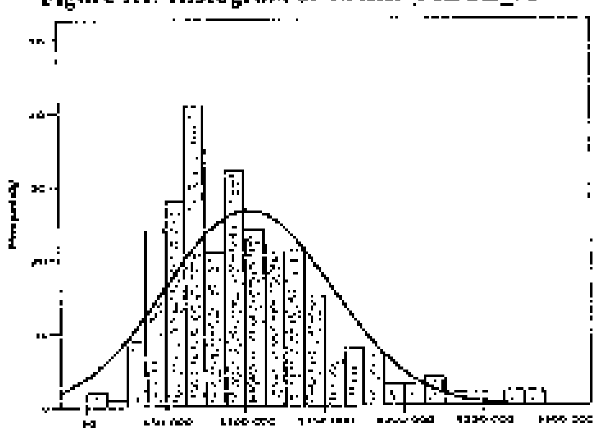
Notes: Line represents normal curve. n=43

Figure X: Histogram of VIEW



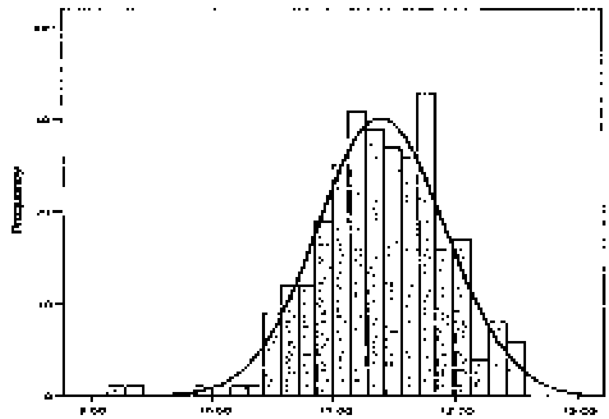
Notes: Line represents normal curve. n=280

Figure XI: Histogram of SALE_PRICE_95



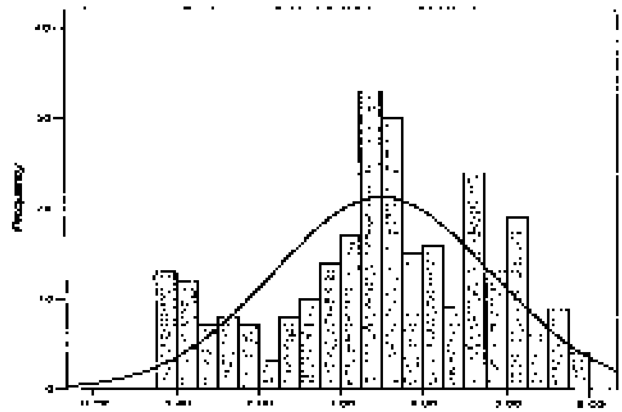
Notes: Line represents normal curve. n=280

Figure XII: Histogram of LogSALE_PRICE_95



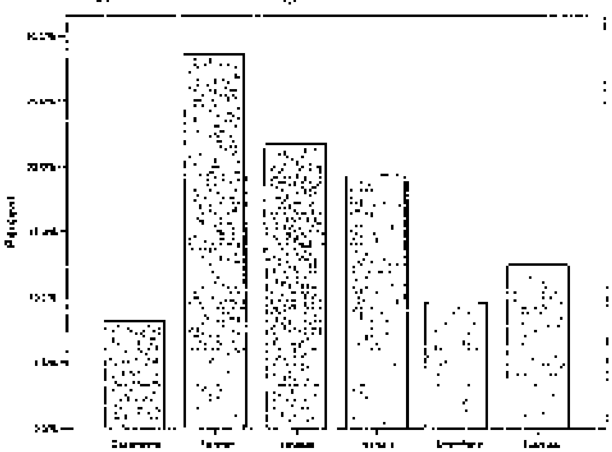
Notes: Line represents normal curve. n=280

Figure XIII: Histogram of DIS_TO_MILLS



Notes: Line represents normal curve. n=280

Figure XIV: Histogram of TOWNSHIP



Notes: n=280

Bibliography

Adams, A. (2005). *"Plaintiffs Trump County's Bid to Dismiss Suit."* The Recorder Online. Bath & Highland Counties, Virginia.

Associated Press (AP) (2006). *"Hearing Draws Opposing Views on Wind Power Project."* The Boston Globe c/o AP Wire Service. Boston.

Arsenault, J. (2006) Phone Conversation Regarding: *Discussion of Results.* Century 21 - Terra Real Estate, Canastota, NY, 1-19-06

American Wind Energy Association (AWEA) (2005b). *"State-Level Renewable Energy Portfolio Standards (RPS)."* American Wind Energy Association. September 2, 2005. http://www.awea.org/pubs/factsheets/RPSfactsheetStateRPSAugust2005.pdf [Viewed 12/15/05].

- - (2005c). *"Wind Energy Basics."* American Wind Energy Association. http://www.awea.org/faq/tutorial/wwt_basics.html#How%20big%20is%20a%20wind%20turbine [Viewed 1-6-06].

--- (2005d). *"Wind Energy Statistics."* American Wind Energy Association http://www.awea.org/faq/tutorial/wwt_statistics.html [Viewed 12-15-05].

--- (2005e). *"Wind Power Outlook 2005."* American Wind Energy Association http://www.awea.org/pubs/documents/Outlook%202005.pdf [Viewed 12-15-05].

--- (2006). *"Annual Industry Rankings Demonstrate Continued Growth in Wind Energy in the United States - Updated."* American Wind Energy Association. March 15, 2006. http://www.awea.org/news/Annual_Industry_Rankings_Continued_Growth_031506.html [Viewed 3-27-06].

Bateman, I. J. and K. G. Willis (2002). Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries. New York, Oxford University Press.

Benson, E. D., J. L. Hansen, *et al.* (2000). *"Water Views and Residential Property Values."* The Appraisal Journal (July 2000): 260-270.

Bishop, J. and A. Proctor (1994). *"Love Them or Loathe Them? Public Attitudes to Wind Farms in Wales."* Department of City and Regional Planning, University of Wales. Aberystwyth. [Viewed 1-9-06].

Bond, M. T., V. L. Seiler, *et al.* (2002). *"Residential Real Estate Prices: A Room with a View."* Journal of Real Estate Research 23 (1/2): 129-137.

Braunholtz, S. and MORI-Scotland (2003). *"Public Attitudes to Windfarms: A Survey of Local Residents in Scotland."* Scottish Executive Social Research. 1-21. http://www.scotland.gov.uk/library5/environment/pawslr.pdf [Viewed 12-15-05].

Brookshire, D. S., M. A. Thayer, *et al.* (1982). *"Valuing Public Goods: A Comparison of Survey and Hedonic Approaches."* The American Economic Review 72 (1): 165-177.

Cary, R. (2005) Phone Conversation Regarding: *Discussion of Fenner Windfarm.* Town Superintendent, Madison County, Wampsville, NY, 10-05-05

Congressional Research Service (CRS) (2005). *"Renewable Energy: Tax Credit, Budget, and Electricity Production Issues."* Updated August 22, 2005. http://www.cnie.org/NLE/CRSreports/05aug/IB10041.pdf [Viewed 01-09-06].

Dale, L., J. C. Murdoch, et al. (1999). "*Do Property Values Rebound from Environmental Stigmas? Evidence from Dallas*." Land Economics 75 (2): 311-326.

Dean, D. J. (1997). "*Improving the Accuracy of Forest Viewsheds Using Triangulated Networks and the Visual Permeability Method*." Canadian Journal of Forest Research 27 (7): 969-977.

Delaney, C. J. and D. Timmons (1992). "*High Voltage Power Lines: Do They Affect Residential Property Value?*" The Journal of Real Estate Research 7 (3): 315-328.

Des-Rosiers, F. (2002). "*Power Lines, Visual Encumbrance and House Values: A Microspatial Approach to Impact Measurement*." Journal of Real Estate Research 23 (3): 275-301.

Devine Wright, P. (2004). "*Beyond NIMBYism: Towards an Integrated Framework for Understanding Public Perceptions of Wind Energy*." Wind Energy 8 (2): 125 - 139

Energy Center of Wisconsin (ECW) (2004). "*Examining Wind Turbine Impact on Local Property Values*." A Study of Wind Energy Development in Wisconsin.. Part 3:119-137. July 1, 2004. http://72.36.212.10/mod/231-1.pdf [Viewed 12-1-05].

Energy Information Administration (EIA) (2006). "*Annual Energy Outlook 2006 - Overview*." 11 p http://www.eia.doe.gov/oiaf/aeo/pdf/earlyrelease.pdf [Viewed 01-09-06].

Environmental Management Council (EMC) (2005). *EIS Primer: A Guide for Reviewing Environmental Impact Statements*. Westchester County. 2nd Edition (January 2005) http://www.westchestergov.com/planning/environmental/EMC%20EIS%20Primer/EIS%20Primer.pdf [Viewed 1-20-06]

Exeter-Enterprises Ltd. (1993). "*Attitudes to Wind Power. As survey of Opinion in Cornwall and Devon*." ETSU Report W/13/00354/038/REP Prepared for the Department of Trade and Industry as Cited in Devine-Wright (2004).

Freris, K. (1998). Love them or loathe them? Public opinion and windfarms. Presented at 20th British Wind Energy Association Conference, Cardiff University of Wales, September 2-4 1998

Government Accounting Office (GAO) (2005). *Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife*. GAO-05-906 http://www.gao.gov/new.items/d05906.pdf [Viewed 1-6-05]

Gipe, P. (2002). Design as if People Matter: Aesthetic Guidelines for a Wind Power Future. Wind Power in View: Energy Landscapes in a Crowded World. Davis, CA, Academic Press: 173-212

Goeters, J. E. (1997). Environmental Issues in Real Estate. Upper Saddle River, NJ, Prentice Hall.

Grover, D. S. (2002). "*Economic Impacts of Wind Power in Kittitas County, WA*." ECONorthwest for Phoenix Economic Development Group. 1-18. November 2002. http://www.cafenergy.com/pdf%20files/Kittitas%20Wind%20final.pdf?mm=4 [Viewed 12-1-05].

Global Wind Energy Council (GWEC) (2005). "*Global Wind Power Continues Expansion*." March 4, 2005. http://www.awea.org/news/03_04-05-GlobalWindEnergyMarkets.pdf [Viewed 12-15-05].

Halcoussis, D. (2005). Understanding Econometrics. Mason, OH, South-Western.

Hamilton, S. and G. Schwann (1995). "*Do High Voltage Electric Transmission Lines Affect Property Value?*" Land Economics 71 (4): 436-444.

Haughton, J., D. Giuffre, *et al.* (2004). "*An Economic Analysis of a Wind Farm in Nantucket Sound.*" Beacon Hill Institute at Suffolk University. 2-83. May 1, 2004. http://www.beaconhill.org/BHIStudies/Windmills2004/WindFarmArmyCorps.pdf [Viewed 12-1 05].

Heckman, J. J. (1979). "*Sample Selection Bias as a Specification Error.*" Econometrica 47 (1): 153-162.

Irwin, E. G. (2002). "*The Effects of Open Space on Residential Property Values.*" Land Economics 78 (4): 465-480.

Jordal-Jorgensen, J. (1996). "*Visual Effect and Noise from Windmills - Quantifying and Valuation.*" Social Assessment of Wind Power in Denmark. The Institute of Local Government Studies (AKF). April 1996. http://www.akf.dk/eng/wind0.htm [Viewed 12-15-05].

Kennedy, P. (2003) A Guide to Econometrics: Fifth Edition. Cambridge, Massachusetts, The MIT Press.

Khatri, M. (2004). "*RICS Wind Farm Research. Impact of Wind Farms on the Value of Residential Property and Agricultural Land.*" Royal Institution of Chartered Surveyors. November 3, 2004. http://www.rics.org/NR/rdonlyres/66225A93-840F-49F2-8820-0EBCCC29E8A4/0/Windfarmsfinalreport.pdf [Viewed 12-15-05].

Krohn, S. and S. Damborg (1999). "*On Public Attitudes Towards Wind Power.*" Renewable Energy 16 (1-4): 954-960.

Kroll, C. A. and T. Priestley (1991). "*The Effects of Overhead Transmission Lines on Property Values: A Review and Analysis of the Literature.*" Prepared for the Siting and Environmental Planning Task Force of the Edison Electric Institute (draft). 99 p. July, 1992. http://staff.haas.berkeley.edu/kroll/pubs/tranline.pdf [Viewed 1-16-06].

Last, J. M. (1995). A Dictionary of Epidemiology, Oxford University Press.

Maloy, M. A. and D. J. Dean (2001). "*An Accuracy Assessment of Various GIS-Based Viewshed Delineation Techniques.*" Photogrammetric Engineering and Remote Sensing 67 (11): 1293-1298.

Malpezzi, S. (2002). "*Hedonic Pricing Models: A Selective and Applied Review.*" Housing Economics: Essays in Honor of Duncan Maclennan. 1-43. April 10, 2002. http://www.bus.wisc.edu/realestate/pdf/pdf/Hedonic%20Pricing%20Models%20Survey%20for%20Maclennan.pdf [Viewed 12-15-05].

Moore, W. B. (2005) Response to Questions regarding Fenner Wind Farm. Sent to B. Hoen. November 11, 2005

New York State Department of Public Service (NYSDPS) (2004). "*Draft Generic EIS for Case# 03-E-0188: Retail Renewable Portfolio Standard for New York State.*" April 8, 2004. http://www.dps.state.ny.us/NY_RPS_EIS_4-8-04.pdf [Viewed 1-6-05].

Pasqualetti, M. J. (2002). Living with Wind Power in a Hostile Landscape. Wind Power in View: Energy Landscapes in a Crowded World. San Diego, CA, Academic Press: 153-172.

Pasqualetti, M. J. and E. Butler (1987). "*Public Reaction to Wind Development in California.*" International Journal of Ambient Energy 8 (2): 83-90.

Poletti, P. (2005). "*A Real Estate Study of the Proposed Forward Wind Energy Center Dodge and Fond Du Lac Counties, Wisconsin.*" Prepared for Invenergy Wind LLC. May 2005. http://psc.wi.gov/apps/erf_share/view/viewdoc.aspx?docid=35184 [Viewed 12-15-05].

Robertson Bell Associates (RBA) (1998a). "*Novar, UK Residents Survey Summary.*" RBA C/O British Wind Energy Association. July 1998. http://www.bwea.com/ref/novar.html [Viewed 12-15-05].

Reeves, R. (2004). "*Scientific Computing Tutorial: Calculating Elevation Zone Thresholds using ArcMap GIS Version 9.0 and Public Domain Digital Elevation Models.*" National Center for Ecological Analysis and Synthesis. November 8, 2004.
http://www.nceas.ucsb.edu/scicomp/Dloads/GISProgramming/McCainESRI_DEMProcTutorial.pdf [Viewed 1-27-06]

Rodriguez, M. and C. F. Sirmans (1994). "*Quantifying the Value of a View in Single-Family Housing Markets.*" The Appraisal Journal (October 1994): 600-603.

Sustainable Energy Ireland (SEI) (2003). "*Attitudes Toward the Development of Windfarms in Ireland*," http://www.irish-energy.ie/uploadedfiles/RenewableEnergy/Attitudestowardswind.pdf [Viewed 1-20-06].

Seiler, M. J., M. T. Bond, *et al.* (2001). "*The Impact of World Class Great Lakes Water Views on Residential Property Values.*" The Appraisal Journal (July 2001): 287-295.

Sirmans, G. S., M. Lynn, *et al.* (2005a). The Value of Housing Characteristics: A Meta Analysis. Presented at Mid Year Meeting of the American Real Estate and Urban Economics Association, May 2005. Published by National Center for Real Estate Research.

Sirmans, G. S., D. A. Macpherson, *et al.* (2005b). "*The Composition of Hedonic Pricing Models.*" Journal of Real Estate Literature 13 (1): 3-42.

Sterzinger, G., F. Beck, *et al.* (2003). "*The Effect of Wind Development on Local Property Values.*" Renewable Energy Policy Project. 1-77. May 2003.
http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf [Viewed 12-15-05].

Thayer, R. L. and C. N. Freeman (1987). "*Altamont: Public Perceptions of a Wind Energy Landscape.*" Landscape and Urban Planning 14 (1987): 379-398.

Thayer, R. L. and H. Hansen (1988). "*Wind on the land: Renewable energy and pastoral scenery vie for dominance in the siting of wind energy developments.*" Landscape Architecture 1988 (78): 69-73.

US Department of Energy (USDOE) (2005). *Advantages and Disadvantages of Wind Energy*.
http://eereweb.ee.doe.gov/windandhydro/wind_ad.html [Viewed 1-6-05]

Warren, C., C. Lumsden, *et al.* (2005). "*Green on Green: Public Perceptions of Wind Power in Scotland and Ireland.*" Journal of Environmental Planning and Management 48 (6): 853-875.

Wolsink, M. P. (1989). "*Attitudes and Expectancies about wind Turbines and Wind Farms.*" Wind Engineering 1989 (13): 196-206.

Zarem, K. L. (2005a). "*Appraisal Consulting Report: Forward Wind Project, Dodge County, WI.*" Prepared For Dowell Baker, P.C. 1-45. May 31, 2005.
http://psc.wi.gov/apps/erf_share/view/viewdoc.aspx?docid=35821 [Viewed 12-15-05].

--- (2005b). *Direct Testimony before the PSC of Wisconsin Regarding Forward Wind Project*. PSC REF# 35803 received 6/10/05 (Docket No. 9300-CE-100)
http://psc.wi.gov/apps/erf_share/view/viewdoc.aspx?docid=35803 [Viewed 12-15-05]

Impacts of Windmill Visibility on Property Values in Madison County, New York

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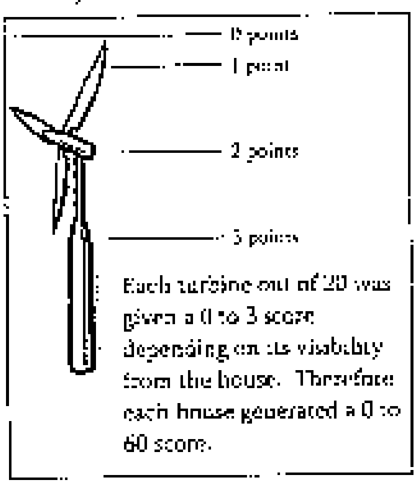
Background

With a growing reliance on wind energy to mitigate risks from energy security and global warming, a continuance of federal renewable energy tax credits, and a number of state incentive packages, U.S. states are seeing wind energy development grow at an unprecedented rate. Additionally windmill and windfarm sizes are increasingly large in order to capture greater efficiencies. Litigious conflicts have occurred between community members and facility developers or town planners over expected aesthetic impacts and their corresponding property value impacts. Changes in property values can potentially represent a large "hidden cost" borne by the community. Tom Grey, former Executive Director of the American Wind Energy Association (AWEA) ranks aesthetics and property values as the #1 concern of communities. Without proper analysis of this subject and a thorough understanding of effects on communities surrounding existing facilities, upcoming projects will be either needlessly delayed or inappropriately approved. Many opinions exist on the effects of wind development on surrounding property values, but no study to date has empirically analyzed the subject and actually visited the homes in the community to establish the degree of turbine visibility.

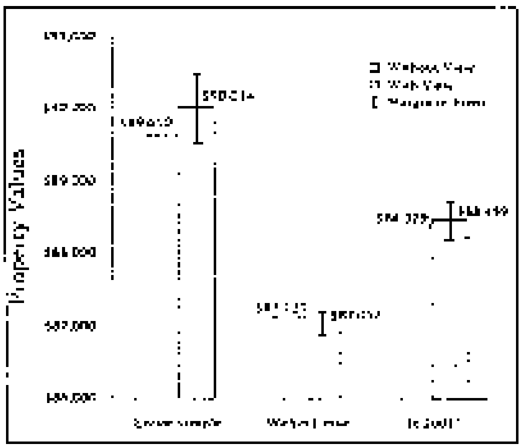
Purpose & Methods

This report analyzed property values surrounding a twenty turbine windfarm, constructed in 2001, in Madison County, New York to establish if any effects actually exist, and to set standards for future research. 280 arms-length residential home sales within 5 miles of the windfarm and occurring between 1996 and 2005 were analyzed. A visit to each home was made and an unbiased scoring method was used (see left) to quantify the degree to which each of these homes could see the windfarm, and the distance from each home to the turbines. These and other characteristics obtained from the assessor records were incorporated into an econometric model to ascertain if the properties sale prices were uniquely affected by the windmill visibility.



Results

The report finds no measurable effects of windmill visibility on property values (p-value 0.410). This absence of evidence holds even when concentrating on homes within a mile (p-value 0.656) or on those that sold immediately following announcement in 2001 (p-value 0.742) (See right).



Conclusions & Recommendations

The report suggests a number of reasons why no effects were found: The windmill array fits the landscape, wind farming fits this community's "sense of place", the payments the community received "balanced" any adverse impacts, a well respected landowner/proponent swayed others, and possibly residents swapped local impacts for global benefits. Further, the report offers the possibility that effects are more myth than reality citing empirical survey studies conducted in Europe which report resident reaction to windfarms largely to be neither good nor bad but rather "acceptable"[1], and another study which finds the local wind facility is rarely (< 3.0%) spontaneously mentioned in residents' descriptions of their surroundings.[2] The author recommends further study of 6 to 10 other sites in the US to ascertain if his results can apply to many of the communities considering wind facilities currently across the county.

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[1] Warren, C., C. Lumsden, et al. (2005). "Green on Green: Public Perceptions of Wind Power in Scotland and Ireland." Journal of Environmental Planning and Management 48 (6): 853-875.

[2] Braunholtz, S. and MORI-Scotland (2003). "Public Attitudes to Windfarms: A Survey of Local Residents in Scotland." Scottish Executive Social Research. 1-21.

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Documents in support of rejecting the

Draft Environmental Impact Statement

given to the

Town of Ellenburg

by

Noble Environmental, LLC.

Documents presented at the public hearing in Ellenburg, NY,

on

May 24, 2006

Oguz A. Soysal, Acoustic noise generated by wind turbines (December 14, 2005)

GP van den Berg, Effects of the wind profile at night on wind turbine sound, Journal of Sound & Vibration 277 (4-5) (2004):955-970.

GP van den Berg, Wind turbines at night: Acoustical practice and sound research, Proceedings Euronoise (2003), Naples.

GP van den Berg, Do wind turbines produce significant low frequency sound levels? 11th International meeting on low frequency noise & vibration and its control, Maastricht, The Netherlands, 30 August to 1 September 2004.

GP van den Berg, The beat is getting stronger: The effect of atmospheric stability on low frequency modulated sound of wind turbines, Journal of Low Frequency Noise, Vibration and Active Control, 24 (1) (March 2005):1-24.

GP van den Berg, "The sound of high winds: The effect of atmospheric stability on wind turbine sound and microphone noise," Ph.D. dissertation, University of Groningen, Netherlands (May 2006).

Clinical abstracts from various medical (clinical) journals, discussing symptoms of "wind turbine syndrome"

Balaban & Thayer, Neurological bases for balance-anxiety links, Journal of Anxiety Disorders 15 (2001):53 79.

Furman & Jacob, A clinical taxonomy of dizziness and anxiety in the otoneurological setting, Journal of Anxiety Disorders 15 (2001):9-26.

Moller & Pedersen, Hearing at low and infrasonic frequencies, Noise & Health 6, no. 23 (2004):37-57.

Waye, Effects of low frequency noise on sleep, Noise & Health 6, no. 23 (2004):87-91.

Waye et al., A descriptive cross-sectional study of annoyance from low frequency noise installations in an urban environment, Noise & Health 5, no. 20 (2003):35-46.

Waye et al., Low frequency noise pollution interferes with performance, Noise & Health 4 (no. 13) (2001)33-49.

Berglund et al., Sources and effects of low-frequency noise, Journal of the Acoustical Society of America 99, no. 5 (1996):2985-3002.

Nina Pierpont on Vibro-Acoustic Disease (VAD)

Alves-Pereira & Branco, Vibro-Acoustic Disease (VAD) symptoms

Alves-Pereira & Branco, Vibro-Acoustic Disease: Biological effects of infrasound & low frequency noise explained by mechano-transduction cellular signaling, Progress in Biophysics & Molecular Biology, in press.

Branco & Alves-Pereira, Vibro-Acoustic Disease, Noise & Health 6, no. 23 (2004):3-20.

Arnot, Vibroacoustic Disease I: The personal experience of a motorman (no date)

Marciniak et al., Echo-cardiographic evaluation of 485 aeronautical workers exposed to different noise environments, Aviation, Space, and Environmental Medicine 70, no. 3, Section II (March 1999):A46 ff.

Claude Henri Chouard, <<Le retentissement du fonctionnement des eoliennes sur la sante de l'homme>> ("The repercussions of wind turbine functioning on human health"), Academie Nationale de Medicine (French National Academy of Medicine) (2005). Calls for 1.5km turbine setbacks.

Marjolaine Villey-Migraine, <<Eoliennes, sons et infrasons: effets de l'eolien industriel sur la sante des hommes>> ("Wind turbines: Sound & infrasound: Effects of industrial wind turbines on human health") (December 2004), 16 pp. Calls for 3-mile turbine setbacks.

Pierre Recher, <<Quelques reflexions sur les consequences de l'eolien industriel sur l'homme---sa sante et son moral>> ("A few observations on the effects of wind turbines on people---their health & morale") (October 2004), 4 pp.

Terry Matilsky, Basic kinematics of wind turbine propeller ice throw (2005)

Calvin Luther Martin, Underground stray voltage from wind turbines? (April 2, 2005)

Wind turbines send wildlife diving for cover, New Scientist Tech (May 3, 2006).

<u>Setbacks</u>

Calvin Luther Martin cover letter to Dick Bowdler letter (August 25, 2005)

Dick Bowdler letter to Susan Sliwinski (October 16, 2002)

John Servo, Analysis of setbacks for noise and projectile hazard in other communities (November 23, 2004)

French National Academy of Medicine calls for 1.5 km setbacks (2005)

M. Villey-Migraine, Wind turbines: Sound & infrasound [calls for 3-mile setbacks] (2004)

Recent earthquakes in the NYS North Country, Plattsburgh Press-Republican archives

Northeast of US quivers in rare quake (April 20, 2002)

Geographic information system as a research & teaching tool (March 14-16, 2005)

Earthquake rattles northern NY Saturday (May 14, 2002)

Minor earthquake shakes up the North Country (January 10, 2006)

Neighbors' noise complaints

DMJP Manley, Concern at wind noise (March 16, 2005)

Ian McCausland, Factual information about wind turbine noise in Australia (August 9, 2005)

James M. Taylor, Wind farm proposed for Vermont National Forest (October 1, 2005)

Karen Ervin letter to Calvin Luther Martin (February 2, 2005)

Katherine Bush quoting Gordon Yancey, Flatrock Inn, Lowville, NY (February 17, 2006)

Robert Lazivee letter to County Commissioners (Meyersdale, PA) (2005)

Arlin Monfils, Supervisor, Lincoln Township, WI, regarding wind company problems (February 1, 2000)

Lincoln Township, Wisconsin, survey on wind turbine noise problems (May 15, 2001)

Linda Cooper, Activist shares wind power concerns (March 3, 2005)

Paula Stahl, The noise was incredible, West Va. (April 4, 2004)

Misty Edgecomb, Many say … turbines are noisy (December 4, 2005)

Pamela Foringer, Our Fenner wind farm story (Autumn 2004)

Neighbors complain of wind farm nuisances, The Albuquerque Tribune (April 28, 2006)

Seth Robson, Noisy turbine annoys neighbours (August 11, 2003)

Nick Churchouse, Neighbors warn of din from wind turbines (November 16, 2005)

Flurry of complaints after wind change (July 24, 2005)

Calvin Luther Martin, Notes on conversation with Darrell Fox (September 25, 2005)

Chuck Shick letter to Susan Shwinski (November 28, 2005)

David Brierley letter to Powergen CEO (October 1, 2004)

David Brierley letter to the editor, Press Republican (NY) (November 1, 2004)

David Brierley report on wind turbine noise and shadow flicker (2004)

Lincoln Township, Wisconsin, survey on wind turbine strobe light problems (May 15, 2001)

Catherine S. Maier, Don't let wind turbines happen here (September 24, 2005)

Tom Venesky, Waymart facility troubles residents (May 16, 2005)

Catherine Milner (see Catharine Lawton), Wind farms "make people sick who live up to a mile away" (January 25, 2004)

Gwen Burkhardt, Wind farm illness (June 6, 2005)

Kathy Webb, And the beat goes on (February 18, 2006)

Lincoln Township, Wisconsin, survey on wind turbine health problems (May 15, 2001)

Lincoln Township, Wisconsin, survey on wind turbine shadow flicker problems (May 15, 2001)

Lincoln Township, Wisconsin, survey on wind turbines and sleeplessness (insomnia) problems (May 15, 2001)

Wind turbine meeting (July 27, 2005)

Kathleen Danley letter to Calvin Luther Martin (February 12, 2006)

Eleanor Tillinghast, The dark side of wind power (February 12, 2005)

Donald Goetz, Promises gone with wind (February 7, 2004)

H. Perraudeau, Noisy wind turbines (October 2003)

Noise studies and reports

French St. Crepin windplant noise survey results (2005)

New York State DEC, Assessing and mitigating noise impacts (February 2, 2001)

Casella Stanger, DEFRA low frequency noise report (2001)

Birgitta Berglund et al., World Health Organization: Guidelines for community noise (1999)

Wind turbine studies & reports

Jonathan Boone, Direct testimony of Jon Boone before the Maryland Public Service Commission (July 25, 2005)

Jonathan Boone, Testimony to the Maryland Public Service Commission (Spring 2005)

Arthur Giacalone letter on flawed REPP report (November 9, 2005)

Eleanor Tillinghast, Wind farms don't make good neighbors (May 14, 2004)

Excerpts from the final report of the Township of Lincoln (Wisconsin) wind turbine moratorium committee (December 4, 2003)

Eric Rosenbloom, A problem with wind power: Summary (December 2004)

Eric Rosenbloom, A problem with wind power (August 23, 2005)

Policy comments on Point Petre commercial wind turbine generating plant, Ontario, Canada

Wind turbines devalue property

Bob Bittner letter to Calvin Luther Martin (December 6, 2005)

Danny Buttler, Blot on the landscape (February 21, 2004)

Alex Mitchell, Court bid to halt wind farm, Australia (April 30, 2006)

Gareth Scourfield, Report on a sample of properties inspected near a proposed wind farm (July 11, 2005)

Jonathan Boone letter to the editor, Caledonian Record (VT) (August 5, 2005)

Lee Matthews, Meridian pays family to move (August 2, 2005)

Lincoln Township, Wisconsin, survey on wind turbine problems, general comments (May 15, 2001)

Lincoln Township, Wisconsin, survey on wind turbines affecting property values (May 15, 2001)

Lynwen Evans, Prices falling (April 11, 2005)

David C. Maturen, Impact of wind turbine generators on property values (September 9, 2004)

Natasha Robinson, Clouds gathering over wind farm plan (January 9, 2006)

Neil Harvey, Windfarms affect house prices (January 17, 2006)

Brian Tilley, Couple hit by winds of change (September 9, 2005)

Suzan Askins letter to Calvin Luther Martin (November 9, 2005)

Lewis Smith, Wind farms ruin peace, says judge (January 10, 2004)

Justin Hawkins, Windfarm blows house value away (January 9, 2004)

Calvin Luther Martin, Tug Hill, NY, windplant: Patricia Leviker (November 4, 2005)

Barbara Kramer letter to Calvin Luther Martin re. Tug Hill windplant (November 7, 2005)

Russell Bounds letter to the Maryland Public Service Commission (November 8, 2005)

Russell Bounds, Testimony to the Maryland Public Service Commission (2005)

Communications interference

Leonard J. Koelmen, Wind farms and their effects on public safety radio systems (February 24, 2005)

Lincoln Township, Wisconsin, survey on wind turbines affecting television reception (May 15, 2001)

Birds & bats: Government studies & scientific reports

National Academy of Science announcement of 20-month study of windplants (September 30, 2005)

Government Accountability Office, Wind power: Impacts on wildlife and government responsibilities for regulating development and protecting wildlife, summary of report (September 2005)

Anne Adams, Wind assessments found lacking (September 30, 2005)

Government Accountability Office, Wind power: Impacts on wildlife and government responsibilities for regulating development and protecting wildlife, the full report (September 2005)

Eric Rosenbloom, US Fish & Wildlife Service criticizes Chautauqua County avian risk analysis (December 8, 2005)

Gerald Duffy et al., Migration patterns & routes of the Greater Snow Goose (Clinton & Franklin counties, NY) (Spring 2005)

John Ross, Migrating geese force energy firm to scrap plans for wind farm (November 25, 2005)

Karen L. Mayne, US Fish & Wildlife Service, letter regarding windplant and federal wildlife standards (September 28, 2005)

David A. Stilwell, US Fish & Wildlife Service, letter regarding windplant and federal wildlife standards sent to Noble Environmental (May 13, 2005)

Pierpont et al., Structure & organization of an Amazonian forest bird community, Ecological Monographs 60 (1990):213-238

Jason Jones et al., Climate and food synchronize regional forest bird abundances (2003)

Richard T. Holmes & Thomas W. Sherry, Thirty-year bird population trends (2001)

Merlin Tuttle, Studies conducted or to be conducted on bats; Greg Johnson, Overview of available bat mortality studies at wind energy projects; Edward B. Arnett, Cooperative efforts to assess the impact of wind power on bats; Wally Erickson, Bat mortality monitoring methods: Fall 2004 Mountaineer & Meyersdale; Wally Erickson, Preliminary fatality results: Meyersdale Wind Energy facility; Jessica Kerns, Preliminary fatality results: Mountaineer Wind Energy Center, WV; Brian Cooper, Preliminary comparison of nocturnal passage rates and bat fatalities in Penn. & W. Virginia; Jason Horn, Bats and wind turbines: Infrared analysis of abundance, flight patterns and avoidance behavior; Merlin Tuttle, Wrap-up: Current knowledge and next steps (March 2005)

Dale Strickland, Methods and metrics for understanding indirect impacts from wind projects; Sarah Mabey, Linking risks across the landscape: Developing a regional perspective (March 2005)

Mark Duchamp, Chilling statistics (September 2004)

Edward B. Arnett letter on flawed bat studies (June 5, 2005)

Do wind turbines kill birds? (2005)

Birds & bats: Reports from the press

David Brandes, Windpower & raptors: An unsolved issue (2005)

Matt Carter, Judge okays wind-farm suit (March 2005)

H. Sterling Burnett, Wind power: Not green but red (May 1, 2004)

Study: Bats killed at wind turbine sites (June 6, 2005)

Jeff Balow, Investigating a turbine tragedy: Bat deaths could threaten green image of wind power (May 9, 2005)

Paula Reed Ward, Windmills a fatal attraction for bats (September 27, 2005)

Larry Lipman, Windmills prove deadly to bats (November 12, 2005)

Health Effects of Wind Turbine Noise

Nina Pierpont, MD, PhD

(www.ninapierpont.com)

March 2, 2006

Industrial wind turbines produce significant amounts of audible and low-frequency noise. Dr. Oguz A. Soysal, Professor and Chairman of the Dept. of Physics and Engineering at Frostburg State University in Maryland, measured sound levels over half a mile away from the Meyersdale, PA, 20-turbine wind farm. Typical audible (A-weighted) dB (decibel) levels were in the 50-60 range, and audible plus low-frequency (C-weighted) dB were in the 65-70 range.[1] 65-70 dB is the loudness of a washing machine, vacuum cleaner, or hair dryer.[2] A difference of 10 dB between A and C weighting represents a significant amount of low-frequency sound by World Health Organization standards.[3] (1)

The noise produced by wind turbines has a thumping, pulsing character, especially at night, when it is more audible. The noise is louder at night because of the contrast between the still, cool air at ground level and the steady stream of wind at the level of the turbine hubs.[4] This nighttime noise travels a long distance. It has been documented to be disturbing to residents 1.2 miles away from wind turbines in regular rolling terrain,[5] and 1.5 miles away in Appalachian valleys.[6]

At night, the WHO recommends, the level of continuous noise at the outside a dwelling should be 45 dB or less, and inside, 30 dB or less. These thresholds should be even lower if there is a significant low-frequency component to the sound, they add – as there is for wind turbines. Higher levels of noise disturb sleep and produce a host of effects on health, well-being, and productivity.[7]

The decibel is logarithmic. Increasing the dB level by 10 multiplies the sound pressure level by 10. Increasing the dB level by 20 multiplies the sound pressure level by 100 (and 30 dB multiplies by 1000, etc.). Thus the 65 dB measured day and night half a mile from the Meyersdale wind farm has a measured intensity 100 times greater than the loudest continuous outdoor nighttime noise (45 dB) recommended by the WHO.

Typical ordinances proposed or passed for NY State communities considering industrial wind turbines allow A-weighted noise levels of 50 dB and construction of turbines only 1000 ft. from dwellings. These ordinances meet neither WHO nor NYS DEC standards, especially compared to the very low ambient noise levels (with dB levels typically in the 20's) in rural NY.[8]

The health effects of excessive community noise are carefully documented in the WHO report with reference to scientific and medical literature. Effects relevant to wind turbines, in terms of dB levels and noise type, are paraphrased and summarized from this report:

- For people to understand each other easily when talking, environmental noise levels should be 35 dB or less. For vulnerable groups (hearing impaired, elderly, children in the process of reading and language acquisition, and foreign language speakers) even lower background levels are needed. When noise interferes with speech comprehension, problems with concentration, fatigue, uncertainty and lack of

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[1] Soysal, OA. 2005. Acoustic Noise Generated by Wind Turbines. Presented to the Lycoming County, PA, Zoning Board 12/14/05. osoysal@frostburg.edu

[2] www.lhh.org/noise/decibel.htm

[3] World Health Organization. 1999. *Guidelines for Community Noise*. Ed. by Berglund B et al. Available at www.who.int/docstore/peh/noise/guidelines2.html

[4] van den Berg, FGP. 2005. "The beat is getting stronger: The effect of atmospheric stability on low frequency modulated sound of wind turbines." *Journal of Low Frequency Noise, Vibration, and Active Control*, 24(1):1-24.

[5] van den Berg, FGP. 2003. "Effects of the wind profile at night on wind turbine sound." *Journal of Sound and Vibration* 277:955-970.

[6] Linda Cooper, Citizens for Responsible Windpower, "Activist Shares Wind Power Concerns." *The Pendleton Times*, March 3, 2005, p. 4.

[7] WHO. 1999. *Guidelines for Community Noise*.

[8] NYS DEC. 2001. *Assessing and Mitigating Noise Impacts*.

self-confidence, irritation, misunderstandings, decreased work capacity, problems in human relations, and a number of stress reactions arise.[9]

- Wind turbine noise, as described above and experienced by many turbine neighbors, is easily within the decibel levels to disturb sleep. Effects of noise-induced sleep disturbance include fatigue, depressed mood or well-being, decreased performance, and increased use of sedatives or sleeping pills. Measured physiologic effects of noise during sleep are increased blood pressure and heart rate, changes in breathing pattern, and cardiac arrhythmias.[10] Certain types of nighttime noise are especially bothersome, the authors note, including those which combine noise with vibration, those with low-frequency components, and sources in environments with low background noise.[11] All three of these special considerations apply to industrial wind turbines in rural NY State. Children, the elderly, and people with preexisting illnesses, especially depression, are especially vulnerable to sleep disturbance.

- Noise has an adverse effect on performance over and above its effects on speech comprehension. The most strongly affected cognitive areas are reading, attention, problem solving, and memory. Children in school are adversely affected by noise, and it is the uncontrollability of noise, rather than its intensity, which is most critical. The effort to tune out the noise comes at the price of increased levels of stress hormones and elevation of resting blood pressure. The adverse effects are larger in children with lower school achievement.[12]

- What is commonly referred to as noise "annoyance" is in fact a range of negative emotions, documented in people exposed to community noise, including anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, and exhaustion.[13] Numerous reports from neighbors of new industrial wind turbine installations document these symptoms. The percentage of highly annoyed people in a population starts to increase at 42 dB, and the percentage of moderately annoyed at 37 dB.[14]

Low-frequency sound is also sensed as pressure in the ears. It modulates the loudness of regular audible frequencies, and is sensed as a feeling or vibration in the chest and throat.[15] Neighbors of industrial wind turbines describe the distressing sensation of having to breathe in sync with the rhythmic thumps of the turbine blades, especially at night when trying to sleep.

The participants in noise studies are selected from the general population and are usually adults. Vulnerable groups of people are underrepresented. Vulnerable groups include people with decreased personal abilities (old, ill, or depressed people), people with particular diseases or medical problems, people (children) dealing with complex cognitive tasks such as reading acquisition, people who are blind or hearing impaired, fetuses, babies and young children, and the elderly. These people may be less able to cope with the impacts of noise exposure and at greater risk for harmful effects than is documented in studies. Attention needs to be paid to them when developing regulations and setback requirements for industrial wind turbines and other sources of annoying and debilitating noise.

Wind turbines also create moving visual disturbances, especially early and late in the day when the long shadows of moving blades sweep rhythmically over the landscape. That portion of the population which is susceptible to vertigo, unsteadiness, or motion sickness (including many children and a large proportion of the elderly) will be vulnerable to unsteadiness and nausea when subjected to this visual disturbance. People with seizure disorders are susceptible to triggering of seizures by the strobe effect of seeing the sun through the moving blades.

To protect the public health, it is critical that industrial wind turbines not be placed within a minimum of 1.5 miles of human dwellings (homes, hospitals, residential schools, nursing homes, prisons, etc.) or schools. In mountainous terrain the setback should be greater, especially in topography with long parallel ridges and valleys as in the Appalachians.

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[9] WHO. 1999. *Guidelines for Community Noise*, pp. 42-44
[10] Ibid, p. 44
[11] Ibid, p. 46
[12] Ibid, pp. 49-50
[13] Ibid, p. 50
[14] Ibid, p. 51
[15] Møller, H. and CS Pedersen. 2004. Hearing at low and infrasonic frequencies. *Noise & Health* 6(23):37-57

NINA PIERPONT M.D. PH.D.

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March 9, 2006

Dear Town Board Member,

I am taking the liberty of sending you the text of my testimony in Albany before the NYS Assembly Energy Committee this past Tuesday (March 7th), summarized here:

Wind Turbine Syndrome

Testimony before the New York State Legislature Energy Committee, Hearing on the RPS

March 7, 2006

Nina Pierpont, MD, PhD

MD, The Johns Hopkins University School of Medicine, 1991
PhD, Population Biology, Princeton University, 1985
BA, Biology, Yale University, 1977
Fellow of the American Academy of Pediatrics
www.ninapierpont.com

To recapitulate, there is in fact a consistent cluster of symptoms, the Wind Turbine Syndrome, which occurs in a significant number of people in the vicinity of industrial wind turbines. There are specific risks factors for this syndrome, and people with these risk factors include a substantial portion of the population. A setback of 1.5 miles from homes, schools, hospitals, and similar institutions will probably be adequate, in most NY State terrain, to protect people from the adverse health effects of industrial wind turbines.

So, I implore you, take this 1.5 mile setback into consideration as you weigh the merits of industrial wind turbines in your township.

Sincerely,

[signature]

Nina Pierpont, MD PhD

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Wind Turbine Syndrome

Testimony before the New York State Legislature Energy Committee

March 7, 2006

Nina Pierpont, MD, PhD

MD, The Johns Hopkins University School of Medicine, 1991
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I am here to talk to you today as a physician-scientist about a clinical phenomenon called Wind Turbine Syndrome. This is relevant to today's hearing because it critically affects implementation of the RPS (Renewable Portfolio Standard) in terms of the siting of industrial wind turbines. Current siting practices (which are solely industry-driven) disregard public health. The supervision of the legislature—of this committee—is needed to create siting standards to protect the citizenry, all the citizenry, including citizens who are rural, old, ill, impaired, and very young.

Federal agencies are trying to put the brakes on willy-nilly wind turbine construction, citing, for instance, wildlife issues. The GAO (Government Accountability Office) last fall told US Fish and Wildlife to get involved. The National Academy of Sciences in April 2005 initiated a 20-month study on environmental impacts whose final report is due in December this year. There also needs to be a focus on human health, and the state needs to step up to the plate in terms of regulation.

I live in Franklin County, the poorest in NY State. Two years ago, after passage of the RPS, wind energy companies showed up there in force, as they have in all the poor, rural parts of the state. They showed up with no controls whatsoever, unregulated by either the legislature or NYSERDA (New York State Energy Research & Development Authority). Our town boards, made up of farmers, teachers, corrections officers, etc., were told, "You guys handle this," by our state representatives. I got involved as a responsible citizen and physician. Over the last 1½ years I have done a lot of reading, research, and interviews. I have spoken at town board meetings and before the St Lawrence County Legislature, and published alone or with my husband (a retired university professor) numerous editorials and letters to the editor in local newspapers. My focus has been health issues and to some degree wildlife, in which I also have credentials in my PhD.

I get a lot of slander and abuse from the wind salesmen. Their favorites are saying that my abundantly referenced and footnoted articles, like the one before you (note: a separate handout), have "no evidence," or that I think wind turbines cause mad cow disease. The latter smear came from a town meeting in Ellenburg, NY, in October 2004, when I presented information culled from the medical literature on possible effects of low frequency noise. This included a paper out of the UK linking low frequency sound to prion diseases by a complex and highly speculative mechanism. I was very clear how speculative it was, but apparently the concept of something being speculative was over their heads, including over the heads of wind salesmen in the room.

I am not for or against the RPS. I'm an intelligent person and I support renewable energy. I am not here to shoot down wind energy, which probably has its place, though that place is not near people's homes or near schools, hospitals, or other locations where people have to sleep or learn.

I would like to stress that these are not "farms." One doesn't "farm" wind any more than one "farms" water in a hydroelectric dam or "farms" neutrons in an atomic plant. These are large, industrial installations. They make large-scale, industrial noise. "Jet engines" is the most common description I hear in surveying people—a jet engine that doesn't go away and which you can't get used to.

A syndrome in medicine is a constellation of symptoms and findings which is consistent from person to person. Defining a syndrome is the first step in investigating any new disease. The symptom cluster has to make sense in terms of pathophysiology—there has to be a plausible mechanism in terms of how the body and brain work. Defining a syndrome, and making that knowledge available to the medical community, lets other doctors go from scratching their heads over weird presentations of illness which are coming through their offices, to being able to validate and name what is going on and start to do something about it. It also opens the door to epidemiologic studies to define prevalence and risk factors, which will guide prevention and treatment.

Describing and documenting symptoms is the province of physicians. So is research on the causes of diseases. Deciding whether people have significant symptoms is not within the expertise of engineers or specialists in acoustics, even when the symptoms appear to be caused by noise. We physicians appreciate the noise data which engineers provide, but this data has nothing to do with whether people have symptoms or not. One British acoustics expert, Dr. Geoff Leventhall, is especially outrageous in this regard, insisting that people "can't" have symptoms because turbines "don't," he says, produce low frequency noise. His fallback, for which he is well paid by the industry, is that people make up their complaints. But he's not trained to distinguish whether people are making up their complaints, or to know about the range of physical, psychiatric, and neurological symptoms people might have. A related point: the hallmark of a good doctor is one who takes symptoms seriously and pursues them until they are understood (and ameliorated). This includes symptoms related to the brain, our most complex organ—symptoms which may be neurologic, psychiatric, or physical.

Three doctors that I know of are studying the Wind Turbine Syndrome: myself, one in England, and one in Australia. We note the same sets of symptoms. The symptoms start when local turbines go into operation and resolve when the turbines are off or when the person is out of the area. The symptoms include:

1) Sleep problems: noise or physical sensations of pulsation or pressure make it hard to go to sleep and cause frequent awakening.
2) Headaches which are increased in frequency or severity
3) Dizziness, unsteadiness, and nausea.
4) Exhaustion, anxiety, anger, irritability, and depression.
5) Problems with concentration and learning.
6) Tinnitus (ringing in the ears).

Not everyone near turbines has these symptoms. This does not mean people are making them up; it means there are differences among people in susceptibility. These differences are known as risk factors. Defining risk factors and the proportion of people who get symptoms is the role of epidemiologic studies. These studies are under way.

Chronic sleep disturbance is the most common symptom. Exhaustion, mood problems, and problems with concentration and learning are natural outcomes of poor sleep.

Sensitivity to low frequency vibration is a risk factor Contrary to assertions of the wind industry, some people feel disturbing amounts of vibration or pulsation from wind turbines, and can count in their bodies, especially their chests, the beats of the blades passing the towers, even when they can't hear or see them. Sensitivity to low frequency vibration in the body or ears is highly variable in people, and hence poorly understood and the subject of much debate.

Another risk factor is a preexisting migraine disorder. Migraine is not just a bad headache: it's a complex neurologic phenomenon which affects the visual, hearing, and balance systems, and can even affect motor control and consciousness itself. Many people with migraine disorder have increased sensitivity to noise and to motion---they get carsick as youngsters, and seasick, and very sick on carnival rides. Migraine-associated vertigo (which is the spinning type of dizziness, often with nausea) is a described medical entity. Migraine occurs in 12% of Americans. It is a common, familial, inherited condition.

To keep our balance and feel steady in space, we use three types of input: from our eyes (seeing where we are in space), from stretch receptors in joints and muscles, and from balance organs in the inner ear. At least two of these systems have to be working, and agreeing, to maintain balance. If the systems don't agree, as in seasickness or vertigo, one feels both ill and unsteady. Wind turbines impinge on this system in two ways: by the visual disturbance of the moving blades and shadows, and by noise or vibration impacting the inner ear.

Other candidate risk factors for susceptibility to Wind Turbine Syndrome are age-related changes in the inner ear. Five percent (5%) of otherwise healthy people from age 57 to 91 experience dizziness, and 24% experience tinnitus or ringing. Damage to the ears or hearing from other causes, such as noise exposure, is also a potential risk factor.

Inner ear organs are closely linked, by proven neurological connections, to the brain systems which control mood, anxiety, and one's sense of well-being. Disturbing the inner ear disturbs mood, not because a person is a whiner or doesn't like turbines, but because of neurology.

Data from a number of studies and individual cases document that in rolling terrain, disturbing symptoms of the Wind Turbine Syndrome occur up to 1.2 miles from the closest turbine. In long Appalachian valleys, with turbines on ridge-tops, disturbing symptoms occur up to 1.5 miles away. In New Zealand, which is more mountainous, disturbing symptoms occur up to 1.9 miles away.

In New York State, with its mixed terrain, I recommend a setback of 1.5 miles (8000 ft.) between all industrial wind turbines and people's homes or schools, hospitals, or similar institutions. This setback should be imposed immediately for turbines not yet built.

The legislature might want to set up a panel of clinicians to review the data and medical information I refer to here, but until this happens, and as research continues, a moratorium on all wind turbine construction within 1.5 miles of homes would be appropriate.

To recapitulate, there is in fact a consistent cluster of symptoms, the Wind Turbine Syndrome, which occurs in a significant number of people in the vicinity of industrial wind turbines. There are specific risks factors for this syndrome, and people with these risk factors include a substantial portion of the population. A setback of 1.5 miles from homes, schools, hospitals, and similar institutions will probably be adequate, in most NY State terrain, to protect people from the adverse health effects of industrial wind turbines.

Nina Pierpont, MD PhD

Fellow of the American Academy of Pediatrics

February 8, 2006

Education

1991	M.D.	The Johns Hopkins University School of Medicine
1985	Ph.D.	Princeton University (Behavioral Ecology)
1981	M.A.	Princeton University (Behavioral Ecology)
1977	B.A.	Yale University, National Merit Scholar (cum laude)

Post-Doctoral Training

1992 to 94	Pediatrics	Dartmouth-Hitchcock Medical Center, Lebanon, NH
1991 to 92	Pediatrics	Children's National Medical Center, Washington, DC
1985 to 86	Ornithology	American Museum of Natural History, New York, NY

Licensure and Certification

1997	Licensed Physician, New York
1997	Licensed Physician, New Hampshire (expired)
1995	Pediatric Advanced Life Support Instructor and Affiliate Faculty
1994	Diplomate, American Board of Pediatrics (recertified 2000, expires 2008)
1994	Licensed Physician, Alaska (expired)

Hospital or Affiliated Institution Appointments

10/00 to 12/03	Senior Attending in Pediatrics Bassett Healthcare, Cooperstown, NY
1997 to 00	Attending Pediatrician Alice Hyde Hospital, Malone, NY
1995 to 96	Chief of Pediatrics Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK
1994 to 95	Staff Pediatrician Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK

Other Professional Positions

2004 to ...	Private Practice (Solo) Pediatrics (emphasizing Behavioral Peds) Malone, NY
1998 to 00	Private Practice (Solo) Pediatrics Malone, NY (poorest county in state)
1997 to 00	Staff Pediatrician St. Regis Mohawk (Iroquois) Health Services, Hogansburg, NY
1997 to 98	Staff Pediatrician North Country Children's Clinic (clinic for needy children), Malone, NY

Academic Appointments

2000 to 03	Assistant Clinical Professor of Pediatrics Columbia University, College of Physicians and Surgeons

Noisy Wind and Hot Air

Nina Pierpont, MD, PhD

As well as being about wind turbine noise, the discussion between **North Country Advocates** and **Noble Environmental** is about credibility, and the validity of information and the validity of sources. I'm going to address both of these—the wind turbine noise issue, and how to decide what and who to believe.

With regard to technical studies, *hired consultants are always less credible than university scientists who are free of industry ties.* Consider the pharmaceutical industry in this country: because the research on ill effects is done by companies selling the products, ill effects are concealed, and we end up with debacles like the recent one with Vioxx. Noble Environmental quotes in public what their paid consultant, Dr. Leventhall, says about my thoughts on wind turbine sound (or perhaps Noble just wrote it themselves, since some of the physics, "Synchronization effects can be reduced by running the turbines unsynchronized," is not worthy of a high school student). Professor van den Berg, a university researcher, replied the following to Noble when they asked him about my March 2 Telegram piece:

> Indeed in the statement the term "low pitched thumping sound," a description of the sound character, seems to be equated to "low frequency noise," a technical term relating to a specific frequency range. The results of my investigations have not led to the conclusion that low frequency sound as such (implying sound of frequencies between 1 and approximately 200 Hz) are the likely cause of annoyance from modern wind turbines for most people. However, *noise from (tall) wind turbines has not been addressed properly by wind turbine (farm) managers and consultants*, and I can understand that residents who have become aware of that feel they have to further their arguments, but got confused by the technical jargon used in acoustics.
>
> You may use this statement publicly, but only in its entirety [as I, NP, have done here]. [1]

Now let us read the summary of Prof. van den Berg's paper, "Do wind turbines produce significant low frequency sound levels?" presented in August 2004 at the 11th International Meeting on Low Frequency Noise and Vibration and its Control, in which his answer is yes, they do, and this sound is significant, though its effect is indirect:

> Wind turbines produce low frequency sounds, but it has not been shown this is a major factor contributing to annoyance. Sound from wind turbines involves several sound production mechanisms related to different interactions between the turbine blades and the air. Low frequency sound is predominantly the result of the displacement of air by a blade and of turbulence at the blade surface.
>
> An important contribution to the low frequency part of the sound spectrum may be the result of the sudden variation in air flow the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimized for the mean flow.
>
> This effect probably has not been considered important, as the blade-passing frequency is of the order of one hertz (one beat per second), where human hearing is very insensitive. *This argument, however, obscures a very relevant effect: the low blade-passing frequency modulates well-audible (easily heard) higher frequency sounds and thus creates periodic sound.* This effect is stronger at night because, in a stable atmosphere, there is a greater difference between rotor-averaged and near-tower wind speed. Measurements have shown that more turbines can interact to further amplify this effect.
>
> The effect is confirmed by residents near wind turbines who mention the same common observation: often late in the afternoon or in the evening the turbine sound changes to a more "clapping" or "beating" sound, the rhythm in agreement with the blade-passing frequency. It is clear from the observations that this is associated to [with] a change to a higher atmospheric stability. The increased annoyance has not been investigated as such, although there are indications from [the] literature [that] this effect is relevant. *It is of increasing relevance as the effect is stronger for modern (that is: tall) wind turbines.* [2]

The university researcher (van den Berg), unlike Noble's paid consultant (Leventhall), states that the true noise issues are not being adequately addressed by wind farm developers or their consultants, and that wind turbines, contrary to what Noble is stating in its current public relations blitz, do produce low frequency sound. Van den Berg is investigating the complex way in which the low frequency vibrations of the blades passing the tower modify higher frequency sounds to produce the clapping or thumping noise that people even at some distance from wind turbines actually hear and complain about. In choosing what to investigate, he keeps his eye on what people are really experiencing.

What is significant about this research, too, is its discovery that taller turbines are louder than smaller ones, and its explanation of why wind turbines in general are so much noisier, at greater distances, than predicted by older sound propagation models. The answer is in the wind flow patterns higher above the ground, especially at night. [3] Van den Berg studies turbines with 328 ft. hub height. Even according to Noble's consultant, Leventhall, the older predictions for how sound will carry apply only up to about 130 ft. hub height, while the turbines proposed for Malone will be 265 (and possibly 390) ft. at the hub. Thus the constant refrain of the Noble salesmen, "The new technology won't have this problem…this study does not apply…that study does not apply…" is contradicted by university research published in peer-reviewed journals.

Given all this argument, and the slowness with which research catches up to people's experience, how do we keep neighbors' needs for peace and quiet from being swept under the carpet?

One way is not by trusting the pre-construction "study" of sound commissioned by Noble. This will not actually be a study (since the turbines will not be up). At worst it could be a generalized piece of writing with no mention of local conditions or terrain at all, like the report prepared by the same consultant (Leventhall) for a wind power developer in New Zealand last year. [4] At best it could be an exercise in *modeling* sound transmission over complex terrain in variable weather conditions, in a field of study in which the models themselves are in flux, changing as new information becomes available from existing wind farms. How will you and I, in Malone, be able to judge whether the models and variables are accurate and yield good results? We won't, of course, but we can be quite confident that a paid consultant will never reach the conclusion, for his client, that they can't go ahead with the project.

As an example of Noble's approach to the issue of pre-construction studies, let's turn to bird populations. This is my area of expertise, in which I have a PhD and scientific papers published in this country and abroad. The Noble representatives tell us that full and appropriate studies of bird and bat populations will be done before any turbines are erected. If this were truly Noble's intention, researchers would be in the field now, and Noble would not be talking about any turbine construction before 2007. [5] Since there are no researchers in the field on the south end of Malone, and the main season for bird studies is well under way, we are really talking about 2008 at the earliest, because two years of study through the whole seasonal cycle—summer plus the spring and fall migrations (which extend from mid-March to December)—are a minimum requirement. Of course, the less you study something, the less chance you have of actually finding out something which might slow down the project.

Since this is the nature of Noble's approach to bird studies, I suspect their approach in other areas, such as noise, aesthetics, hydrology, soil, economic impact, etc., will be similar.

How can we prevent this, and have recourse if the turbines are actually built? Both problems require a tough, well-written town ordinance, specifying how studies are to be conducted and their results reviewed before permits are issued and, for later recourse, an escrow fund or cash bond to be put up by the developers, also before permits are issued. The escrow fund should be managed by a community committee, and set up to provide as many forms of economic safety for the community as are allowed by law. In it there needs to be a decommissioning fund for each turbine, to take it down, remove the concrete footer, and restore the land to its original state at the end of the turbine's useful life. There need to be funds to cover damages to the health, property values, and quality of life of nearby residents, should these occur. It would be good, too, if we could protect the town against future unfavorable changes in state tax law which might allow wind turbines to escape local taxation altogether, as they did in the State of Kansas. [6] Wind energy companies have influence over tax law in both Washington and Albany, and there is already a New York State law on the books saying wind turbines are not subject to local taxes unless overridden by a specific local ordinance. Obviously, this override needs to be in our ordinance.

A powerful town ordinance has already been written for us by a group of lawyers. My husband, Calvin Luther Martin, circulated a preliminary version to the Malone Planning Board and Malone Town Board over a month ago, but it has now been refined and given a strong legal basis, anchored in the existing Malone Town Code. I urge townspeople to support a 6-month moratorium during which these issues are reviewed with the help of experienced outside counsel, followed by adoption of a strong regulatory ordinance that keeps our town and natural beauty from becoming another of civilization's waste heaps.

[1] GP van den Berg, personal communication, May 2, 2005.

[2] GP van den Berg, "Do wind turbines produce significant low frequency sound levels?" *Eleventh International Meeting on Low Frequency Noise and Vibration and its Control*, Maastricht, The Netherlands, 30 August to 1 September 2004, p. 1.

[3] GP van den Berg, 2004. "Effects of the wind profile at night on wind turbine sound." *Journal of Sound and Vibration* 277:955-970.

[4] Geoff Leventhall, "Notes on low frequency noise from wind turbines with special reference to the Genesis Power Ltd. proposal, near Waiuku, NZ," prepared for Genesis Power/Hegley Acoustic Consultants by Dr. Geoff Leventhall, June 4, 2004. Available from Dr. Leventhall at geoff@activenoise.co.uk.

[5] See Charles Hinckley, "Comments of Noble Environmental Power, LLC, in response to the initial facility certification and procurement notice (SAPA) No. 03-E-0188SA3, State Register, November 10, 2004," in which Noble Environmental informed the *NY* State Public Service Commission that "Noble is seeking to bring on line one or more wind generation facilities before the end of 2005." It appears from Noble's comments, in its petition to the PSC, that it is seeking an "expedited or fast-track" process, so as to "capture" the federal Production Tax Credit due to expire December 31, 2005.

[6] Glenn R. Schleede, "Misplaced State Government Faith in 'Wind Energy' - This Time by the Kansas Energy Council." Round Hill, VA, 3/1/05, available at: http://www.glebemountaingroup.org/Viewpoints.htm

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Wind power issues

To the editor:

I write in response to an article written by Denise Raymo which appeared 4/23/05 in the Press Republican, wherein my husband (Calvin Luther Martin) and I were interviewed about wind power. Since many folks read both the PR and the Telegram, and since the issues raised by Ms. Raymo's article impact our area significantly, I am submitting this letter to the Telegram.

A few quick clarifications: I am a pediatrician, not a psychologist. Second, the noise made by wind turbines is not constant; neighbors say it may be constant for days on end, and then the noise disappears for awhile.

With regard to mad cow disease: neither my husband nor I say that sound of any sort or turbines of any variety "cause" mad cow disease or any other prion disease. What we have said, and continue to say, is that there is a speculative paper in the medical literature laying out a hypothesis by which infrasound might be connected to prion disease (see Dr. Mark Purdey, Medical Hypotheses, 2003, vol. 60, no. 6, pp. 797-820). If we had not been widely misquoted by Noble Environmental in the first place (who were not even at the meeting where we brought this up) there would be no need to continue beating this dead horse (or cow).

With regard to low-frequency sound, I reviewed with Ms. Raymo a paper by the sound engineer G.P. van den Berg, a Dutch scientist ("Do wind turbines produce significant low frequency sound levels?" Eleventh International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, The Netherlands, 30 August to 1 September 2004, 8 pp.; contact g.p.van.den.berg@phys.rug.nl). Prof. van den Berg's paper unequivocally documents the low-frequency sound produced by wind turbines.

Moreover, most of the sound energy produced by wind turbines is in the lower frequencies. What I told Ms. Raymo was perhaps too complicated to include in a newspaper article, but it is my answer to repeated Noble assertions that wind turbines "do not" create low-frequency sound. They do, and the low-frequency sound has an important role in creating the pulsating quality of wind turbine noise at night, which is one of its most troubling features (see van den Berg, "Effects of the wind profile at night on wind turbine sound," Journal of Sound and Vibration, 2004, vol. 277, pp. 955-970; go to http://www.nowap.co.uk/docs/windnoise.pdf for a pre-publication copy).

Finally, I raised the issue of the Lincoln Township (Wisconsin) Wind Turbine Moratorium Survey not to provide evidence about low-frequency sound, but because Noble representatives are circulating the Survey's summary statistics here in Malone (and perhaps elsewhere) to refute data I used from the Survey's tables in my Telegram article of 3/2/05. The Survey asked people whether they were bothered by noise, flicker, lights and other issues during the first two years of wind turbine operation in 1999-2001. The summary statistics (which Noble is circulating) include all people who answered within two miles of the turbines. The data I quote break down these totals by distance from the turbines, so that we hear, for example, what people within half a mile are saying. Needless to say, the percentages complaining are higher closer to the turbines (e-mail me at rushton2@westelcom.com for a copy of the entire survey, or go to http://www.glebemountaingroup.org/Articles/Lincoln120403.doc for excerpts and comments).

Nina Pierpont, MD, Ph.D
Malone

NINA PIERPONT M.D. PH.D.

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February 8, 2006

To whom it may concern:

I was contacted recently by Daniel & Carolyn d'Entremont of Yarmouth County, Nova Scotia (Canada), to ask for my assistance explaining a variety of ailments they and their six children have been suffering over the past year—ever since 17 industrial wind turbines were built within a mile of their home (the nearest being 1000' away). (Incidentally, they found me by way of an article I published on the Internet a year ago on the health effects of wind turbines.)

The d'Entremonts and I had a lengthy phone conversation on February 4, 2006, wherein they described a variety of ailments that I recognized as being associated with long-term exposure to industrial low frequency noise. I assured them that their symptoms are no fabrication or illusion; they are genuine and confirmed by clinical literature.

In the interest of helping the d'Entremonts get these turbines turned off and getting these good people back into their home (which they are about to abandon), and back to good health, I offered to do a formal telephone interview, but this time to tape record it. The enclosed CD contains the recording of that interview, made with the d'Entremonts' permission both to make the recording and distribute it widely. Toward the end of the interview I offer my clinical judgment on their ailments.

The second enclosed CD contains photographs of the d'Entremont home showing the industrial turbines nearby. This CD has, in addition, photographs of the Fenner (New York) and Tug Hill Plateau (Lewis County, New York) windplants, illustrating the same problem: turbines sited far too close to people's homes. I can virtually guarantee that people in Fenner and on the Tug Hill Plateau who live within 1.5 miles of these turbines will suffer (or are suffering) from identical health effects described herein by the d'Entremonts. The medically irresponsible siting of turbines is not restricted to Nova Scotia, Fenner, and Tug Hill; it's a global problem.

I enclose, as well, a short report I did recently on the "Health effects of wind turbine noise" (2/4/06). This merely samples the literature on low frequency sound and strobing (from the propellers) impacting human health; I am happy to supply anyone, who wishes to see it, with further evidence from peer-reviewed scientific and clinical journals.

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May 12, 2006

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PERSONAL

Place of birth: Stamford, CT
Date of birth: May 18, 1955
Married with two grown stepchildren

EDUCATION AND TRAINING

Education

1991	M.D.	The Johns Hopkins University School of Medicine
1985	Ph.D.	Princeton University (Ecology, Evolution, and Behavior)
1981	M.A.	Princeton University (Ecology, Evolution, and Behavior)
1977	B.A.	Yale University (cum laude)
1973		Milton Academy, Milton, Mass.
1970		New Canaan Country Day School, Conn.

Post-Doctoral Training

1992 to 94	Pediatrics	Dartmouth-Hitchcock Medical Center, Lebanon, NH
1991 to 92	Pediatrics	Children's National Medical Center, Washington, DC
1985 to 86	Ornithology	American Museum of Natural History, New York, NY

Licensure and Certification

1997	Licensed Physician, New York
1997	Licensed Physician, New Hampshire (expired)
1995	Pediatric Advanced Life Support Instructor and Affiliate Faculty
1994	Diplomate, American Board of Pediatrics (recertified 2000, expires 2008)
1994	Licensed Physician, Alaska (expired)
1994	DEA Registration
1994	Advanced Trauma Life Support Provider
1994	Advanced Cardiac Life Support Provider
1992	Neonatal Advanced Life Support Provider

PROFESSIONAL APPOINTMENTS

Hospital or Affiliated Institution Appointments

10/00 to 12/03	Senior Attending In Pediatrics Bassett Healthcare, Cooperstown, NY
1997 to 00	Attending Pediatrician Alice Hyde Hospital, Malone, NY
1995 to 96	Chief of Pediatrics Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK
1994 to 95	Staff Pediatrician Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK

Other Professional Positions

2004 to ...	Private Practice (Solo) Behavioral Pediatrics Malone, NY (poorest county in state)
1998 to 00	Private Practice (Solo) Pediatrics Malone, NY (poorest county in state)
1997 to 00	Staff Pediatrician St. Regis Mohawk (Iroquois) Health Services, Hogansburg, NY
1997 to 98	Staff Pediatrician North Country Children's Clinic (clinic for needy children), Malone, NY

Academic Appointments

2000 to 03	Assistant Clinical Professor of Pediatrics Columbia University College of Physicians and Surgeons
1980 to 85	Teaching Assistant Princeton University
1978	Teacher Children's School of Science, Woods Hole, MA
1977 to 78	Research Assistant Yale University

LANGUAGES SPOKEN Spanish, French

AWARDS AND HONORS

1984	National Science Foundation Dissertation Grant (Princeton)
1979 to 82	National Science Foundation Predoctoral Fellowship (Princeton)
1979, 80	Dunlop Prize, Biology Department, Princeton University
1981 to 83	Research grants from the National Academy of Sciences, American Museum of Natural History, American Ornithologists' Union, and others
1973	National Merit Scholar to Yale University

MAJOR ADMINISTRATIVE RESPONSIBILITIES

1995 to 96	Chief of Pediatrics Yukon-Kuskokwim (Yup'ik Eskimo) Delta Regional Hospital, Bethel, AK

PROFESSIONAL SOCIETY INVOLVEMENT

1997 to ...	American Academy of Pediatrics Fellow

COMMUNITY SERVICE

1998 to 00	Physician member, Child Abuse Response Team, Franklin County, NY (poorest county in state)
1994 to 96	Physician member, Child Abuse Response Team, Yukon-Kuskokwim (Yup'ik Eskimo) Delta, AK

GRAND ROUNDS

spring 01	"Vaccinations: The Debate" at Bassett Healthcare (Cooperstown)
spring 02	"Attention Deficit Hyperactivity Disorder in Children" at Bassett Healthcare (Cooperstown)
spring 02	"Vaccinations: An Overview for Family Practitioners" at Bassett Healthcare (Cobleskill)
winter 03	"Learning Disabilities in Children" at Bassett Healthcare (Cooperstown)

BIBLIOGRAPHY

Original reports

Pierpont N, Fitzpatrick JW. Specific status and behavior of *Cymbilaimus sanctaemariae*, the Bamboo Antshrike, from southwestern Amazonia. Auk (Journal of the American Ornithologists' Union) 1983; 100: 645-52.

Terborgh JT, Robinson SK, Parker TA, Munn CA, and Pierpont N. Structure and organization of an Amazonian forest bird community. Ecological Monographs 1990; 60: 213-38.

Proceedings of Meetings

Pierpont, N. Competencia y coexistencia de trepadores [Competition and coexistence of woodcreepers]. In: Rios MA, ed. Reporte Manu. Lima, Peru: Centro de Datos para Conservacion, 1985, 13 pp.

Abstracts

Pierpont N. Interspecific dominance and the structure of woodcreeper guilds [Abstract]. American Zoologist 1983; 23: 1001.

Pierpont N. Interspecific aggression and the ecology of woodcreepers (Aves: Dendrocolaptidae). Ph.D. Dissertation, Princeton University, Princeton, NJ. Ann Arbor, Michigan: University Microfilms, 1986; Abstract No. 8602443.

Pierpont N. Habitat selection induced by interspecific aggression in Amazonian birds [Abstract]. Proceedings of the IV International Congress of Ecology, Syracuse, N.Y., 1986, p. 271.

Karron RA, Singleton RJ, Petersen KM, Bonilla D, Hughes B, Davidson N, Bulkow L, Pierpont N, Wainwright R, Santosham M, Harrison LH. RSV is a frequent cause of hospitalization in Alaska Native infants. Poster, ICAAC meeting, 1995.

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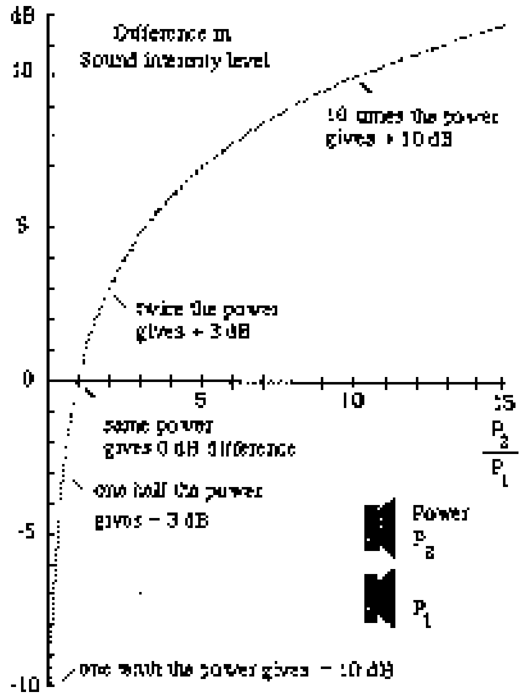
What is a decibel?

And what are the different types of decibel measurement: dB, dBA, dBC, dBV, dBm and dBi? How are they related to loudness? (A related page allows you to measure your hearing response and to compare with standard hearing curves.)

- Definition and examples
- Sound files to show the size of a decibel
- Standard reference levels ("absolute" sound level)
- Logarithmic response, psychophysical measures, sones and phons
- Recording level and decibels (dBV and dBm)
- dBi and radiation
- Example problems using dB for amplifier gain, speaker power, hearing sensitivity etc
- Related pages
- What is a logarithm? A brief introduction.



Plot of 10 log (P_2/P_1)

Definition and examples

The decibel (dB) is used to measure sound level, but it is also widely used in electronics, signals and communication. The dB is a logarithmic unit used to describe a ratio. The ratio may be power, sound pressure, voltage or intensity or several other things. Later on we relate dB to the phon and the sone (other units related to loudness). But first, to get a taste for logarithmic units, let's look at some numbers. (If you have forgotten, go to What is a logarithm?)

For instance, suppose we have two loudspeakers, the first playing a sound with power P_1, and another playing a louder version of the same sound with power P_2, but everything else (how far away, frequency) kept the same.

The difference in decibels between the two is defined to be

$$10 \log (P_2/P_1) \text{ dB} \qquad \text{where the log is to base 10.}$$

If the second produces twice as much power than the first, the difference in dB is

$$10 \log (P_2/P_1) = 10 \log 2 = 3 \text{ dB}.$$

If the second had 10 times the power of the first, the difference in dB would be

$$10 \log (P_2/P_1) = 10 \log 10 = 10 \text{ dB}.$$

If the second had a million times the power of the first, the difference in dB would be

$$10 \log (P_2/P_1) = 10 \log 1000000 = 60 \text{ dB}.$$

This example shows one feature of decibel scales that is useful in discussing sound: they can describe very big ratios using numbers of modest size. But note that the decibel describes a *ratio*: so far we have not said what power either of the speakers radiates, only the ratio of powers. (Note also the factor 10 in the definition, which puts the 'deci' in decibel).

Sound pressure, sound level and dB. Sound is usually measured with microphones and they respond (approximately) proportionally to the sound pressure, p. Now the power in a sound wave, all else equal, goes as the square of the pressure. (Similarly, electrical power in a resistor goes as the square of the voltage.) The log of the square of x is just 2 log x, so this introduces a factor of 2 when we convert to decibels for pressures. The difference in sound pressure level between two sounds with p_1 and p_2 is therefore:

$$20 \log (p_2/p_1) \text{ dB} = 10 \log (p_2^2/p_1^2) \text{ dB} = 10 \log (P_2/P_1) \text{ dB}$$ where again the log is to base 10.

Sound files to show the size of a decibel

What happens when you halve the sound power? The log of 2 is 0.3, so the log of 1/2 is −0.3. So, if you halve the power, you reduce the power and the sound level by 3 dB. Halve it again (down to 1/4 of the original power) and you reduce the level by another 3 dB. That is exactly what we have done in the first graphic and sound file below.

The first sample of sound is white noise (a mix of all audible frequencies, just as white light is a mix of all visible frequencies). The second sample is the same noise, with the voltage reduced by a factor of the square root of 2. The reciprocal of the square root of 2 is approximately 0.7, so −3 dB corresponds to reducing the voltage or the pressure to 70% of its original value. The green line shows the voltage as a function of time. The red line shows a continuous exponential decay with time. Note that the voltage falls by 50% for every second sample.

Note, too, that a doubling of the power does not make a huge difference to the loudness. We'll discuss this further below, but it's a useful thing to remember when choosing sound reproduction equipment.

Sound files and flash animation by John Tann and George Hatsidimitris.

If this animation doesn't work, or if you want .wav files, go to No flash version

How big is a decibel? In the next series, successive samples are reduced by just one decibel.

One decibel is close to the Just Noticeable Difference (JND) for sound level. As you listen to these files, you will notice that the last is quieter than the first, but it is rather less clear to the ear that the second of any pair is quieter than its predecessor. $10 \cdot \log_{10}(1.26) = 1$, so to increase the sound level by 1 dB, the power must be increased by 26%, or the voltage by 12%.

What if the difference is less than a decibel? Sound levels are rarely given with decimal places. The reason is that sound levels that differ by less than 1 dB are hard to distinguish, as the next example shows.

You may notice that the last is quieter than the first, but it is difficult to notice the difference between successive pairs. $10 \cdot \log_{10}(1.07) = 0.3$, so to increase the sound level by 0.3 dB, the power must be increased by 7%, or the voltage by 3.5%.

Standard reference levels ("absolute" sound level)

When the decibel is used to give the sound level for a single sound rather than a ratio, then a reference level must be chosen. For sound intensity, the reference level (for air) is usually chosen as 20 micropascals, or 0.02 mPa. (This is very low: it is 2 ten billionths of an atmosphere. Nevertheless, this is about the limit of sensitivity of the human ear, in its most sensitive range of frequency. Usually this sensitivity is only found in rather young people or in people who have not been exposed to loud music or other loud noises. Personal music systems with in-ear speakers ('walkmans') are capable of very high sound levels in the ear, and are believed by some to be responsible for much of the hearing loss in young adults in developed countries.)

So if you read of a sound intensity level of 86 dB, it means that

$$20 \log (p_2/p_1) = 86 \text{ dB}$$

where p_1 is the sound pressure of the reference level, and p_2 that of the sound in question. Divide both sides by 20:

$$\log (p_2/p_1) = 4.3$$

$$p_2/p_1 = 10^{4.3}$$

4 is the log of 10 thousand, 0.3 is the log of 2, so this sound has a sound pressure 20 thousand times greater than that of the reference level ($p_2/p_1 = 20,000$). 86 dB is a loud but not dangerous level of sound, if it is not maintained for very long.

What does 0 dB mean? This level occurs when the measured intensity is equal to the reference level. i.e., it is the sound level corresponding to 0.02 mPa. In this case we have

$$\text{sound level} = 20 \log (p_{measured}/p_{reference}) = 20 \log 1 = 0 \text{ dB}$$

So 0 dB does not mean no sound, it means a sound level where the sound pressure is equal to that of the reference level. This is a small pressure, but not zero. It is also possible to have negative sound levels: - 20 dB would mean a sound with pressure 10 times smaller than the reference pressure, ie 2 micropascals.

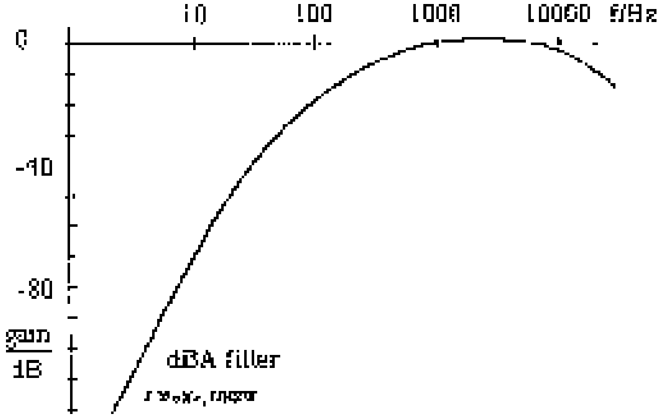
Not all sound pressures are equally loud. This is because the human ear does not respond equally to all frequencies: we are much more sensitive to sounds in the frequency range about 1 kHz to 4 kHz (1000 to 4000 vibrations per second) than to very low or high frequency sounds. For this reason, sound meters are usually fitted with a filter whose response to frequency is a bit like that of the human ear. (More about these filters below.) If the "A weighting filter" is used, the sound pressure level is given in units of **dB(A)** or **dBA**. Sound pressure level on the dBA scale is easy to measure and is therefore widely used. It is still different from loudness, however, because the filter does not respond in quite the same way as the ear. To determine the loudness of a sound, one needs to consult some curves representing the frequency response of the human ear, given below. (Alternatively, you can measure your own hearing response.)

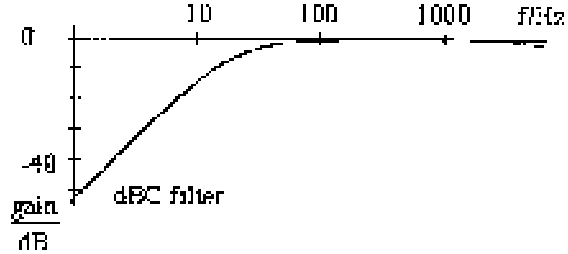
Logarithmic response, psychophysical measures, sones and phons

Why do we use decibels? The ear is capable of hearing a very large range of sounds: the ratio of the sound pressure that causes permanent damage from short exposure to the limit that (undamaged) ears can hear is more than a million. To deal with such a range, logarithmic units are useful: the log of a million is 6, so this ratio represents a difference of 120 dB. Psychologists also say that our sense of hearing is roughly logarithmic (see under sones below). In other words, they think that you have to increase the sound intensity by the same factor to have the same increase in loudness. Whether you agree or not is up to you, because this is a rather subjective question. (Listen to the sound files linked above.)

The filters used for dBA and dBC

The most widely used sound level filter is the A scale, which roughly corresponds to the inverse of the 40 dB (at 1 kHz) equal-loudness curve. Using this filter, the sound level meter is thus less sensitive to very high and very low frequencies. Measurements made on this scale are expressed as dBA. The C scale is practically linear over several octaves and is thus suitable for subjective measurements only for very high sound levels. Measurements made on this scale are expressed as dBC. There is also a (rarely used) B weighting scale, intermediate between A and C. The figure below shows the response of the A filter (left) and C filter, with gains in dB given with respect to 1 kHz. (For an introduction to filters, see RC filters, integrators and differentiators.)

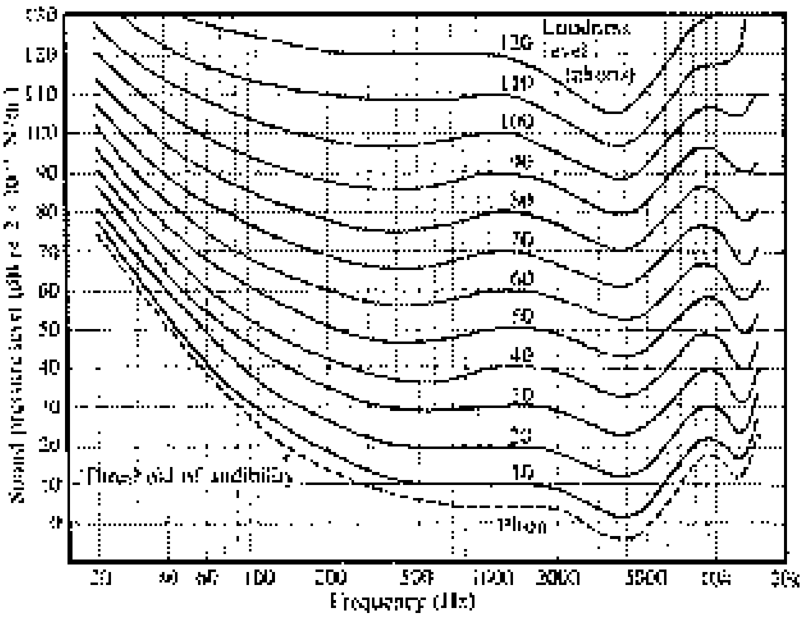




On the music acoustics and speech acoustics sites, we plot the sound spectra in dB. The reason for this common practice is that the range of measured sound pressures is large. We plot acoustic impedance spectra in dB for the same reason: the input impedance of a musical instrument, such as the flute, varies over a factor of several thousand.

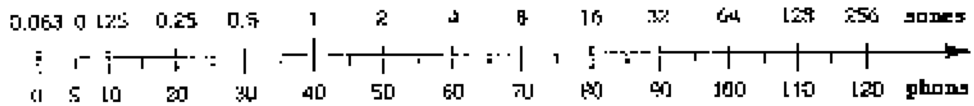
Loudness, phons and sones

The **phon** is a unit that is related to dB by the *psychophysically measured* frequency response of the ear. At 1 kHz, readings in phons and dB are, by definition, the same. For all other frequencies, the phon scale is determined by the results of experiments in which volunteers were asked to adjust the loudness of a signal at a given frequency until they judged its loudness to equal that of a 1 kHz signal. To convert from dB to phons, you need a graph of such results. Such a graph depends on sound level: it becomes flatter at high sound levels.



Curves of equal loudness determined experimentally by Robinson & Dadson in 1956, following the original work of Fletcher & Munson (Fletcher, H. and Munson, W.A. (1933) J.Acoust.Soc.Am. 6:59; Robinson, D.W. and Dadson, R.S.(1956) Br. J. Appl. Phys. 7:166. Plots of equal loudness as a function of frequency are often generically called Fletcher-Munson curves.)

The **sone** is derived from psychophysical measurements which involved volunteers adjusting sounds until they judge them to be twice as loud. This allows one to relate perceived loudness to phons. A sone is defined to be equal to 40 phons. Experimentally it was found that a 10 dB increase in sound level corresponds approximately to a perceived doubling of loudness. So that approximation is used in the definition of the phon: 0.5 sone = 30 phon, 1 sone = 40 phon, 2 sone = 50 phon, 4 sone = 60 phon, etc.



Wouldn't it be great to be able to convert from dB (which can be measured by an instrument) to sones (which approximate loudness as perceived by people)? This is usually done using tables that you can find in acoustics handbooks. However, if you don't mind a rather crude approximation, you can say that the A weighting curve approximates the human frequency response at low to moderate sound levels, so dBA is *very roughly* the same as phons. Then use the logarithmic relation between sones and phons described above.

Recording level and decibels

Meters measuring recording or output level on audio electronic gear (mixing consoles etc) are almost always recording the AC rms voltage (see links to find out about AC and rms). For a given resistor R, the power P is V^2/R, so

difference in voltage level = $20 \log (V_2/V_1)$ dB = $10 \log (V_2^2/V_1^2)$ dB = $10 \log (P_2/P_1)$ dB, or

absolute voltage level = $20 \log (V/V_{ref})$

where V_{ref} is a reference voltage. So what is the reference voltage?

The obvious level to choose is one volt rms, and in this case the level is written as **dBV**. This is rational, and also convenient with modern analog-digital cards whose maximum range is often about one volt rms. So one has to remember to the keep the level in negative dBV (less than one volt) to avoid clipping the peaks of the signal, but not too negative (so your signal is still much bigger than the background noise).

Sometimes you will see **dBm**. This used to mean decibels of electrical power, with respect to one milliwatt, and sometimes it still does. However, it's complicated for historical reasons. In the mid twentieth century, many audio lines had a nominal impedance of 600 Ω. If the impedance is purely resisitive, and if you set $V^2/600\ \Omega = 1$ mW, then you get V = 0.775 volts. So, providing you were using a 600 Ω load, 1 mW of power was 0 dBm was 0.775 V, and so you calibrated your level meters thus. The problem arose because, once a level meter that measures voltage is calibrated like this, it will read 0 dBm at 0.775 V even if it is not connected to 600 Ω So, perhaps illogically, dBm will sometimes mean dB with respect to 0.775 V. (When I was a boy, calculators were expensive so I used dad's old slide rule, which had the factor 0.775 marked on the cursor window to facilitate such calculations.)

How to convert dBV or dBm into dB of sound level? There is no simple way. It depends on how you convert the electrical power into sound power. Even if your electrical signal is connected directly to a loudspeaker, the conversion will depend on the efficiency and impedance of your loudspeaker. And of course there may be a power amplifier, and various acoustic complications between where you measure the dBV on the mixing desk and where your ears are in the sound field.

dBI and radiation that varies with direction

Radiation that varies in direction is called **anisotropic**: a source that emits sound (or something else) equally in all directions is called an isotropic source. When you want to emit in (or receive from) a particular direction, you want the ratio of intensity measured in that direction, at a given distance, to be higher than that measured at the same distance from an isotropic radiator. This ratio is called the **gain**; express the ratio in dB and you have the gain in dBi for that radiator. This unit is mainly used for antennae, either transmitting and receiving.

Example problems

A few people have written asking for examples in using dB in calculations. So...

- An amplifier has an input of 10 mV and and output of 2 V. What is its voltage gain in dB?

Voltage, like pressure, appears squared in expressions for power or intensity. (The power dissipated in a resistor R is V^2/R.) So, by convention, we define:

gain = 20 log (V_{out}/V_{in})
= 20 log (2V/10mV)
= 46 dB

(In the acoustic cases given above, we saw that the pressure ratio, expressed in dB, was the same as the power ratio: that was the reason for the factor 20 when defining dB for pressure. It is worth noting that, in the voltage gain example, the power gain of the amplifier is unlikely to equal the voltage gain. The power is proportional to the square of the voltage in a given resistor. However, the input and output impedances of amplifiers are often quite different. For instance, a buffer amplifier or emitter follower has a voltage gain of about 1, but a large current gain.)

- All else equal, how much louder is loudspeaker driven (in its linear range) by a 100 W amplifier than by a 10 W amplifier?

  The powers differ by a factor of ten, which, as we saw above, is 10 dB. All else equal here means that the frequency responses are equal and that the same input signal is used, etc. So the frequency dependence should be the same. 10 dB corresponds to 10 phons. To get a perceived doubling of loudness, you need an increase of 10 phons. So the speaker driven by the 100 W amplifier is twice as loud as when driven by the 10 W, assuming you stay in the linear range and don't distort or destroy the speaker. (The 100 W amplifier produces twice as many sones as does the 10 W.)

- If, in ideal quiet conditions, a young person can hear a 1 kHz tone at 0 dB emitted by a loudspeaker (perhaps a softspeaker?), by how much must the power of the loudspeaker be increased to raise the sound to 110 dB (a dangerously loud but survivable level)?

  The difference in decibels between the two signals of power P_2 and P_1 is defined above to be

  $\Delta L = 10 \log (P_2/P_1)$ dB   so, raising 10 to the power of these two equal quantities:

  $10^{L/10} = P_2/P_1$ so:

  $P_2/P_1 = 10^{110/10} = 10^{11}$ = one hundred thousand million.

  which is a demonstration that the human ear has a remarkably large dynamic range, perhaps 100 times greater than that of the eye.

A FAQ

A few people have written asking for examples of sounds in dB or dBA. How loud is an aircraft? A train? A person singing? A dog barking? A power tool? The answers to this question vary considerably. It depends strongly upon how far away you are, whether you are indoors or not, whether there is reverberation, how strong the particular source is and what its spectrum is. To give values, without being very specific about the conditions, would be somewhat misleading. Because the rest of this page is intended to be reliable, as far as it goes, I'd rather not give values here.

Related pages

- Measure your own hearing response
- What are interference beats and Tartini tones?
- FAQ in music acoustics
- Music acoustics home page
- A list of other educational web sites from this author.

© Joe Wolfe / J.Wolfe@unsw.edu.au phone 61-2-9385 4954 (UT + 10, +11 Oct-Mar) Joe's music site

What is a logarithm? A brief introduction.

First let's look at exponents. If we write 10^2 or 10^3 , we mean

$10^2 = 10*10 = 100$ and $10^3 = 10*10*10 = 1000$.

So the exponent (2 or 3 in our example) tells us how many times to multiply the base (10 in our example) by itself. For this page, we only need logarithms to base 10, so that's all we'll discuss. In these examples, 2 is the log of 100, and 3 is the log of 1000. If we multiply ten by itself only once, we get 10, so 1 is the log of 10, or in other words

$10^1 = 10$.

We can also have negative logarithms. When we write 10^{-2} we mean 0.01, which is 1/100, so

$10^{-n} = 1/10^n$

Let's go one step more complicated. Let's work out the value of $(10^2)^3$. This is easy enough to do, one step at a time:

$(10^2)^3 = (100)^3 = 100*100*100 = 1,000,000 = 10^6$.

By writing it out, you should convince yourself that, for any whole numbers n and m,

$(10^n)^m = 10^{nm}$.

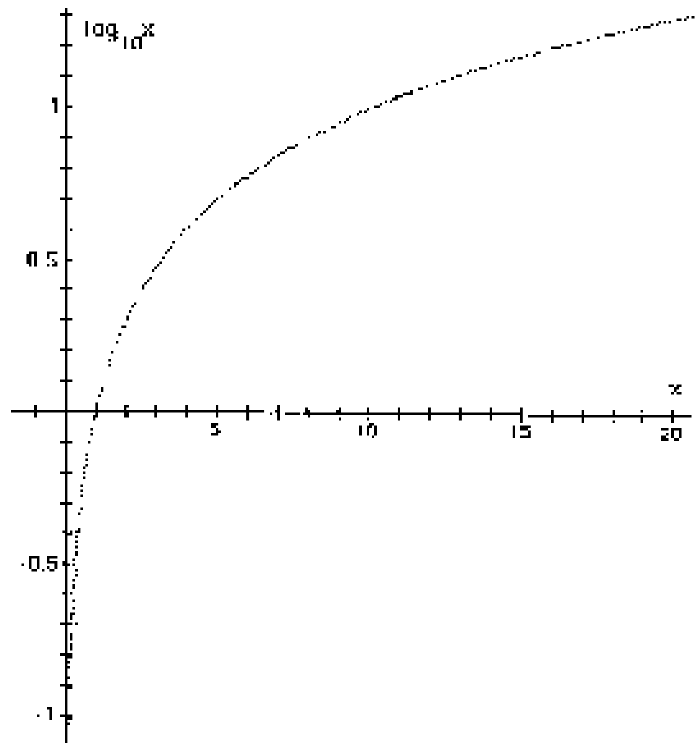
But what if n is not a whole number? Since the rules we have used so far don't tell us what this would mean, we can define it to mean what we like, but we should choose our definition so that it is consistent. **The definition of the logarithm** of a number a (to base 10) is this:

$10^{\log a} = a$.

In other words, **the log of the number a is the power to which you must raise 10 to get the number a.** For an example of a number whose log is not a whole number, let's consider the square root of 10, which is 3.1623..., in other words $3.1623^2 = 10$. Using our definition above, we can write this as

$3.1623^2 = (10^{\log 3.1623})^2 = 10 = 10^1$.

However, using our rule that $(10^n)^m = 10^{nm}$, we see that in this case log 3.1623*2 = 1, so the log of 3.1623... is 1/2. The square root of 10 is $10^{0.5}$. Now there are a couple of questions: how do we calculate logs? and Can we be sure that all real numbers greater than zero have real logs? We leave these to mathematicians (who, by the way, would be happy to give you a more rigorous treatment of exponents that this superficial account).

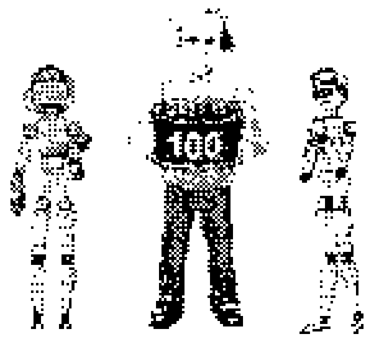


$\log_{10}x$ vs x.

A few other important examples are worth noting. 10^0 would have the property that, no matter how many times you multiplied it by itself, it would never get as large as 10. Further, no matter how many times you divided it into 1, you would never get as small as 1/10. Using our $(10^n)^m = 10^{nm}$ rule, you will see that $10^0 = 1$ satisfies this, so the log of one is zero. The log of 2 is used often in acoustics, and it is 0.3010 (see graph at right). Hence, a factor of 2 in power corresponds to 3.01 dB, which we should normally write as 3 dB because, as you can discover for yourself in hearing response, decimal points of decibels are usually too small to notice.

Go back to top of page.

Happy birthday, theory of relativity!



As of June 2005, relativity is 100 years old. Our contribution is Einstein Light: relativity in brief... or in detail. It explains the key ideas in a short multimedia presentation, which is supported by links to broader and deeper explanations.

The Strange Case of Dr. Geoff Leventhall

by

Calvin Luther Martin, PhD
Associate Professor of History (retired)
Rutgers University
New Brunswick, NJ

2-25-06

There is a man named Dr. Geoff Leventhall from the United Kingdom who hires himself out to wind energy companies as a noise consultant -- the noise being from industrial wind turbines.

The interesting thing about this Leventhall is that he insists, in the face of clear evidence to the contrary, that industrial wind turbines produce no low frequency noise (basically, infrasound). So he wrote in the *Malone (New York, USA) Telegram* this past autumn, "I have always said ... there is no problem of infrasound from wind turbines" (p. 4). Earlier this month (February 2006) he was quoted in the *Hawke's Bay Today (New Zealand)* newspaper as saying, "'I can state quite categorically that there is no significant infrasound from current designs of wind turbines.'"

Dr. Leventhall doesn't seem to know what he thinks. For when we turn to his May 2003 DEFRA (UK) "Review of Published Research on Low Frequency Noise and Its Effects," he writes: "Infrasound ... is common in urban environments, and as an emission from many artificial sources ... including wind turbines." Oops! Leventhall goes on: "The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low frequency noise compared with other noise" (p. 54). (Turn to the footnote back on p. 53 of the "Review" and we're told this section was "contributed by" Dr. P.L. Pelmear. This does not let Leventhall off the ethical hook, however; as lead author he must take full responsibility for everything in his report.)

Like I say, Leventhall doesn't seem to know what he thinks. For that matter, it's not clear he and his co-authors do the thinking they take credit for. When we turn to Dr. Birgitta Berglund's "Sources and Effects of Low-Frequency Noise" in the *Journal of the Acoustical Society of America* (May 1996), we find that the entire paragraph, above, appears to be lifted virtually verbatim from Berglund's article (compare the two paragraphs, below).

Hmmmm. Pelmear/Leventhall fail to acknowledge Berglund as their (apparent) source, nor do they put quotation marks around their text. A double infraction. (When I was a university professor, I gave students a failing grade for copying someone else's material without credit; indeed I had a colleague who was de-tenured and fired for publishing other people's text without credit.)

At a minimum, Leventhall appears to be careless. He also appears to be indecisive. Mostly, however, given the growing body of research on low frequency noise from industrial wind turbines (see GP van den Berg's scholarly articles, along with Dr. O. Soysal's noise measurements at the Meyersdale, PA, USA, windplant, and Dr. DMJP Manley's research), Leventhall seems to be a man representing, above all, the agenda of the wind energy companies (like Noble Environmental, LLC) that employ his services.

I have always said, and am now backed up by recent work from others, **that there is no problem of infrasound from wind turbines.**

--- Geoffrey Leventhall, *Malone (New York, USA) Telegram*, **9-12-05**, p. 4

Dr Geoff Leventhall, a noise vibration and acoustics expert from the UK who looked into infrasound at the request of Genesis Power, says "I can state quite categorically that there is no significant infrasound from current designs of wind turbines".

— Geoffrey Leventhall, *Hawke's Bay Today (New Zealand)*, **2-18-06**

Infrasound exposure is ubiquitous in modern life. It is generated by natural sources such as earthquakes and wind. It is common **in urban environments, and as an emission from many artificial sources: automobiles, ... aircraft, industrial machinery, artillery and mining explosions, air movement machinery including wind turbines, compressors, and ventilation or air-conditioning**

units.... The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low frequency noise compared with other noise.

. Geoffrey Leventhall, "A Review of Published Research on Low Frequency Noise and Its Effects," Report for DEFRA (United Kingdom) by Dr. Geoff Leventhall, Assisted by Dr. Peter Pelmear and Dr. Stephen Benton, **May 2003**, p. 54.

Low-frequency noise is common as background noise **in urban environments, and as an emission from many artificial sources: road vehicles, aircraft, industrial machinery, artillery and mining explosions, and air movement machinery including wind turbines, compressors, and ventilation or air-conditioning units. The effects of low-frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient** propagation, **and reduced efficacy of many structures (dwellings, walls, and hearing protection) in attenuating low-frequency noise compared with other noise.**

— B. Berglund, P. Hassmen, and RF Job, "Sources and Effects of Low-Frequency Noise," Journal of the Acoustical Society of America, vol. 99, no. 5 (**May 1996**):2985-3002, Abstract.

Letters to the editor

Not 'employee of Noble'

To the editor:

I am accustomed to having my views misrepresented by both sides of the wind farm debate, but in her letter published on August 30th, Kaye Johnson is going a bit too far. I believe that she has impugned my ethics, morality and scientific integrity. Although it would probably be futile to ask her for an apology, I expect you, as a party to this, to publish some facts.

I am not "an employee of Noble," a term which implies dependence on them for my income. I am an independent noise and vibration consultant and Noble is one of my many clients, contributing a very small part of my turnover.

I have never "provided the scientific community with hard evidence about the severity of the noise problem around industrial wind turbines." That is one of the many misrepresentations by objector groups. I am known internationally for my work on infrasound and low frequency noise, which is the area for which Noble retained me, as it is in these areas that I have made statements about wind turbine noise. I have been consistent in my views and am not now "singing a different song."

I have always said, and am now backed up by recent work from others, that there is no problem of infrasound from wind turbines.

Low frequency noise arises from the mechanical systems in wind turbines and from particular inflow air conditions. Mechanical noise is not a problem in modern wind turbines. Turbulent air inflow may increase levels of low frequency noise due to the interaction of the blades with the turbulence. This is normally an occasional occurrence for a turbine, if at all.

The regular swish – swish from wind turbines is not low frequency noise, but a change in level of a high frequency. This is an important point as, over the years, infrasound and low frequency noise have attracted a lot of negative baggage, which has been applied, incorrectly and without justification, to wind turbines. My advice to objector groups in this connection has been that, by squandering their energies on infrasound and low frequency noise, they are losing credibility and not giving sufficient attention to other factors, such as optimum siting of the turbines.

I am organising an International Conference on Wind Turbine Noise to be held in Berlin, Germany 17/18 October 2005 - see www.windturbinenoise2005.org – where it is hoped that delegates from all sides of the debate will be present.

Dr. Geoff Leventhall
Ashtead, Surrey, UK

"And the beat goes on . . .and on and on"

Hawke's Bay Today (New Zealand), February 18, 2006

KATHY WEBB

They call it the train that never arrives. It's a low, rumbling sound that goes on and on ... and on.

Sometimes, in a stiff easterly, the rumbling develops into a roar, like a stormy ocean.

But worst of all is the beat. An insidious, low-frequency vibration that's more a sensation than a noise. It defeats double-glazing and ear plugs, coming up through the ground, or through the floors of houses, and manifesting itself as a ripple up the spine, a thump on the chest or a throbbing in the ears. Those who feel it say it's particularly bad at night. It wakes them up or stops them getting to sleep.

Wendy Brock says staff from Meridian Energy promised her the wind turbines at Te Apiti, 2.5km [1.6 miles] from her Ashhurst home in southern Hawke's Bay, would be no noisier than waves swishing on a seashore.

"They stood in my lounge and told me that."

But during a strong easterly, the noise emitted by the triffid-like structures waving their arms along the skyline and down the slopes behind the Brock family's lifestyle block is more like a thundering, stormy ocean. Sometimes it goes on for days. And when the air is still, there's the beat - rhythmic and relentless, "like the boom box in a teenager's car".

"It comes up through the floor of our house. You can't stop it."

Mrs Brock says she can feel it rippling along her spine when she's lying in bed at night. Blocking her ears makes no difference.

"It irritates you, night after night. Imagine you've done your day's work, then you go to bed, and there's this bass beat coming up through the floor and you can't go to sleep. You can't even put headphones on and get away from it.

"My older son sometimes gets woken up by the noise. He gets up and prowls around the house."

She tells of other Ashhurst residents who "feel" the sound hitting their chests in the Ashhurst Domain 3km [1.9 miles] from the turbines. She says one woman is so distressed by the sensation she has put her home on the market.

Not everyone in the village hears the infrasound – Mrs Brock reels off the names of residents wondering what the fuss is all about – but says those who do feel the sound are distressed by it and have nowhere to turn for redress.

There's little point complaining to the Tararua District Council because all it does is record each complaint and forward it to Meridian, and nothing ever happens.

"What are they (the council) going to do to Meridian - fine them, or shut down the turbines?" asks Mrs Brock.

Meridian is dismissive of complaints about noise from Te Apiti.

"Infrasound is just not an issue with modern turbines," insists spokesman Alan Seay.

"We take it very seriously. We have looked into it seriously, but the advice we are getting from eminently qualified people is that it is just not an issue."

Many people claiming to be putting forward scientific argument about noise from turbines "are not qualified in this area of expertise. I have a problem with some of their statements", Mr Seay said.

He asked Hawke's Bay Today for the names of those complaining about noise from Te Apiti.

Asked why he wanted the names, he replied: "There is a group of people there. They are opposed to wind farms per se".

Asked why he thought they were opposed, Mr Seay said "I don't want to speculate. They just are. Possibly for the visual impact."

Meridian had complied with all legal requirements for sound emissions from Te Apiti, and "the people of Ashhurst are very happy to have those turbines there. They have become an icon," Mr Seay said.

Meridian is currently appealing noise restrictions placed on its proposed 70-turbine wind farm at Makara, near Wellington, where some houses will be about 1km [0.6 miles] away, and downwind of, the turbines.

John Napier lives on the Woodville side of the Te Apiti turbines, about 2km [1.24 miles] from the nearest one.

When they first began operating, he couldn't believe the roaring noise they made.

"We can hear it in our bedroom at night."

One night, about 2am, he got out of bed to check whether the bedroom windows were vibrating, and about five times since, he has been woken up and thought "they're making a racket tonight".

He doesn't hear the infrasound beat so much. It's mainly "a roar like a train going through a tunnel or over a bridge, but it never stops".

He complained to Meridian about the noise, and the company put a noise meter on his property for a couple of weeks, but wouldn't tell him the results.

"Wind farm companies say noise from turbines is not an issue, but it is an issue all right. I would be very concerned if I lived in Karori (near Makara, in Wellington)," Mr Napier said.

Harvey Jones, who lives in a valley 3km [1.9 miles] from Te Apiti, says there is an easterly wind blowing across the wind farm about 10 percent of the time. The wind goes across the top of the hill, but the noise from the turbines rolls down the valley. It sounds like a train constantly passing by, and the stronger the wind, the louder the noise. When there's a westerly blowing, he can even hear the turbines in Woodville, 6-7km [3.7 to 4.3 miles] away.

"Once you get tuned in to it you can easily pick it up," he says.

Mr Jones says the amount of noise generated by the Te Apiti turbines was unexpected, and landowners prepared to put turbines on their land at Te Pohue should think very carefully about the possibility of a repeat scenario.

He predicts disaster for the residents of Makara and Karori.

"They're going to get hammered, but they don't realise."

Steve Griffin, of Te Pohue, is secretary of the Outstanding Natural Landscape Protection Society, formed to oppose two windfarms proposed for his area on the Napier-Taupo road.

Lines company Unison has resource consent to put up about 50 turbines, and Hawke's Bay Windfarms plans to erect 75 turbines nearby.

The landscape protection society is appealing all the consents in the Environment Court.

Mr Griffin, who is "sick to death of wind farms", says the prospect of 128 giant industrial turbines visually disrupting pristine skyline and covering more than 16km [10 miles] of prominent mountain range near Te Pohue is bad enough. But he and other residents are worried sick about the noise potential -- both normal-range and infrasound – from the turbines. Each turbine will have an 80m tower and three 45m blades. They will be 125m high and 90m wide, each taking up the equivalent of 1.5 rugby fields.

They will encircle Te Pohue village and its school, in a valley downwind of the turbines in prevailing winds – and nobody in authority seems to care, he says.

The Government has thrown the doors wide open to wind farm developers, in a bid to meet its Kyoto commitments; there are no national guidelines specific to wind turbines. That stance is unbalanced and unfair, Mr Griffin says.

"Our view is that while wind farms are part of our energy solution, sites must be selected in a socially responsible manner.

"They should not be placed within 5km [3 miles] of schools, hospitals, rest homes, or the private homes of those not involved with a wind farm development."

They should also be kept out of coastal, and recreation areas, and those with high scenic value, he says.

The landscape protection society wants the Government to establish national guidelines for wind farms, and review noise-testing standards to include measurement of low-frequency sound.

Low-frequency sound – sometimes called infrasound – is controversial.

Dr Geoff Leventhall, a noise vibration and acoustics expert from the UK who looked into infrasound at the request of Genesis Power, says "I can state quite categorically that there is no significant infrasound from current designs of wind turbines".

He says "the ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it". Engineer Ken Mosley, of Silverstream, has an entirely different view.

The foundations of modern turbines create vibrations in the ground when they are moving, and also sometimes when they are not moving, Dr Mosley says.

"This vibration is transmitted seismically through the ground in a similar manner to earthquake shocks and roughly at similar frequencies.

"Generally, the vibrations cannot be heard until they cause the structure of a house to vibrate in sympathy, and then only inside the house. The effects inside appear as noise and vibrations in certain parts of a room. Outside these areas, little is heard or felt.

"However, the low frequency components of the noise and vibration can cause very unpleasant effects which eventually cause the health of people to deteriorate to an extent where living in the property can become impossible."

Dr Mosley says that wherever wind farms are built close to houses, people complain about noise and vibration.

He quotes a scientist in South West Wales, David Manley, who has been researching noise and vibration phenomena associated with turbines since 1994.

An acoustician and engineer, Dr Manley writes "it is found that people living within 8.2km [5 miles] of a wind farm cluster can be affected and if they are sensitive to low frequencies they may be disturbed".

Two GPs in the UK have researched the health effects of noise and vibrations from turbines. Amanda Harry documented complaints of headaches, migraines, nausea, dizziness, palpitations, sleep disturbance, stress, anxiety and depression. People suffered flow-on effects of being irritable, unable to concentrate during the day, losing the ability to cope.

Bridget Osborne, of Moel Maelogan, a village in North Wales, where three turbines were erected in 2002, is reported as saying "there is a public perception that wind power is 'green' and has no detrimental effect on the environment, but these turbines make low-frequency noises that can be as damaging as high-frequency noises.

"When wind farm developers do surveys to assess the suitability of a site they measure the audible range of noise but never the infrasound measurement - the low-frequency noise that causes vibrations that you can feel through your feet and chest.

"This frequency resonates with the human body, their effect being dependent on body shape. There are those on whom there is virtually no effect, but others for whom it is incredibly disturbing."

Dr Mosley says wind-power generators in New Zealand are aware of such literature on turbine noise and infrasound from all around the world.

"Are they therefore just ignoring what is happening in the rest of the world in the hope that once turbines are up and running, people will quietly endure, or when the noise/vibration situation really starts to damage their health, the community will cut their losses, leave their homes and quietly fade away? Of course, wherever they end up, they must still pay their electricity bills, which is rather like paying the landlord who has evicted you."

The New Zealand Wind Energy Association, which did not return calls from Hawke's Bay Today, acknowledges that turbines produce infrasound, but insists it is so minimal from modern turbines that human beings cannot perceive it. Its website says "there is no evidence to indicate that low frequency sound or infrasound from current models of wind turbine should cause concern."

Infrasound was more of a problem with older turbines, which had their blades downwind of the turbine tower, the association says.

"That caused a low frequency thump each time a blade passed behind the tower."

In contrast, modern turbines "have their blades upwind of the tower, thus reducing the level of this type of noise to below the threshold of human perception, thereby minimising any possible effect on human health or wellbeing".

The association has published excerpts of a report by Dr Leventhall, who suggests that infrasound is a concept that could be classified as pop-science, seized upon by emotionally-overwrought wind farm opponents.

"When a group of residents decides to object to a development, they often support each other with strong emotions, which can sometimes lead them astray. The emphasis on low-frequency noise is an example of this. Over the past 30 years there has been a great deal of confusion and misinformation about low frequency noise, mainly in the popular media. Much of it can best be described as "hot air" but complainants' uncritical acceptance of what they read in unreliable sources has two unfortunate effects:

- It detracts from those people who have genuine low-frequency noise problems, often from industrial exhaust fans, compressors and similar.
- It undermines the credibility of the complainants, who may be harming their own cause in their apparent 'grasping at straws' approach."

Dr Leventhall goes on to say "the rational study of low frequency noise, its effects and criteria for control, has been bedeviled by exaggerations, half-truths and misrepresentations, much of it fomented by media stories over the last 35 years. The result in the UK, and it is probably similar in other countries, is that an incorrect concept – 'low frequency noise is a hazard' – has taken root in the national psyche, where it lies dormant waiting for a trigger to arouse it. The current trigger is wind turbines."

Dr Leventhall says:

- High levels of low-frequency noise are needed before people can perceive it, and the levels must increase as frequency reduces.
- The ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it.
- When there are problems with predominantly low-frequency noise, that is because assessment methods do not cater for it. That leads to the noises being dismissed as not being a nuisance, which in turn leaves unhappy complainants in a distressed state.

Up on the Napier-Taupo road, the printer in Steve Griffin's office is working overtime in preparation for an Environment Court battle. It might be a David and Goliath confrontation, but there's too much at stake to sit back and take it quietly, he says.

Note: "*Hawkes Bay Today* is the regional daily newspaper for Hawkes Bay. Our circulation area ranges from Mahia in north to Dannevirke in the South and to the central ranges in the west. We are also the youngest newspaper in New Zealand, launched on May 3, 1999."

See:

http://www.hbtoday.co.nz/localnews/storydisplay.cfm?storyId=3673106&thesection=localnews&thesubsection=&thesecondsubsection

A Review of Published Research on Low Frequency Noise and its Effects

Report for Defra by Dr Geoff Leventhall
Assisted by Dr Peter Pelmear and Dr Stephen Benton

May 2003

many parameters measured was an insignificant (< 1.5 mm Hg) increase in the minimal arterial blood pressure. However, Borredon also reported that several of his subjects felt drowsy after the infrasound exposure.

13.2 **Effects on humans.** Infrasound exposure is ubiquitous in modern life. It is generated by natural sources such as earthquakes and wind. It is common in urban environments, and as an emission from many artificial sources: automobiles, rail traffic, aircraft, industrial machinery, artillery and mining explosions, air movement machinery including wind turbines, compressors, and ventilation or air-conditioning units, household appliances such as washing machines, and some therapeutic devices. The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low-frequency noise compared with other noise.

In humans the effects studied have been on the cardiovascular and nervous systems, eye structure, hearing and vestibular function, and the endocrine system. Special central nervous system (CNS) effects studied included annoyance, sleep and wakefulness, perception, evoked potentials, electroencephalographic changes, and cognition. Reduction in wakefulness during periods of infrasonic exposure above the hearing threshold has been identified through changes in EEG, blood pressure, respiration, hormonal production, performance and heart activity. Infrasound has been observed to affect the pattern of sleep minutely. Exposure to 6 and 16 Hz levels at 10 dB above the auditory threshold have been associated with a reduction in wakefulness (Landström and Byström, 1984). It has also been possible to confirm that the reduction on wakefulness is based on hearing perception since deaf subjects have an absence of weariness (Landström, 1987).

In moderate infrasonic exposures, the physiological effects observed in experimental studies often seem to reflect a general slowdown of the physiological and psychological state. The reduction in wakefulness and the correlated physiological responses are not isolated phenomena and the physiological changes are considered to be secondary reactions to a primary effect on the CNS. The effects of moderate infrasound exposure are thought to arise from a correlation between hearing perception and a following stimulation of the CNS. The participation of the reticular activating system (RAS) and the hypothalamus is thought to be of great importance. Taking this into account, changes in the physiological reactions are not just a question of whether the sound waves are above the hearing threshold. Furthermore reactions within the CNS, including RAS, hypothalamus, limbic system, and cortical regions are probably highly influenced by the quality of the sound. Some frequencies and characters of the noise are probably more effective than others for producing weariness.

A high degree of caution is necessary before ascribing the origin of physiological changes in working situations to infrasonic exposure because of their association. When analysing the factors promoting fatigue e.g. driving, many aspects have to be considered. The environment is usually a combination of many factors such as seat comfort, visibility, instrumentation,

1: J Acoust Soc Am. 1996 May;99(5):2985-3002. Related Articles, Links

Sources and effects of low-frequency noise.

Berglund B, Hassmen P, Job RF.

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The sources of human exposure to low-frequency noise and its effects are reviewed. Low-frequency noise is common as background noise in urban environments, and as an emission from many artificial sources: road vehicles, aircraft, industrial machinery, artillery and mining explosions, and air movement machinery including wind turbines, compressors, and ventilation or air-conditioning units. The effects of low-frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficacy of many structures (dwellings, walls, and hearing protection) in attenuating low-frequency noise compared with other noise. Intense low-frequency noise appears to produce clear symptoms including respiratory impairment and aural pain. Although the effects of lower intensities of low-frequency noise are difficult to establish for methodological reasons, evidence suggests that a number of adverse effects of noise in general arise from exposure to low-frequency noise: Loudness judgments and annoyance reactions are sometimes reported to be greater for low-frequency noise than other noises for equal sound-pressure level; annoyance is exacerbated by rattle or vibration induced by low-frequency noise; speech intelligibility may be reduced more by low-frequency noise than other noises except those in the frequency range of speech itself, because of the upward spread of masking. On the other hand, it is also possible that low-frequency noise provides some protection against the effects of simultaneous higher frequency noise on hearing. Research needs and policy decisions, based on what is currently known, are considered.

Publication Types:

- Review

MeSH Terms:

- Auditory Threshold
- Blood Pressure
- Cognition
- Comparative Study
- Female
- Hearing
- Humans
- Loudness Perception
- Male

67

Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms

Recommendations on the Siting of Windfarms in the Vicinity of Eskdalemuir, Scotland

Professor Peter Styles, Dr Ian Stimpson, Mr S Toon, Mr R England, Mr M Wright

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18 July 2005

Abstract

In order to meet, and in fact exceed, Kyoto targets, the UK government has set a challenging target of reducing the UK's carbon dioxide emissions by 60% by 2050. The development of renewable energy, especially wind power, will be an important contributor to the success of that policy.

Some 40% (in excess of 1 Gigawatt), of this wind generation capacity, was planned for the southern uplands of Scotland. However, the United Kingdom seismic monitoring site which constitutes our component of the Comprehensive Test Ban Treaty compliance for nuclear testing is situated at Eskdalemuir near Langholm in the Scottish Borders. The Ministry of Defence therefore placed a precautionary blanket objection to any wind farm developments within 80 km of Eskdalemuir in case this compromised UK capability to detect distant nuclear test and breached our agreement under the CTBT. This effectively removed at least 40% of the UK renewable wind resource identified by the DTI.

Because of our previous, unique experience in monitoring seismic vibrations from wind turbines in the UK, the Applied and Environmental Geophysics Group of the School of Physical and Geographical Sciences at Keele University, were asked by the MOD, the DTI and the British Wind Energy Association to investigate whether there was a solution to this impasse. By carrying out a detailed programme of seismic and infrasound measurements in the vicinity of several wind farms in Scotland we have been able to identify the characteristic frequencies and mode of propagation of seismic vibrations from wind turbines and develop a model for the integrated seismic vibration at the Eskdalemuir site which will be created by any distribution of wind farms. By carefully considering the present ambient background experienced at the monitoring site it has been possible to set a noise budget which is permissible at Eskdalemuir without compromising its detection capabilities, and we have demonstrated that at least 1.6 GW of planned capacity can be installed and have developed software tools which allow the MOD and planners to assess what further capacity can be developed against criteria established by this study.

Introduction

The Eskdalemuir Seismic Array (EKA)

Eskdalemuir in the Scottish Borders is the location of a monitoring facility operated by the British Geological Survey where seismological, magnetic and other environmental parameters are monitored because the site is located in a very quiet magnetic and seismic environment. Measurements include horizontal and vertical magnetic field components and declination, total field intensity, and absolute values of the geomagnetic field. Three-component seismological measurements are made at the sites. An environmental monitoring facility operates at Eskdalemuir, monitoring soil and air temperature, wind speed and direction; UV and nuclear radiation; sunshine; concentrations of ozone, SO2 and NOx gases; rainfall; humidity and surface wetness.

In addition the UK seismological array (EKA) operated by AWE Blacknest is also sited at Eskdalemuir. The facility at Eskdalemuir is part of the auxiliary seismic network of the International Monitoring System (IMS) being set up to help verify compliance with the Comprehensive Test Ban Treaty (CTBT) which bans nuclear-test explosions. So far the CTBT has been signed by 175 states, and ratified by 121. The UK and France were the first nuclear-weapons states to ratify the treaty. The facility at Eskdalemuir is to be upgraded to be an alternate primary IMS seismic station. The treaty requires that States Parties shall not interfere with the verification system, of which Eskdalemuir is an element.

The seismometer array at Eskdalemuir (EKA) (Figure 1) became operational on the 19 May 1962. The recording station comprises a recording laboratory, a seismological vault and an array of seismometers installed in pits spaced over an area 10 km square. The laboratory is situated on the eastern side of the Langholm-Innerleithen road (B709) about 30 km north of Langholm and 3 km north of the Eskdalemuir meteorological observatory. The seismological vault is about 400 m east south east of the laboratory, and the array lies to the east in the form of a cross with its centre, about 2.5 km from the laboratory. The latitude of the point of intersection of the two lines of the array is 55º 20' north and the longitude is 03º 09½' west. The array is situated across the watershed between tributary headstreams of the Teviot and Tweed flowing to the north-east, and headstreams of the Esk which generally flow to the south-west. The ground surface is largely open rolling moorland and forest plantations, which in is in many places peat covered. The altitude of the seismic pits varies from c 210 m to c 430 m. The isolated location ensures that microseismic interference is kept to a minimum. While there is very little light vehicular traffic on the Langholm-Innerleithen road logging trucks and heavy forestry machinery do use this road albeit intermittently.

Conclusions

At present there are no current, routinely implemented vibration mitigation technological solutions which can reduce the vibration from wind turbines. Technologies which are helpful in the reduction of vibration from mechanical systems **do** exist and in the long-term and at some additional cost it should be possible for manufacturers/developers to modify/augment these for application to wind turbines to reduce the levels of vibration transmitted into the ground.

However, the following conclusions are based on **current** turbine designs as built.

1 This analysis allows us to define an exclusion zone of 10 km within which **NO** windfarm/turbine development is acceptable

2 We recommend that in order to optimise total energy generation, it would be inadvisable to permit any additional windfarms of **current** design to be permitted within 17.5 km of Eskdalemuir as these will effectively sterilise the whole region from generating additional capacity.

3 It allows us to calculate that presently consented and planned windfarms as defined in Table 4, will not exceed the limit of 0.336 nm for approximately 80% of the time and that during the remaining 20% of the time where they ***might*** exceed the limit, the ambient background noise at Eskdalemuir will also be higher than the median value and as discrimination will be sub-optimal during these periods of higher windspeed this is acceptable.

4 Beyond 50 km, we do not anticipate that **ANY** reasonable windfarm development will have an impact on the detection capabilities of Eskdalemuir.

5 There is some limited headroom for additional capacity with currently available turbine designs ***IF*** it is required, up to the aggregate noise level of 0.336 nm, but we would strongly recommend that in order to maximise the energy generation capability this takes place at distances greater than 25 km from Eskdalemuir. The algorithms developed here will permit this to be assessed.

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Why the Taralga Windfarm Environmental Impact Statement – Noise Impact Assessment is critically flawed

Andrew Miskelly BCompSci*
January, 2005

* The meteorological content of this document has been viewed and verified by C. Arthur BSc (Hons), a qualified meteorologist currently employed by The Weather Co.

This document aims to illustrate why the Noise Impact Assessment (NIA) provided in the Environmental Impact Statement (EIS) for the Taralga Windfarm is flawed to the point that it has no real value. It will focus on the fact that the NIA has made an assumption which is only applicable a certain amount of the time. That assumption is that the wind speed at a reference height of 10 metres can be related to the wind speed at turbine height using a linear logarithmic equation, and can thus be used to calculate the likely noise output of turbines. It will show that the predicted noise output from turbines with respect to background noise on nearby premises has likely been underestimated in the NIA and will suggest that the proposal be rejected on these grounds, or at least that the NIA be repeated after more suitable input data has been acquired.

Contents

A soft copy of this document may be found online at
http://members.ozemail.com.au/~amiskelly/windfarm_taralga_submission_noise_am.pdf

Introduction

The Environmental Impact Statement (EIS) for the Taralga Windfarm includes a Noise Impact Assessment (NIA) which is detailed in Appendix H. Appendix H states the following in its introduction (Taralga EIS, Appendix H, p1).

"[The NIA] describes the assessment of the likely acoustic impact of the proposed Taralga wind farm. Noise can have an effect on the environment and on the quality of life enjoyed by individuals and communities."

The NIA also correctly states the following, under the heading '1.5 Background Noise Survey' (Taralga EIS, Appendix H, p7):

"...background noise levels depend upon wind speed, as indeed do wind turbine noise emissions..."

The NIA follows the guidelines set out in the 'Environmental Noise Guidelines - Wind Farms' (produced by the EPA-SA) and uses a method described in the 'Acoustic Report for a Wind Energy Converter Type NEG Micon NM 82/1650' to calculate the likely noise output of wind turbines.

The latter document describes how a method of calculating noise output of turbines was formed for which wind speed data at a height of 10 metres could be used as input. This involved calculating the 'standardised wind speed' at 10m using the actual wind speed at turbine height, which in this case was 96.5 metres (Acoustic Report - NM 82, p11), over a period of 4 hours during the day (Acoustic Report - NM 82, p7). Presumably the purpose of forming this method was to make noise assessments easier for prospective users of the turbine.

The NIA is summarised in Volume 1 of the EIS and states the following (Taralga EIS, Volume 1, p5.19):

"A unique characteristic of windfarms is that the noise level from each wind turbine increases as the wind speed at the site increases. As an offset, the background noise also generally increases under these conditions and masks the noise from the turbine."

Unfortunately both the method described by the NEG report and the statement made above are too simplistic for practical use in Taralga's case. This statement is only applicable a certain amount of the time but despite this it is the principle on which the integrity of the entire NIA depends.

The reason the statement is simplistic is that it assumes that the wind speed at a height of 10 metres (which is related to background noise) is relatable to the wind speed at turbine height (which is related to turbine noise – both aerodynamic and mechanical). This assumption does not account for all situations and is generally only applicable during daylight hours.

In fact it is very common for a meteorological condition to arise where the wind speed at the surface and at a height of 10 metres is nil or very light, but the wind speed at turbine height (69 metres in Taralga's case) remains well above cut-in speed. This condition is generally brought about by a nocturnal temperature inversion.

The effect of this is that there is no ambient noise at the surface as the wind has been displaced upwards by the inversion layer, but the turbine noise remains as wind speeds at turbine height are unaffected by the surface inversion.

The fact that the NIA does not address the occurrence of this condition is a major oversight. A strong and well defined nocturnal temperature inversion is extremely common all over the Tablelands due in part to their elevation and inland location. The result of this oversight is that the turbine noise figures produced in the NIA are likely to be badly underestimated at times when this condition occurs (generally at night when people are trying to sleep).

The nocturnal (radiation) temperature inversion

Nocturnal temperature inversions come about due to the land's ability to absorb solar heat during the day and radiate it rapidly after sunset.

During daylight hours the temperature profile of the planetary boundary layer (PBL) is maintained by deep convective mixing which occurs due to solar heating of the surface. This mixing breaks down any stratification (layers) that may form in the lower atmosphere and means that wind blows relatively uniformly throughout, though increasing with height as friction with the surface becomes less of a factor (this increase is known as 'wind gradient').

On reasonably sunny days where convective mixing is occurring, a logarithmic profile for wind speed is suitable.

After sunset the surface cools rapidly as heat is radiated back into the atmosphere. Through conduction, the surface layer (the lowest few metres) of the atmosphere also cools rapidly resulting in a shallow, stable and dense layer near the surface. Above this layer the temperature rises rapidly and the nocturnal inversion is formed. Because the inversion grows largely through conductive processes, it slowly increases in depth, with a maximum depth of some tens of metres usually reached just before dawn (at which time the effects of solar radiation will break down the inversion once more).

All frictional effects become confined to the shallow surface layer, and the atmosphere above this layer is decoupled from normal frictional effects. This results in near-surface winds becoming calm (or almost calm), while winds above the inversion remain at a similar speed to the pre-sunset surface winds. In fact it is not unusual for the winds above the inversion to accelerate because of the reduced friction on the bottom boundary (the inversion results in an almost 'free slip' bottom boundary condition for the flow – a condition associated with a well documented phenomenon known as the 'nocturnal jet').

The development of a nocturnal inversion is not dependent on near-calm conditions. While near-calm conditions will result in faster growth of the inversion, it is still common for the inversion to develop when wind speeds are significant. This is demonstrated below under the heading 'an example from the EIS' using data from Goulburn Airport automatic weather station.

The nocturnal inversion has been recognised as a hazard to aviation at HMAS Albatross, Nowra. In a document entitled 'Winter Westerlies' the Station's Meteorological Officer states the following (Lance, 2004):

"Cooling of the ground over night causes the lowest few hundred of feet of the atmosphere to cool, creating a temperature inversion near the surface. This inversion causes the winds at the surface to decouple from the winds above, creating large amounts of wind shear. This also creates a false impression of the upper wind conditions due to light winds at the surface."

In situations where a nocturnal inversion has developed, it is not possible to relate a 10 metre wind speed to the wind speed above the inversion layer. A logarithmic profile will at the very least underestimate the wind speed drastically, and if the 10 metre winds are calm then the data is certainly unrepresentative.

Image 1 and image 2 graphically depict typical day time and night time conditions respectively.

Image 1

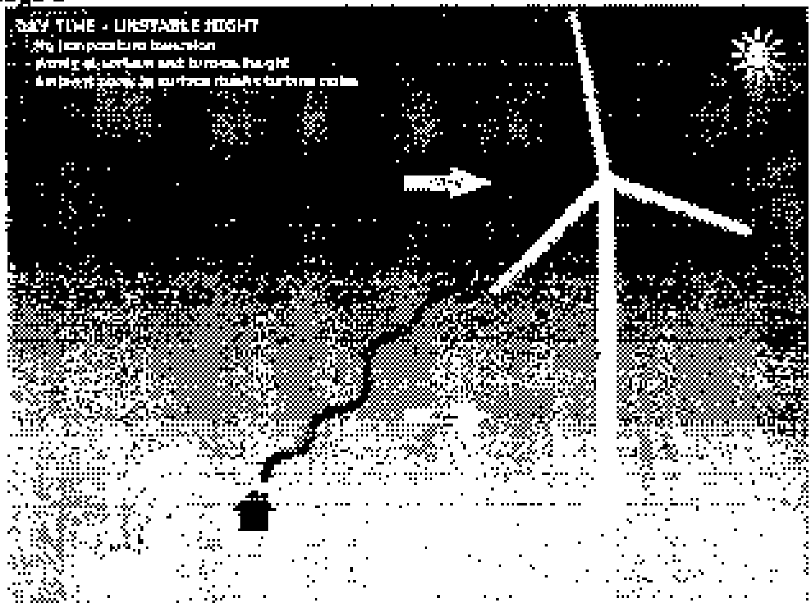


Image 1 shows a typical lower atmosphere during the day time and on less stable nights where a surface temperature inversion is not allowed to form. The lower atmosphere is mixed by convection that occurs during the day, thanks to solar heating of the surface. The wind blows right throughout the lower atmosphere and increases with height as friction with the surface becomes less of a factor. This increase with height is known as wind gradient.

Image2

Image 2 shows the situation on a stable night. After sunset the earth's surface commences radiation of heat back into the atmosphere. This radiation results in the formation of a layer of cold, dense, still air which grows in depth, upwards from the surface as the night progresses. This dense layer displaces the mixed, windy layer upwards until it is broken down once more by convection when the sun rises the following morning.

The scenario depicted in image 2 is most common under the following conditions:

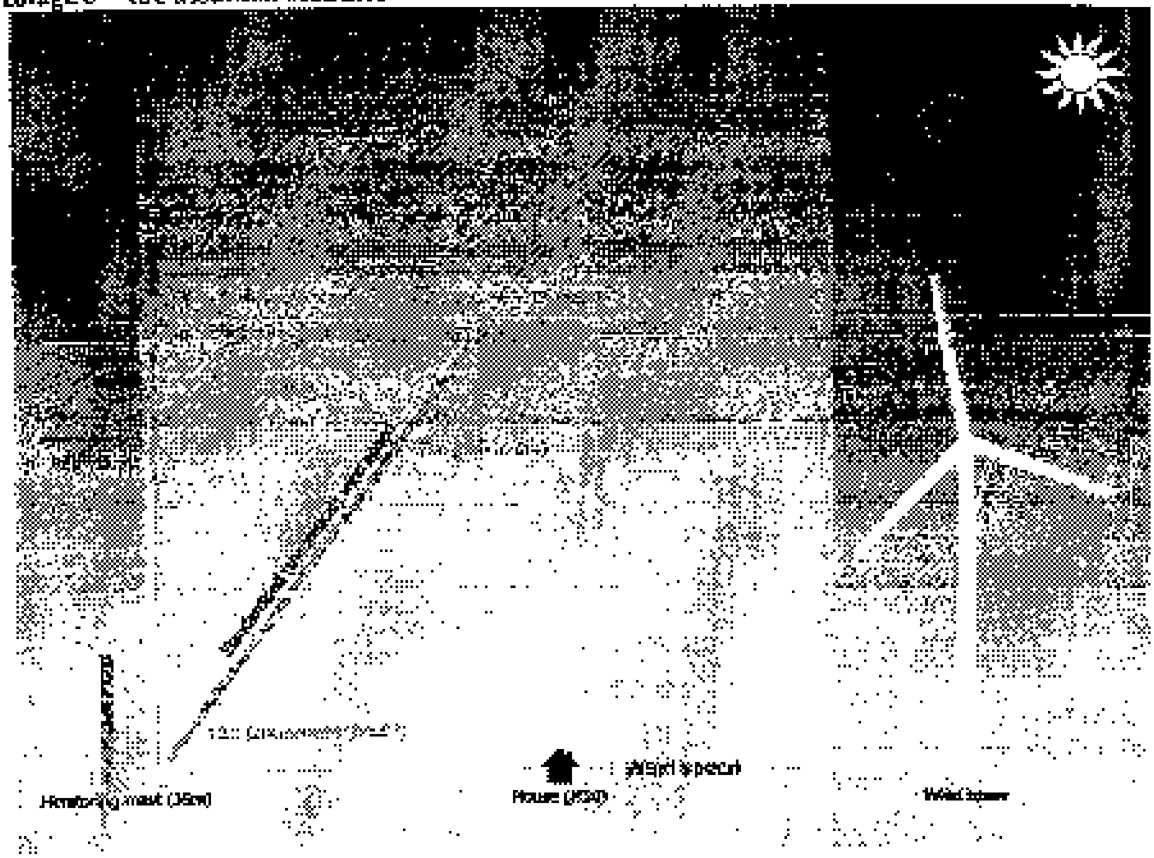
- at inland locations, away from maritime influence
- at elevated locations where radiation into the atmosphere is more pronounced
- in winter when the surface is cold

The Taralga area and indeed the greater Tablelands meet both of the first two criteria which is why they are famous for cold, frosty nights and mornings in autumn, winter and spring (Foley, 1945, p17). Radiative frosts occur in the cold, still conditions underneath a temperature inversion

The Noise Impact Assessment's assumption versus reality

The difference between the lower atmospheric conditions assumed by the NIA, and the conditions in reality with a surface temperature inversion in place are illustrated below

Image 3 – the assumed scenario



Description of Image 3 – the assumed scenario

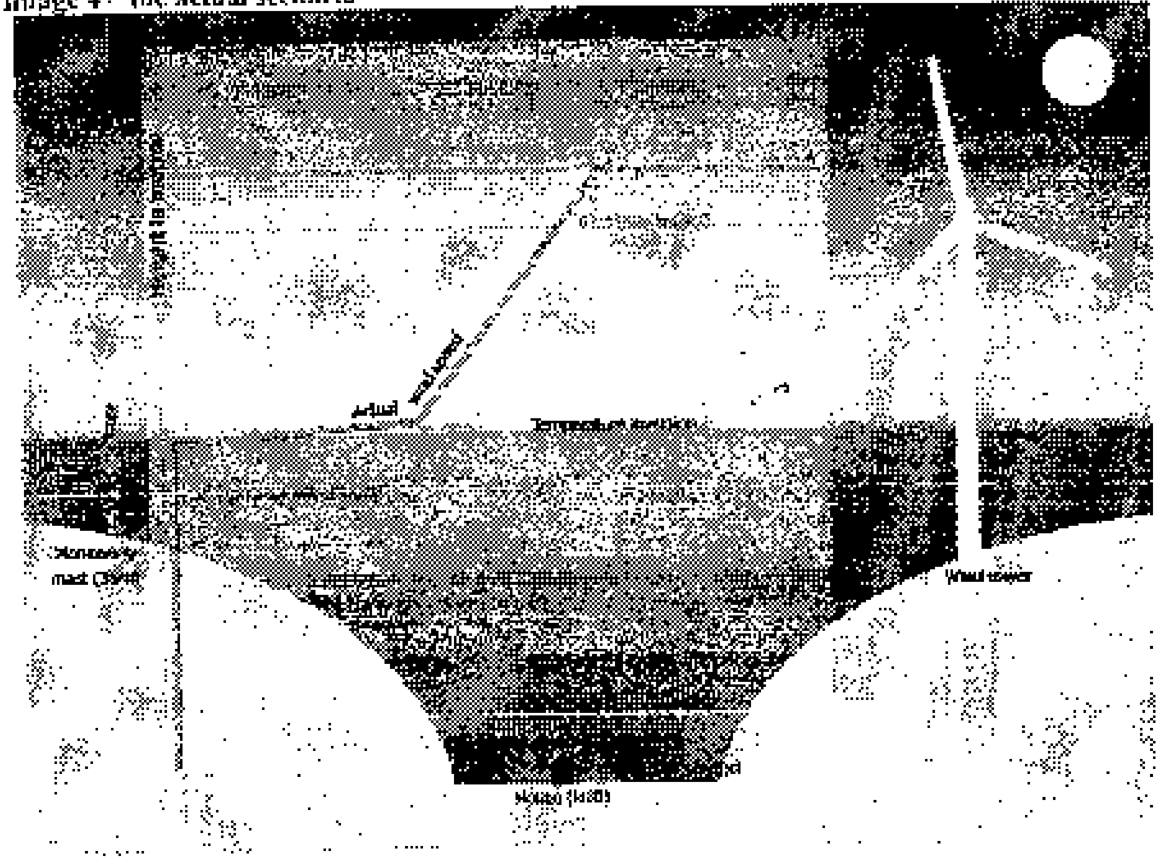
Monitoring mast: The existing monitoring masts associated with the site stand at a height of 35 metres, though wind data for the noise assessment has been used from 10 metres.

House: In this example we will look at H10 – "Killarney" (Taralga EIS, Appendix H, p3).

Wind tower: The wind tower stands at a height of approximately 110 metres with the hub at 69 metres (Taralga EIS, Volume 1, p2.10).

Height in metres vs Wind speed: The graph shows in simple form (the relationship depicted is not logarithmic) the assumption that the NIA makes. That is, that wind speed is related to height and that the wind speed at hub height can be calculated from the wind speed at a lower anemometer height (10m). Thus it assumes that turbine noise output can be calculated using the 10m wind speed This assumption is meteorologically unsound.

Image 4 - the actual scenario



Description of image 4 – the actual scenario

Monitoring mast: The bases of the monitoring masts associated with the site are all at an elevation of approximately 920 metres. One of these is located adjacent to T10 (Taralga EIS, Vol. 1, figure 2.4).

House: H10 – "Killarney" – is at an elevation of 886 metres. It is located 513 metres to the north of wind tower T10 (Taralga EIS, Appendix H, pp3-4)

Wind tower: The base of wind tower T10 is at an elevation of approximately 920 metres. It stands on a hill 513 metres to the south of H10. The blades of the wind tower are high enough above the surrounding terrain (up to 142m above H10) to be well clear of any surface temperature inversion, thus the turbine is operational.

Temperature inversion: A nocturnal, surface temperature inversion has formed, as described above.

By the early hours of the morning the cold, still layer underneath it has developed to a depth of around 50 metres. There is no ambient noise whatsoever around the house.

Above the temperature inversion a moderate wind is blowing. The wind turbines are operational

Height in metres vs Wind speed: The graph shows how the wind profile might appear through the lower atmosphere. Underneath the temperature inversion conditions are calm as the cold, dense air hugs the surface. Around the level of the temperature inversion the wind speed increases rapidly to the free atmospheric wind speed. Above the level of the temperature inversion the wind speed increases as consistent with the wind gradient.

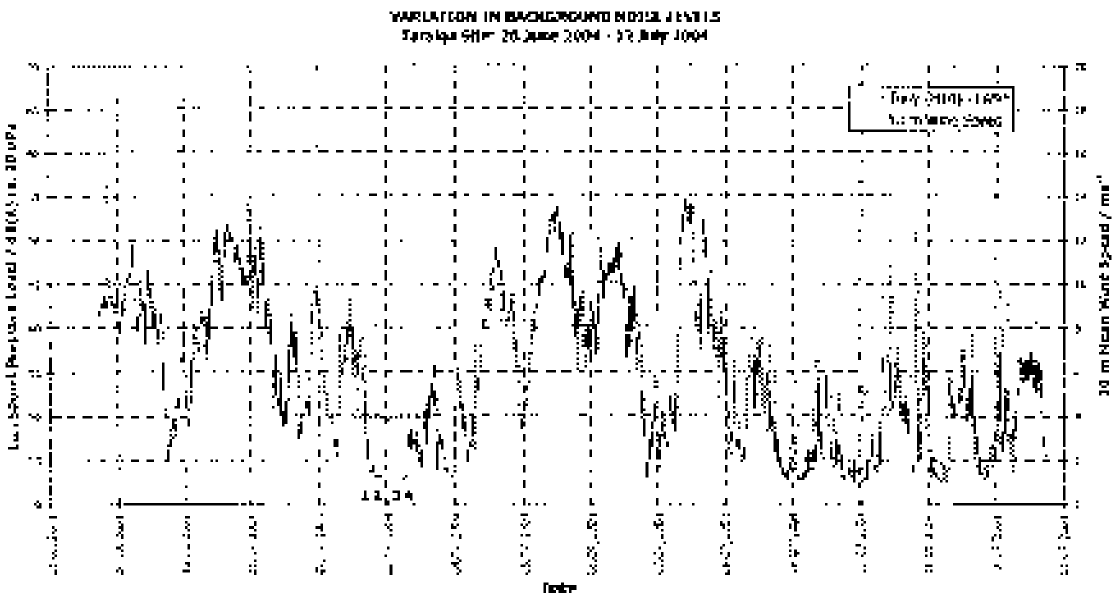
What is demonstrated here is that under the conditions depicted by image 4 and described above, the method used by the NIA would have produced a 10 metre wind speed of zero, a background noise level of zero and a turbine noise output level of zero (due to its inclusion of 10 metre wind speed as a factor). In reality the 10 metre wind speed and hence background noise level were indeed both zero, but the turbine noise output level was above zero (due to the 69 metre wind speed being the required factor).

A real-life example from the EIS

Below is a graph which appears in the NIA (Taralga EIS, Appendix H, p17). It displays the measured background noise at H10 against the wind speeds at a height of 10 metres (around 44 metres above H10) measured nearby.

Image 5

Figure 1.5 Measured Background Noise Levels at Taralga – Phase 1



I have highlighted the period representing the night of July 2 (into July 3), 2004 for consideration. It is an example of what image 4 above depicts in action.

At time (1) - the evening of the 2nd - we see the background noise levels at H10 drop off rapidly. This is an indication that the sun has just set and the surface inversion has begun to form. At this time even the 10 metre winds are above turbine cut-in speed (approximately 4ms^{-1} (Taralga EIS, Volume 1, p2.10), highlighted in red).

Between times (1) and (2) there is near-silence at H10 as the ground radiates heat and the inversion layer deepens but the wind speeds at 10 metres suggest that the wind speeds at 69 metres would certainly be strong enough for the turbines to remain operational.

At time (3) – the early hours of the morning of the 3rd - the inversion layer finally reaches 10m at the monitoring mast (44 metres higher than H10). The briefness of the period of calmness at the monitoring tower suggests that as in image 3 the inversion layer didn't get any deeper and the turbines were likely to be operational throughout the period. There is complete silence at H10.

At time (4) – mid-morning on the 3rd - the inversion layer finally breaks down and the fog clears as the ground is heated once more by the sun. The winds that have been present above the inversion layer all along are once again allowed to mix back down to the surface and ambient noise returns at H10.

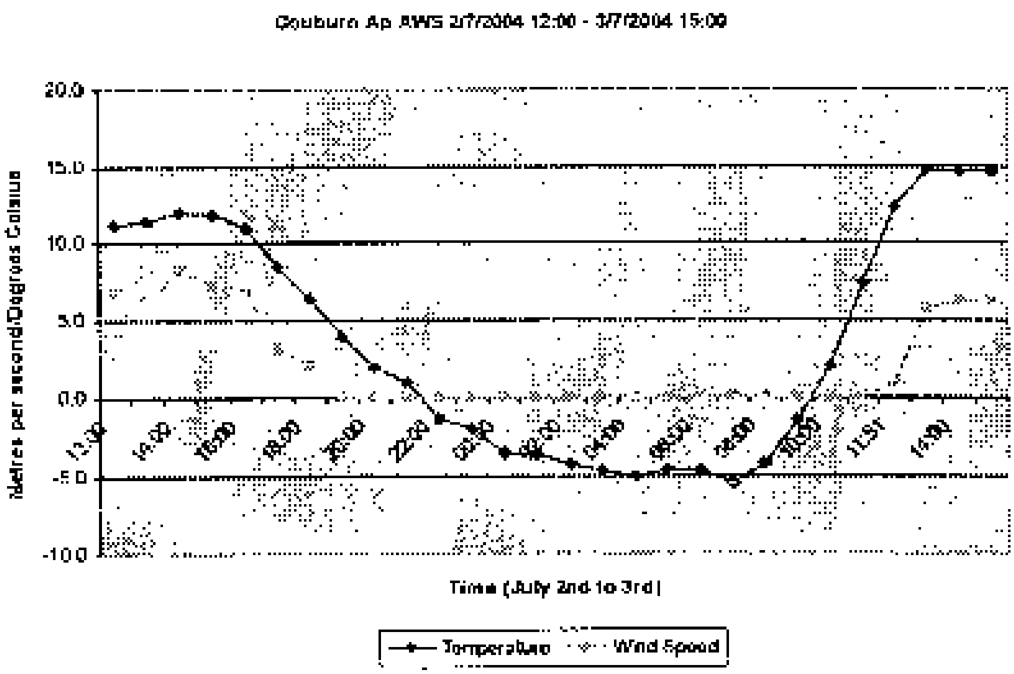
The data in the graph confirms that this pattern is quite common, particularly that data in the final week of the survey. Note that the survey only spans a little over a fortnight.

For extra background I have included and summarised some independent and more detailed meteorological observations from both the Taralga Post Office manual weather station and the Goulburn Airport automatic weather station for 2nd and 3rd (Bureau of Meteorology).

Firstly, the observations from Taralga Post Office are noted and summarised below.

Time	Weather	Summary
9am, July 2.	Weather: None. Wind: Moderate westerly Temperature: 7.4°C	This indicates that winds were present during the 2nd. These winds are displaced upwards some tens of metres overnight by the surface inversion.
Daytime, July 2.	Maximum temperature: 11°C	1°C above average.
Nighttime, July 2.	Minimum temperature: -4°C	The severity of the frost indicates that a deep surface inversion formed.
9am, July 3.	Weather: Fog clearing. Wind: Calm. Temperature: 0.5°C	The clearing fog and the temperature both indicate that the inversion is still breaking down. The timing is consistent with the indications of the graph in image 5.

Secondly, the temperature and wind speed at a height of 10 metres at Goulburn Airport are graphed below for the period between midday on July 2 and 15:00 on July 3. This data shows the 10 metre winds becoming calm overnight as the nocturnal inversion and associated frost form, and returning late in the morning as the inversion breaks down



Conclusion

The validity of the information provided above, the detail supplied in the document entitled 'Effects of the wind profile at night on wind turbine sound' and the plight of many windfarm affected residents both in Australia and abroad all indisputably suggest that the results of Noise Impact Assessments being provided by developers are critically flawed.

In Taralga's case I would suggest given the proximity of neighbours to landowners signed up with the developer that the noise issue cannot possibly be addressed satisfactorily. This then is enough reason to reject the development.

At least I would recommend that the Department demand a more adequate Noise Impact Assessment from the developer, specifying that it include input wind measurements taken at the proposed turbine height. This way there is no speculation and it is less likely that we will repeat mistakes that have been made elsewhere.

Appendix A – References

Anon. 2004, **Environmental Impact Statement – Taralga Windfarm**, Prepared for RES Southern Cross PTY LTD by Geolyse

Anon. 2003, **Environmental Noise Guidelines: Wind Farms**, Environment Protection Authority – South Australia

Anon. 2003, **Acoustic report for a wind energy converter type NEG Micon NM 82/1650, hub height 93.6m**, WINDTEST Grevenbroich GmbH (this document is provided as Appendix C under Taralga EIS, Appendix H)

van den Berg, G.P. 2003, **Effects of the wind profile at night on wind turbine sound**, Journal of Sound and Vibration (this document is available online at http://www.sciencedirect.com)

Lance, Leut. B. 2004, **Winter Westerlies**, Royal Australian Navy, Nowra http://www.navy.gov.au/publications/touchdown/html/april2004/winter.htm

Foley, J C. 1945, **Frost in the Australian Region**, Commonwealth Meteorological Bureau J. J. Gourley, Government Printer, Melbourne. Pages 12, 17, 141

Appendix B – Communication to the Environment Protection Authority – South Australia

The following is a comment I sent to the EPA-SA regarding their 'Environmental Noise Guidelines: Wind Farms'. The communication was not responded to.

Attn: Information Officer
Environment Protection Authority

I would like to make a comment on the document entitled 'Environmental Noise Guidelines: Wind Farms' (ISBN 1 876562 43 9) which you published in February 2003 and would appreciate a response including any remarks or explanations you may have.

My comment relates to the practice of using wind speed data at a height of 10 metres for establishing both background noise levels and wind farm turbine noise levels, as prescribed by your document.

The validity of this practice appears to rely on the idea that wind speed at turbine height (say 70 metres) can be calculated from the wind speed at 10 metres using a linear equation. Using this idea, one could go on to assume that when the wind speeds lower at 10 metres the noise generated by a turbine also lowers. This idea is meteorologically unsound.

In fact, a scenario where the wind speed at 10 metres and below is zero and the wind speed at turbine height is above turbine cut-in (say 3.5 metres per second) is common - particularly at inland locations, at night and during winter.

This scenario generally comes about due to nocturnal radiation of heat from the earth's surface causing the formation of a cold, still layer near the surface underneath a temperature inversion. The depth of this layer is often such that background noise at the surface in the area of wind turbines is nil but turbine noise remains significant. The depth of this still layer would seldom ever reach turbine height.

Your noise guidelines do not appear to address this likelihood.

I would appreciate your comments on this matter including whether or not you consider your guidelines suitable for locations outside of South Australia.

Kind regards,
Andrew Miskelly

Appendix C – Information on nocturnal (radiation) temperature inversions

Gill, A.E. 1982, **Atmosphere-Ocean Dynamics**, Academic Press

Blackadar, A.K. 1957, **Boundary layer wind maxima and their significance for the growth of the nocturnal inversion**, Bulletin of the American Meteorological Society. Pages 38, 283-290

Foley, J.C. 1945, **Frost in the Australian Region**, Commonwealth Meteorological Bureau J. J. Gourley, Government Printer, Melbourne. Pages 12, 17, 141

Lance, Leut. B. 2004, **Winter Westerlies**, Royal Australian Navy, Nowra http://www.navy.gov.au/publications/touchdown/html/april2004/winter.htm

Acoustic Noise Generated by Wind Turbines

Presented at the Lycoming County, PA
Zoning Board Hearing on 12/14/2005

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Overview

- Measurements at distance of 0.55 miles from wind farm in Meyersdale, PA
  - Sound level measurements
  - Sound recordings
- Analysis of the frequency composition of the noise generated by wind turbines
- Analysis of the ambient noise level as a function of wind speed
- Discussion of the wind turbine noise characteristics

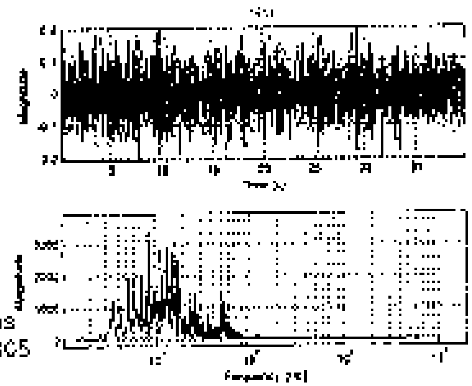
Meyersdale Wind Generation Facility

- Located in Somerset County near Meyersdale, in southwestern Pennsylvania
- Consists of 20 wind turbines,
- Rated power of turbines: 1.5-MW
- Tower height: 375'

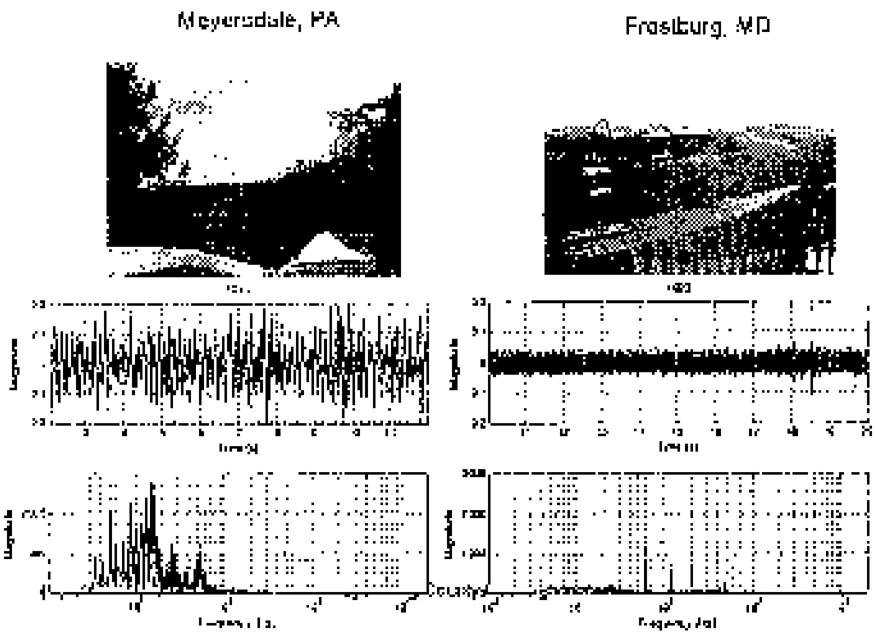
Test Equipment

- Extech Datalogging sound level meter (Model#407764)
- Marantz Professional portable solid state recorder (Model PMD670)
- Omni-Directional microphone with frequency response 60Hz – 12kHz and sensitivity – 70 dB

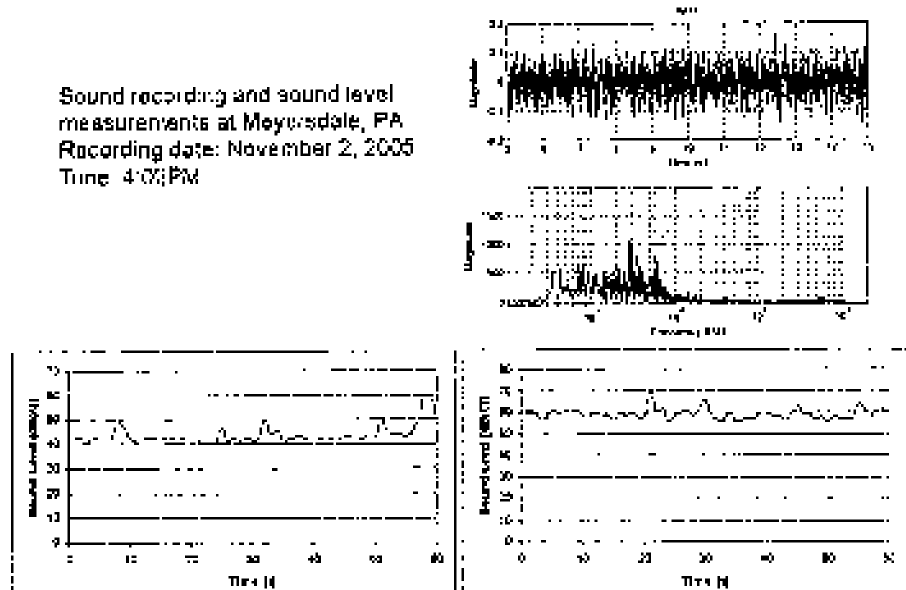
Meyersdale, PA
Sound recordings



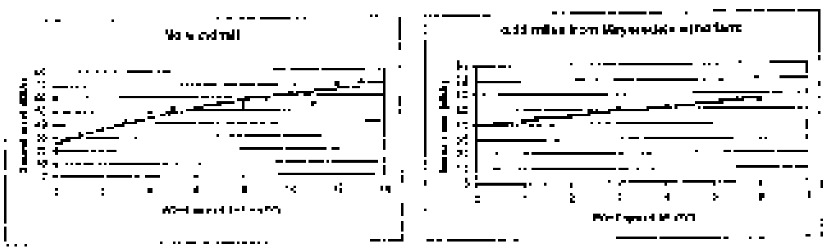
Distance to windmills: 0.55 miles
Recording date: October 29, 2005
Time 11.15



Sound recording and sound level measurements at Meyersdale, PA
Recording date: November 2, 2005
Time: 4:00 PM



Ambient Noise versus Wind Speed



Wind speed measured in ground level, at the same location as the sound level measurement

Lycoming County Zoning Ordinance Noise Protection Levels

Frequency Band (Cycles/second)	Maximum Permitted Sound-Pressure Level (dB)	Corrected max. level as per Table 5130 B due to periodic character of noise (dB)
0 – 150	67	62
150 – 300	59	54
300 – 600	52	47
600 – 1,200	46	41
1,200 – 2,400	40	35
2,400 – 4,800	34	29
Above 4,800	32	27

IEC 61400-Wind Turbine Generator Systems

Part 11 – Acoustic Noise Measurement Techniques

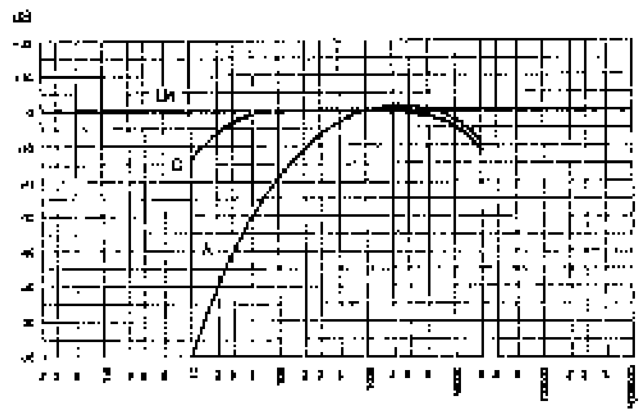
- Annex A – Other possible characteristics of wind turbine noise emission and their quantification (page 35)

A disturbance can be caused by low-frequency noise with frequencies in the range from 20 to 200 Hz. The annoyance caused by noise dominated by low frequencies is often not adequately described by the A-weighted sound pressure level, with the result that nuisance of such a noise may be underestimated if assessed using only an L_{Aeq} value.

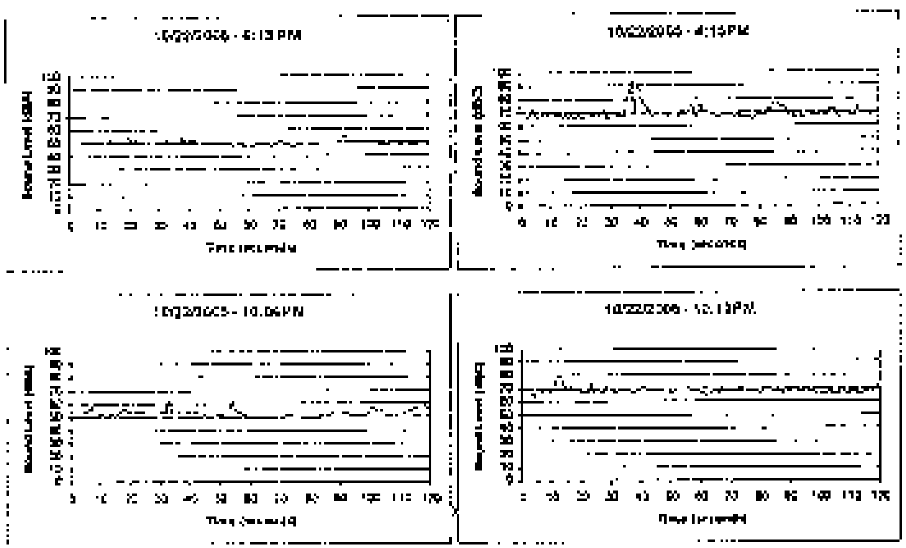
It may be possible to decide whether the noise emission can be characterised as having a low frequency component. This is likely to be the case if the difference between the A and C-weighted sound pressure levels exceeds approximately 20 dB.

In these circumstances, low-frequency noise may be quantified by extending the one-third octave band measurements described in the main body of the text, down to 20 Hz. For one-third octave bands, the 20, 25, 31.5 and 40 Hz bands should additionally be determined.

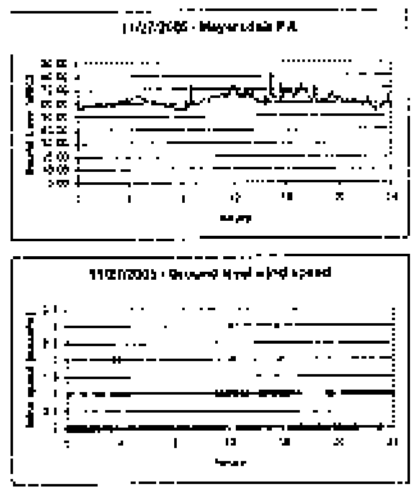
dB Weighing



Sound Level Measurements in Meyersdale, PA; Distance to wind farm. 0.55 miles



One-day Noise Measurements



Subjective Issues

- A listener's ability to hear noises depend on many subjective factors
- The turbine noise is distinguished from the random background noise because of its periodic characteristic
- Wind speed in the ground level usually do not correlate to the wind speed at the height of the turbine
- A lower level masking noise in the ground level affect the listener's ability to hear the turbine noise

Conclusions

- Recorded wind mill noise contains dominant low frequency components below 100 Hz
- Recordings clearly show the noise is distinguished from the background noise due to its periodic characteristic
- The noise level difference between A and C weighing is approximately 20 dB
- A weighing does not represent adequately the wind turbine noise
- C weighing noise level measurements indicate that the noise level at 0.55 mile distance exceeds the Lycoming County Zoning ordinance

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Effects of the wind profile at night on wind turbine sound

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Received 22 January 2003; accepted 22 September 2003

Abstract

Since the start of the operation of a 30 MW, 17 turbine wind park, residents living 500 m and more from the park have reacted strongly to the noise; residents up to 1900 m distance expressed annoyance. To assess actual sound immission, long term measurements (a total of over 400 night hours in 4 months) have been performed at 400 and 1500 m from the park. In the original sound assessment a fixed relation between wind speed at reference height (10 m) and hub height (98 m) had been used. However, measurements show that the wind speed at hub height at night is up to 2.6 times higher than expected, causing a higher rotational speed of the wind turbines and consequentially up to 15 dB higher sound levels, relative to the same reference wind speed in daytime. Moreover, especially at high rotational speeds the turbines produce a 'thumping', impulsive sound, increasing annoyance further. It is concluded that prediction of noise immission at night from (tall) wind turbines is underestimated when measurement data are used (implicitly) assuming a wind profile valid in daytime.

1. Introduction

In Germany several wind turbine parks have been and are being established in sparsely populated areas near the Dutch border. One of these is the Rhede Wind Park in northwestern Germany with seventeen 1.8 MW turbines of 98 m hub height and with 3-blade propellers of 35 m wing length. The turbines have a variable speed increasing with wind speed, starting with 10 r.p.m. (revolutions per minute) at a wind speed of 2.5 m/s at hub height up to 22 r.p.m. at wind speeds of 12 m/s and over.

At the Dutch side of the border is a residential area along the Oude Laan and Veendijk (see Fig. 1) in De Lethe: countryside dwellings surrounded by trees and agricultural fields. The dwelling nearest to the wind park is some 500 m west of the nearest wind turbine (W 16).

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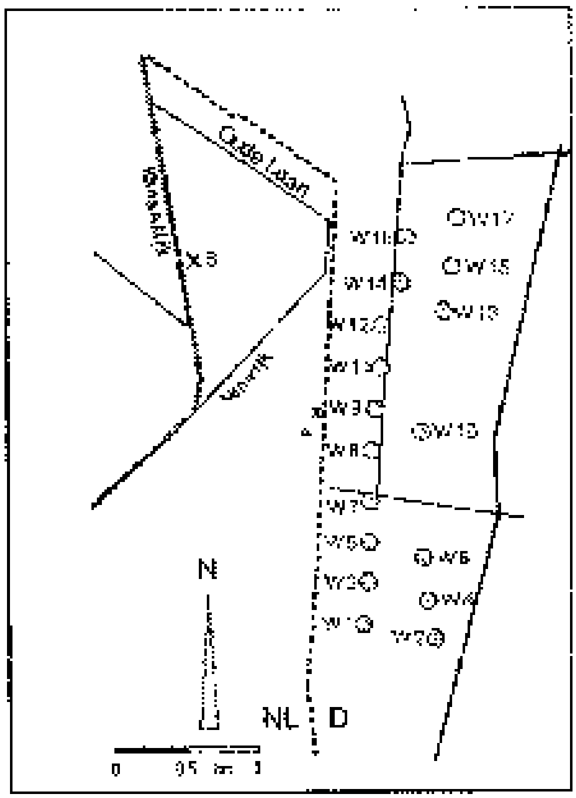

Fig. 1. Location of wind turbines (W_{nn}) and immission measurements (A and B) near the Dutch/German (NL/D) border.

According to a German noise assessment study a maximum immission level of 43 dB(A) was expected, 2 dB below the applied German noise limit. According to a Dutch consultancy immission levels would comply with Dutch (wind speed dependent) noise limits.

After the park was put into operation residents made complaints about the noise, especially at (late) evening and night-time. The residents, united in a neighbourhood group, could not persuade the German operator to put in place mitigation measures or to carry out an investigation of the noise problem and brought the case to court. The Science Shop for Physics had just released a report explaining a possible discrepancy between the calculated and the actual sound immission levels of the wind turbines because of changes in wind profile, and was asked to investigate the consequences of this discrepancy by sound measurements. Although at first the operator agreed to supply measurement data from the wind turbines (such as power output, rotation speed, axle direction), this was withdrawn after the measurements had started. All relevant data therefore had to be supplied or deduced from the author's own measurements.

2. Noise impact assessment

In the Netherlands and Germany noise impact on dwellings near a wind turbine or wind turbine park is calculated with a sound propagation model. Wind turbine sound power levels L_W are used as input for the model, based on measured or estimated data. In Germany a single 'maximum' sound power level (at 95% of maximum electric power) is used to assess sound impact. In the Netherlands sound power levels related to wind speeds at 10 m height are used; the resulting sound immission levels are compared to wind speed-dependent noise limits. Implicitly this assessment is based on measurements in daytime and does not take into account atmospheric conditions affecting the wind profile, especially at night.

In the Netherlands a national calculation model is used [1] to assess noise impact, as is the case in Germany [2]. According to Kerkers [3] there are, at least in the case of these wind turbines, no significant differences between both models.

In both sound propagation models the sound immission level L_{imm} at a specific observation point is a summation over j sound power octave band levels L_{Wj} of k sources (turbines), reduced with attenuation factors $D_{j,k}$:

$$L_{imm} = 10\log\left[\sum_j \sum_k 10^{(L_{Wj}-D_{j,k})/10}\right], \tag{1}$$

where L_{Wj}, assumed to be identical for all k turbines, is a function of rotational speed. $D_{j,k}$ is the attenuation due to geometrical spreading (D_{geo}), air absorption (D_{air}) and ground absorption (D_{ground}): $D_{j,k} = D_{geo} + D_{air} + D_{ground}$.

Eq. (1) is valid for a downwind situation. For long-term assessment purposes a meteorological correction factor is applied to (1) to account for an 'average atmosphere'. When comparing calculated and measured sound immission levels in this study no such meteo-correction is applied.

3. Wind turbines noise perception

There is a distinct audible difference between the night and daytime wind turbine sound at some distance from the turbines. On a summer's day in a moderate or even strong wind the turbines may only be heard within a few hundred metres and one might wonder why residents should complain of the sound produced by the wind park. However, on quiet nights the wind park can be heard at distances of up to several kilometres when the turbines rotate at high speed. On these nights, certainly at distances between 500 and 1000 m from the wind park, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broadband 'noisy' sound. A resident living at 1.5 km from the wind park describes the sound as 'an endless train'. In daytime these pulses are not clearly audible and the sound is less intrusive or even inaudible (especially in strong winds because of the then high ambient sound level).

In the wind park the turbines are audible for most of the (day and night) time, but the thumping is not evident, although a 'swishing' sound—a regular variation in sound level caused by the pressure variation when a blade passes a turbine mast—is readily discernible. Sometimes a rumbling sound can be heard, but it is difficult to assign it, by ear, to a specific turbine or to assess its direction.

4. Stability-dependent wind profiles

Usually a fixed relation is assumed between the wind speed v_h at height h and the wind speed v_{ref} at a reference height h_{ref} (usually 10 m), which is the widely used logarithmic wind profile with surface roughness z as the only parameter. See for example the international recommendations for wind turbine noise emission measurements [4,5]. For height h the wind speed v_h is calculated as follows:

$$v_h = v_{ref}\,\log(h/z)/\log(h_{ref}/z). \tag{2}$$

This equation is an approximation of the wind profile in the turbulent boundary layer of a neutral atmosphere, when the air is mixed by turbulence resulting from friction with the surface of the earth. During daytime thermal turbulence is added, especially when the heating of the earth surface by the sun is significant. At night-time a neutral atmosphere, characterized by the adiabatic temperature gradient, occurs under heavy cloud and/or at relatively high wind speeds. When there is some clear sky and in the absence of strong winds the atmosphere becomes stable because of radiative cooling of the surface: the wind profile changes and can no longer be adequately described by Eq. (2). The effect of the change to a stable atmosphere is that, relative to a given wind speed at 10 m height in daytime, at night there is a higher wind speed at hub height and thus a higher turbine sound power level; also there is a lower wind speed below 10 m and thus less wind-induced sound in vegetation. According to measurements by Holtslag [6] in a non-neutral atmosphere (either stable or unstable) a correction must be added to the logarithmic terms in the wind profile according to Eq. (2):

$$v_h = v_{ref}[\log(h/z) - \Psi_m]/[\log(h_{ref}/z) - \Psi_m], \tag{3}$$

where $\Psi_m = \Psi_m(h/L)$ is a rather elaborate function of height h and Monin–Obukhov length L. L is a stability measure and is positive for a stable, negative for an unstable atmosphere; for a neutral atmosphere L is a large number, either positive or negative. For calculations of sound propagation in the atmosphere Kühner [7] proposes a simple equation used in the German Air Quality Guideline "TA-Luft" [8]:

$$v_h = v_{ref}(h/h_{ref})^m, \tag{4}$$

where m is a number that depends on stability.

Stability can be categorized in Pasquill classes that depend on observations of wind speed and cloud cover (see, e.g. Ref. [9]). They are usually referred to as classes A (very unstable) through F (very stable). In "TA-Luft" a closely related classification is given (again closely related, according to Kühner [7], to the international Turner classification). An overview of stability classes with the appropriate value of m is given in Table 1. In Fig. 2 wind profiles are given as measured by Holtslag [6], as well as wind profiles according to Eqs. (2) and (4).

According to long-term data from Eelde and Leeuwarden [10], two meteorological measurement sites of the KNMI (Royal Dutch Meteorological Institute) in the northern part of the Netherlands, a stable atmosphere (Pasquill classes E and F) at night occurs for a considerable proportion of night-time: 34% and 32%, respectively.

According to Eq. (2) the ratio of wind speed at hub height (98 m) to wind speed at reference height, over land with low vegetation ($z = 3$ cm), would be $f_{98} = v_{98}/v_{10} = 1.4$. According to

Table 1
Stability classes and factor m

Pasquill class	Name	Comparable stability class "TA-Luft" [8]	m
A	Very unstable	V	0.09
B	Moderately unstable	IV	0.20
C	Neutral	III2	0.22
D	Slightly stable	III1	0.28
E	Moderately stable	II	0.37
F	(Very) stable	I	0.41

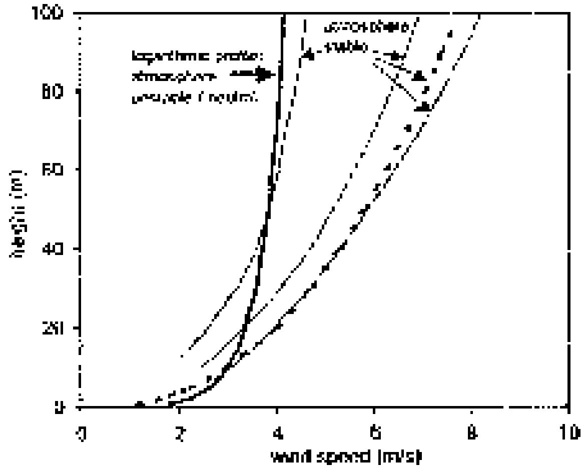

Fig. 2. Measured wind profiles (thin lines, [6]) and wind profile according to TA Luft (dotted line, [8]) in a stable atmosphere, and wind profile according to logarithmic model of formula 2 with $z = 3$ cm (bold line).

Eq. (4) and Table 1 this ratio would be 1.2 in a very unstable atmosphere and $f_{stable} = 2.5 = 1.8 f_{log}$ in a (very) stable atmosphere.

The fact that wind speeds at 10 m height may not be a good, unique predictor for hub height wind speeds has been put forward by Rudolphi [11]. He concluded from measurements that wind speed at 10 m height is not a good measure for wind turbine sound power: according to his measurements near a 58 m hub height wind turbine at night the turbine sound level was 5 dB higher than expected. This conclusion was not followed by a more thorough investigation.

The question addressed in this study is: what is the influence of the change in wind profile on the sound immission near (tall) wind turbines?

5. Measurement method

Sound immission measurements were made over 1435 hours, of which 417 hours were at night, within four months at two consecutive locations with an unmanned Sound and Weather

Measurement System (SWMS) consisting of a type 1 sound level meter with a microphone at 4.5 m height with a 9 cm diameter foam wind shield, and a wind meter at 10 m as well as at 2 m height. Every second, wind speed and wind direction (at 10 and 2 m height) and the A-weighted sound level were measured; the measured data are stored as statistical distributions over 5 min intervals. From these distributions all necessary wind data and sound levels can be calculated, such as average wind speed, median wind direction or equivalent sound level and any percentile (steps of 5%) wind speed, wind direction or sound level, in intervals of 5 min or multiples thereof.

Also complementary measurements were done with logging types 1 and 2 sound level meters and a type 1 spectrum analyzer to measure immission sound levels in the residential area over limited periods ([12], not reported here), and emission levels near the wind turbines. Emission levels were measured according to international standards [4,5], but for practical purposes the method could not be adhered to in detail; with respect to the recommended values a smaller reflecting board was used for the microphone ($30 \times 44\,\mathrm{cm}^2$ instead of a 1 m diameter circular board) and a smaller distance to the turbine (equal to tower height instead of tower height + blade length); reasons for this are given in a separate paper [13]. Also it was not possible to carry out emission measurements with only one turbine in operation.

6. Results: sound emission

Emission levels L_{eq} measured very close to the centre of a horizontal, flat board at a distance R from a turbine hub can be converted to a turbine sound power level L_W [4,5]:

$$L_W = L_{eq} - 6 + 10\log(4\pi R^2). \tag{5}$$

From earlier measurements [3] a wind speed dependence of L_W was established as given in Table 2. As explained above, the wind speed at 10 m height is not considered a reliable single measure for the turbine sound power. Rotational speed is a better measure.

Emission levels have been measured, typically for 5 min per measurement, at nine turbines on seven different days with different wind conditions. The results are plotted in Fig. 3; the sound power level is plotted as a function of rotational speed N. N is proportional to wind speed at hub height and could be determined by counting, typically during 1 min, blades passing the turbine mast. This counting procedure is not very accurate (accuracy per measurement is $\leqslant 2$ counts, corresponding to 2/3 r.p.m.) and is probably the dominant reason for the spread in Fig. 3. The best logarithmic fit to the data points in Fig. 3 is

$$L_W = 67.1\log(N) + 15.4\,\mathrm{dB(A)} \tag{6}$$

with a correlation coefficient of 0.98. The standard deviation of measurement values with respect to this fit is 1.0 dB.

Table 2
Sound power level of wind turbines [3]

Wind speed V_{10}	m/s	5	6	7	8	9	10
Sound power level L_W	dB(A)	94	96	98	101	102	103

At the specification extremes of 10 and 22 r.p.m. the (individual) wind turbine sound power level L_W is 82.8 and 105.7 dB(A), respectively.

In Table 3 earlier measurement results [3] are given for the octave band sound power spectrum. Also in Table 3 the results of this study are given: the logarithmic average of four different spectra at different rotational speeds. In all cases spectra are scaled, with Eq. (6), to the same sound power level of 103 dB(A).

To calculate sound immission levels at a specific rotational speed (or vice versa) the sound power level given in Eq. (6), and the spectral form in Table 3 ('this study') have been used.

7. Results: sound immission

The sound immission level has been measured with the unmanned SWMS on two locations. Between May 13 and June 22, 2002 it was placed amidst open fields with barren earth and later low vegetation 400 m west of the westernmost row of wind turbines (location A, see Fig. 1). This site was a few metres west of the Dutch–German border, visible as a ditch and a 1.5–2 m high dike. Between June 22 and September 13, 2002 the SWMS was placed on a lawn near a dwelling 1500 m

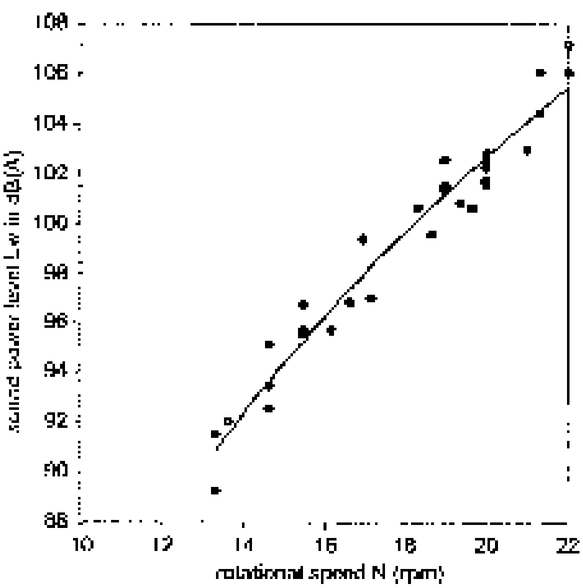

Fig. 3. Measured wind turbine sound power level L_W as a function of turbine rotational speed N.

Table 3
Octave band spectra of wind turbines at L_W = 103 dB(A)

Frequency	Hz	63	125	250	500	1000	2000	4000	L_W
This study	dB(A)	82	92	94	98	98	93	88	103
[3]	dB(A)	85	91	95	98	98	92	83	103

west of the westernmost row (location B), with both low and tall trees in the vicinity. On both locations there were no reflections of turbine sound towards the microphone, except via the ground, and no objects (such as trees) between the turbines and the microphone. Apart from possible wind induced sound in vegetation relevant sound sources are traffic on rather quiet roads, agricultural activities, and birds. As, because of the trees, the correct (potential) wind speed and direction could not be measured on location B, wind measurement data provided by the KNMI were used from their Nieuw Beerta site 10 km to the north. These data fitted well with the measurements on location A.

At times when the wind turbine sound is dominant, the sound level is relatively constant within 5 min intervals. In Fig. 4 this is demonstrated for two nights. Thus measurement intervals with dominant turbine sound could be selected with a criterion based on a low variation in sound level: $L_5 - L_{95} \leq 4$ dB, where L_5 and L_{95} are 5 and 95 percentile sound level. In a normal (Gaussian) distribution this would equal $\sigma \leq 1.2$ dB, with σ the standard deviation.

On location A, 400 m from the nearest turbine, the total measurement time was 371 h. For 25% of this time the wind turbine sound was dominant, predominantly at night (72% of all 105 nightly hours) and hardly during daytime (4% of 191 h) (see Table 4).

At location B, 1500 m from the nearest turbine, these percentages were almost halved, but the turbine sound remained dominant for over one-third of the time at night (38% of 312 h). The trend in percentages agrees with complaints mostly concerning noise in the (late) evening and at night and their being more strongly expressed by residents closer to the wind park.

In Fig. 5 the selected (i.e., with dominant wind turbine sound) 5 min equivalent immission sound levels $L_{eq,5\,min}$ are plotted as a function of wind direction (left) and of wind speed (right) at 10 m height, for both location A (above) and B (below). It is not clear why the KNMI wind speed data (used for location B) cluster around integer values of the wind speed.

Also the wind speed at 10 and 2 m height at location A are plotted (in 5A and 5B, respectively), and the local wind speed (influenced by trees) at 10 m at location B (5C). The immission level data points are separated in two classes where the atmosphere was stable or neutral, according to

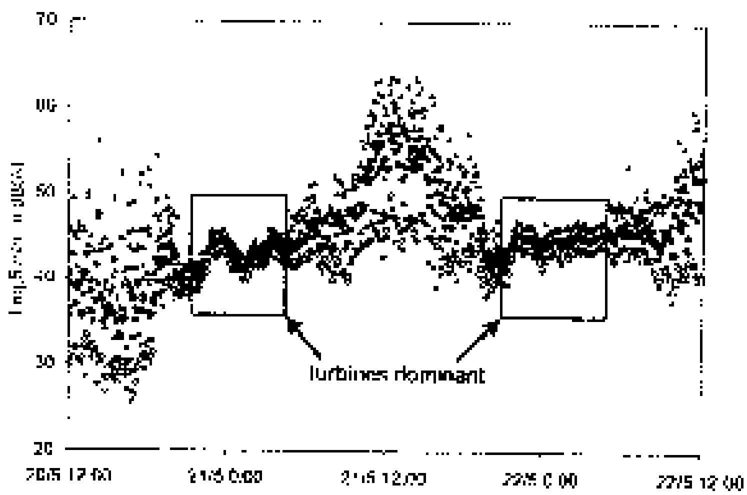

Fig. 4. 48 h registration of immission level (L_5 = Δ; L_{eq} = ▪; L_{95} = ○) per 5 min at location A; turbines are considered the dominant sound source if $L_5 - L_{95} \leq 4$ dB.

Table 4
Total measurement time in hours and selected time with dominant wind turbine sound

Location	Total time	Night 23:00–6:00	Evening 19:00–23:00	Day 6:00–19:00
A: Total	371	105	75	191
A: Selected	92	76	9	7
	25%	72%	12%	4%
B: Total	1064	312	183	569
B: Selected	136	119	13	4
	13%	38%	7%	0.7%

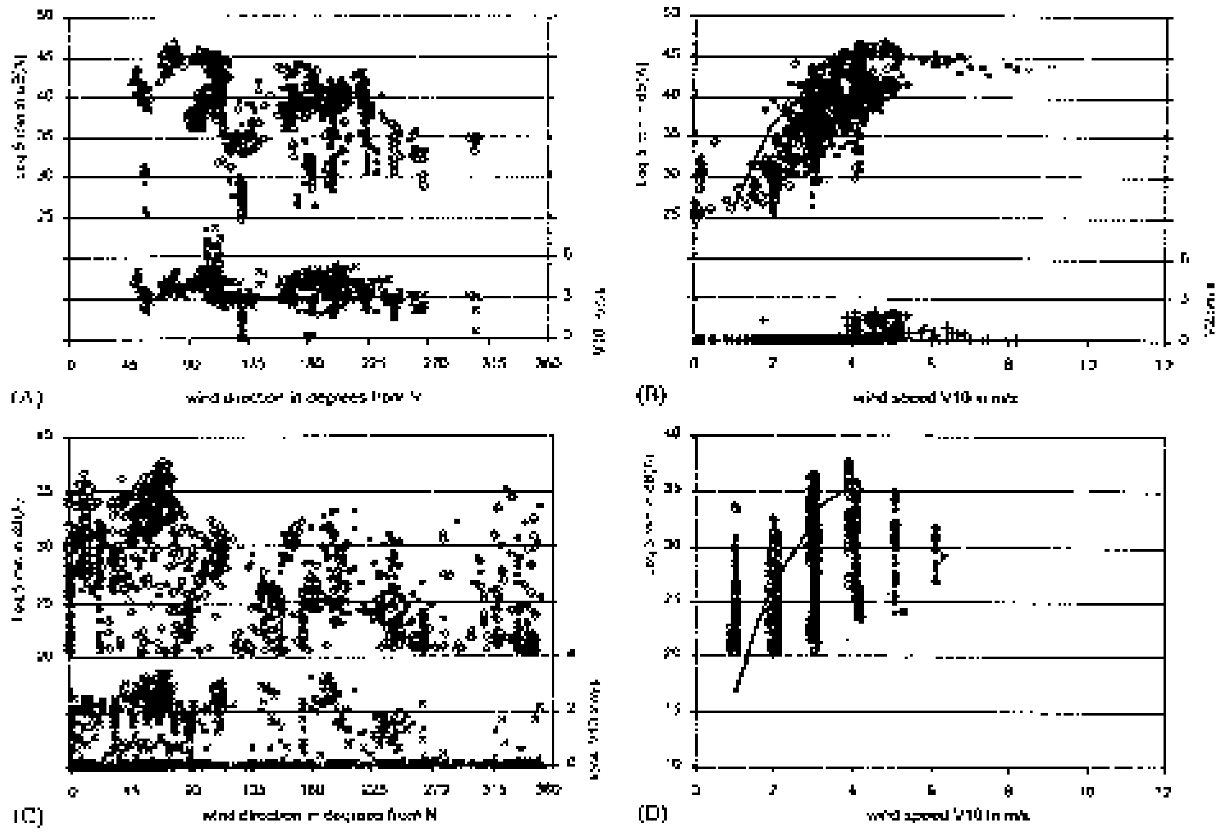

Fig. 5. Measured sound levels $L_{eq,1\,min}$ at locations A (above) and B (below) as a function of median wind direction (left) and average wind speed (right) at reference height (10 m), separated in classes where the atmosphere at Eelde was observed as stable (◇) or neutral (•). Also plotted are expected sound levels according to logarithmic wind profile and wind speed at reference height (grey lines in B and D), and at a 2.6 higher wind speed (black lines in B and D). Figures A, B and C also contain the wind speed v_{80} (A), v_1 (B), and the local v_{10} (C) disturbed by trees, respectively.

observations of wind speed and cloud cover at Eelde. Eelde is the nearest KNMI site for these observations, but it is 40 km to the west, so not all observations will be valid for the area of the study.

In Fig. 5B a grey line is plotted connecting calculated sound levels with sound power levels according to Table 2 (the lowest value at 2.5 m/s is extrapolated [12]), implicitly assuming a fixed logarithmic wind profile according to Eq. (2). If this line is compressed in the direction of the abscissa with a factor 2.6, the result is a (black) line coinciding with the highest 1 h values ($L_{eq,1\,h}$) at each wind speed. Apparently, at these immission levels, the wind speed is 2.6 times higher than expected. In Fig. 6 this is given in more detail: all 5 min measurement periods that satisfied the L_5–L_{95}-criterion, with at least 4 periods per hour, were taken together in consecutive hourly periods and the resulting $L_{eq,T}$ ($T = 20$–60 min) was calculated. These 83 L_{eq}-values are plotted against the average wind speed v_{10} over the same time T. Also plotted in Fig. 6 are: the expected immission levels calculated from (1), implicitly assuming a logarithmic wind profile according to (2), so $f_{log} = 1.4$; the immission levels assuming a stable wind profile (4) with $m = 0.41$, so $f_{stable} = 2.5 = 1.8 \cdot f_{log}$; the maximum immission levels assuming $f_{max} = 3.7 = 2.6 \cdot f_{log}$, in agreement with a wind profile (4) with $m = 0.57$. The best fit of all data points ($L_{eq,T}$) in Fig. 6 with $1 < v_{10} < 5.5$ m/s is $L_{eq,T} = 32 \cdot \log(v_{10}) + 22$ dB (correlation coefficient 0.80); this fit agrees within 0.5 dB with the expected level according to the stable wind profile. The best fit of all 5 min data-points in Fig. 5B yields the same result.

Thus on location A the highest one hour averaged wind speeds at night are 2.6 times the expected values according to the logarithmic wind profile in Eq. (2). As a consequence, sound levels at (during night-time) frequently occurring wind speeds of 3 and 4 m/s are up to 15 dB higher than expected, 15 dB being the vertical distance between the expected and highest 1-h immission levels at 3–4 m/s (upper and lower lines in Figs. 5B and 6).

The same lines as in 5B, but valid for location B, are plotted in Fig. 5D; immission levels here exceed the calculated levels, even if calculated on the basis of a 2.6 higher wind speed at hub height. This is the result of shortcomings of the calculation model for long distances, at least for

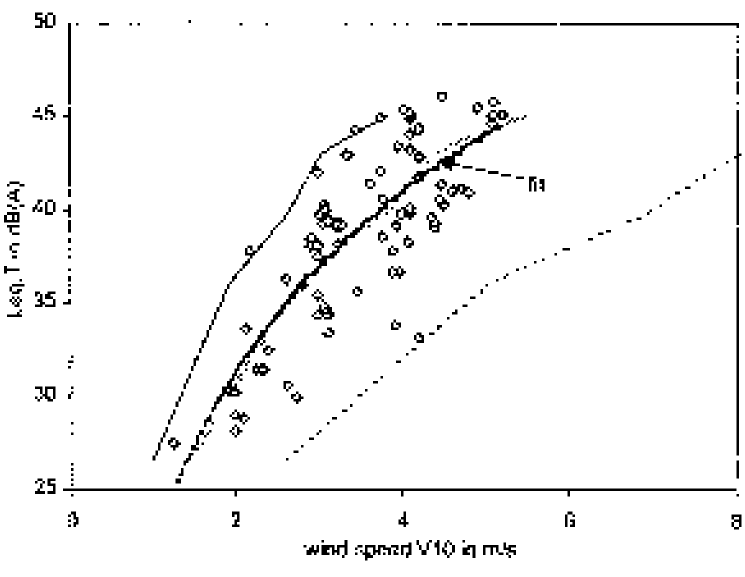

Fig. 6. Measured sound levels $L_{eq,T}$ ($T = 20$–60 min) at location A with best fit and expected sound levels according to a logarithmic wind profile ($v_{hh}/v_{10} = f_{log} = 1.4$; dotted line), a stable wind profile ($v_{hh}/v_{10} = 1.8 \cdot f_{log}$; thick grey line) and maximum wind speed ratio ($v_{hh}/v_{10} = 2.6 \cdot f_{log}$; thin line).

night-time conditions: from the long-term measurements at location B and short term (one night) at other locations ([12], not reproduced here) it follows that sound immission levels calculated according to the standard model used in the Netherlands [1], underestimate measured levels at night with ca. 1 dB at distances of 550–1000 m increasing to about 3 dB at distances up to 1900 m.

As is clear from the wind speed at 2 m height plotted in Fig. 5B, there is only a very light wind near the ground even when the turbines rotate at high power. This implies that in a quiet area with low vegetation the ambient sound level may be very low. The contrast between the turbine sound and the ambient sound is therefore higher at night than during the daytime.

Although at most times the wind turbine sound dominates the sound levels in Fig. 5, it is possible that at low sound levels, i.e., at low rotational speeds and low wind speeds, the L_5–L_{95}-criterion is met while the sound level is not entirely determined by the wind turbines. This is certainly the case at levels close to 20 dB(A), the sound level meter noise floor.

The long-term night-time ambient background level, expressed as the 95-percentile (L_{95}) of all measured night-time sound levels on location B, was 23 dB(A) at 3 m/s (v_{10}) and increasing with 1.3 dB/(m s^{-1}) up to v_{10} = 8 m/s [12]. Comparing this predominantly non-turbine background level with the sound levels in Figs. 5B and D, it is clear that the lowest sound levels may not be determined by the wind turbines, but by other ambient sounds (and instrument noise). This wind speed dependent, non-turbine background sound level L_{95} is, however, insignificant with respect to the highest measured levels. Thus, the high sound levels do not include a significant amount of ambient sound not coming from the wind turbines. This has also been verified on a number of evenings and nights by personal observation.

8. Comparison of emission and immission sound levels

From the 30 measurements of the equivalent sound level $L_{eq,T}$ (with T typically 5 min) measured at distance R from the turbine hub (R typically $100\sqrt{2}$ m), a relation between sound power level L_W and rotational speed N of a turbine could be determined: see Eq. (6).

This relation can be compared with the measured immission sound level $L_{eq,T}$ ($T = 5$ min) at location A, 400 m from the wind park (closest turbine), in 22 cases where the rotational speed was known. These measurements were taken at different times to the emission measurements. The best logarithmic fit for the data points of the immission sound level L_{imm} as a function of rotational speed N is

$$L_{imm} = 57.6\log(N) - 30.6\,\text{dB(A)} \tag{7}$$

with a correlation coefficient of 0.92 and a standard deviation of 1.5 dB. Both relations from Eqs. (6) and (7) and the data points are given in Fig. 7. The difference between both relations is $L_W - L_{imm} = 9.5\log(N) + 46.0$ dB. For the range 14–20 r.p.m., where both series have data points, the average difference is 57.9 dB, the maximum deviation from this average is 0.8 dB (14 r.p.m.: 57.1 dB(A); 20 r.p.m.: 58.6 dB(A); see lower part of Fig. 7). It can be shown by calculation that about half of this deviation can be explained by the variation of sound power spectrum with increasing speed N.

The sound immission level can be calculated using Eq. (1). For location A, assuming all turbines have the same sound power L_W, this leads to $L_W - L_{imm} = 58.0$ dB. This is independent

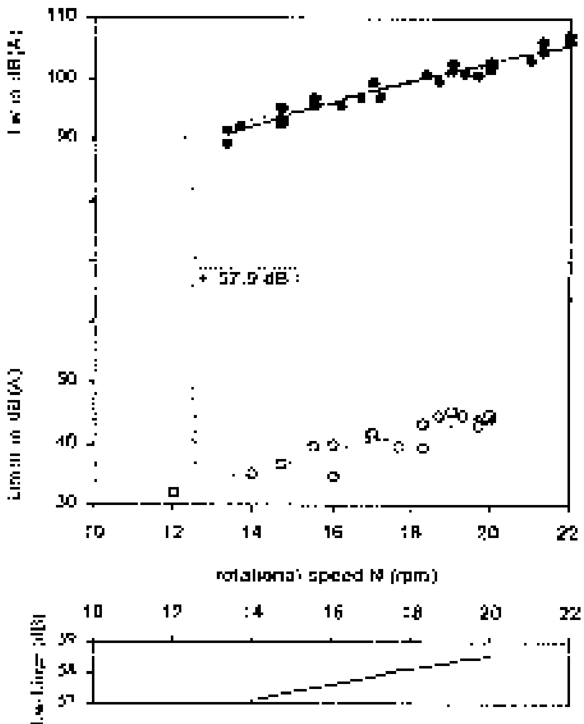

Fig. 7. Turbine sound power levels L_W measured near wind turbines (●) and immission levels L_{imm} measured at 400 m from wind park (○): averages differ 57.9 dB; (below) increase of difference L_W-L_{imm} with rotational speed.

of sound power level or rotational speed, as it is calculated with a constant spectrum averaged over several turbine conditions, i.e., speeds. The measured difference (57.9 dB) matches very closely the calculated difference (58.0 dB).

The variation in sound immission level at a specific wind speed v_{10} in Figs. 5B and D is thus seen to correspond to a variation in rotational speed N, which in turn is related to a variation in wind speed at hub height, not to a variation in v_{10}. At location A, N can be calculated from the measured immission level with the help of Eq. (7) or its inverse form $N = 3.4 \times 10^{L_{imm}/51.6}$.

9. Effect of atmospheric stability

In Fig. 5 measurement data have been separated into two sets according to atmospheric stability in Pasquill classes, supplied by KNMI from their measurement site Eelde, 40 km to the west of our measurement site. Although the degree of stability will not always be the same for Eelde and our measurement location, the locations will correlate to a high degree in view of the relatively small distance between them. For night-time conditions 'stable' refers to Pasquill classes E and F (lightly to very stable) and corresponds to $V_{10} \leqslant 5$ m/s and cloud coverage $C \leqslant 50\%$ or $V_{10} \leqslant 3.5$ m/s and $C \leqslant 75\%$, 'neutral' (class D) corresponding to all other situations. Although from Fig. 5 it is clear that the very highest sound levels at an easterly wind ($\approx 80°$) do indeed occur in stable conditions, it is also clear that in neutral conditions too the sound level is higher than expected for most of the time, the expected values corresponding to the grey lines in Figs. 5B and D, derived from daytime conditions. According to this study the sound production, and thus wind speed, at 100 m height is often higher than expected at night, in a stable, but also in a neutral atmosphere. On the other hand, even in stable conditions sound levels may be lower than expected (i.e., below the grey lines), although this rarely occurs. It may be concluded from these measurements that a logarithmic wind profile based only on surface roughness does not apply to the night-time atmosphere in our measurements, not in a stable atmosphere and not always in a neutral atmosphere.

10. Impulsive sound

At night the sound from the wind park contains repetitive pulses, unlike the sound in daytime. According to the long-term auditory observation of residents this pulse-like character or 'thumping', is more pronounced and more annoying at high turbine rotational speed. Fig. 8 shows a recording of the sound pressure level every 50 ms over a 180 s period, taken from a DAT-recording on a summer night (June 3, 0:40 h) on a terrace of a dwelling at 750 m west of the westernmost row of wind turbines (this sound includes the reflection on the façade at 2 m). There is a slow variation of the 'base line' (minimum levels) probably caused by variations in wind speed and atmospheric sound transmission. There is furthermore a variation in dynamic range: a small difference between subsequent maximum and minimum levels of less than 2 dB is alternated by larger differences. In the lower part of Fig. 8 part of the sequence is amplified and shows at first a somewhat irregular pattern of dynamic range 1–1.5 dB leading to a more regular pattern of a pulse every second with a pulse height of 3–4 or 5–6 dB. This pattern is compatible with a complex of three pulse trains with pulse height of about 1 dB and slightly different repetition frequencies

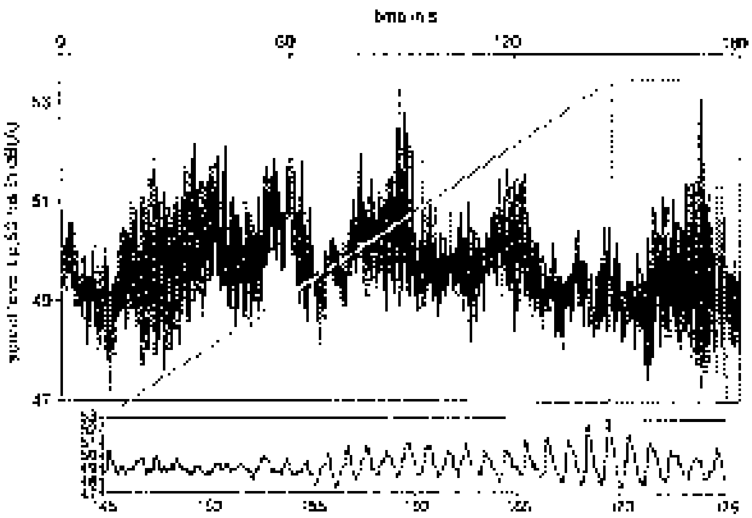

Fig. 8. Sound pressure level caused by wind turbines per 50 ms near dwelling at 750 m from nearest turbine (including reflection at façade at 2 m) over a 3 min period; part of the sequence is amplified below.

of about 1 Hz. When the pulses are out of phase (around 150 s in Fig. 8), there are only 1 dB variations. When 2 of them are in phase (around 160 s) pulse height is doubled (+3 dB), and tripled (+5 dB, 170 s) when all three are in phase. The rotational speed of the turbines at the time was 20 r.p.m., so the repetition rate of blades passing a mast was 1 Hz.

The low number of pulse trains, compared to 17 turbines, is compatible with the fact that only a few turbines dominate the sound immission at this location. The calculated immission level is predominantly caused by two wind turbines (numbers 11 and 12: see Fig. 1, contributing 35% of the A-weighted sound energy), less by two others (9 and 14; 21%), so only 4 turbines contribute more than half of the sound immission energy

A pulse-like character was not expected; e.g., in a recent Dutch report [14] it was stated that wind turbines do not produce impulsive noise. However, when measurements are made at a single turbine, as is usual, no pulses will be audible according to the explanation given above.

11. Annoyance

The immission sound level at location A is for most of the time (at least 72% of night-time hours) higher than expected. At the most frequent night-time wind speeds (v_{10}) of 3 and 4 m/s the sound level is up to 15 dB more than expected. Also at location B, at a considerable distance (1500 m) from the wind park, the immission level is for a considerable amount of time (at least 38% of night-time hours) higher than expected. At location B and at wind speeds of 2–4 m/s the actual sound level is up to 18 dB higher than expected, of which 3 dB are due to limitations of the calculation model, and 15 dB to the underestimate of wind speed at hub height. With these higher sound levels and the impulsive character of the sound more annoyance than predicted is to be expected.

Pedersen et al. [15] have investigated the annoyance around wind turbines in the south of Sweden. Their paper gives preliminary results, and definitive results have yet to published [personal communication Pedersen]. They found highly annoyed residents at (calculated) sound levels as low as 32.5–35 dB(A). This study shows that tall wind turbines may in fact be up to 18 dB noisier than the calculated values suggest. A further increase in annoyance may be expected because of the pulse-like character of the wind turbine noise, especially at high rotational speeds.

12. Conclusions

Sound immission measurements have been made at 400 m (location A) and 1500 m (location B) from the wind park Rhede with 17 tall (98 m hub height), variable speed wind turbines. It is usual in wind turbine noise assessment to calculate immission sound levels assuming wind speeds based on wind speeds v_{10} at reference height (10 m) and a logarithmic wind profile. This study shows that the sound immission level may, at the same wind speed v_{10} at 10 m height, be significantly higher (up to 18 dB) during night-time than in the daytime. Another, 'stable' wind profile predicts a wind speed v_h at hub height 1.8 times higher than expected and agrees excellently with the average measured night-time sound immission levels. Wind speed at hub height may still be higher: at low wind speeds v_{10} up to 4 m/s, the wind speed v_h is at night is up to 2.6 times higher than expected.

Thus, the logarithmic wind profile, depending only on surface roughness and not on atmospheric stability, is not a good predictor for wind profiles at night. Especially for tall wind turbines, estimates of the wind regime at hub height based on the wind speed distribution at 10 m, will lead to an underestimate of the immission sound level at night: at low wind speeds ($v_{10} \leq 4$ m/s) the actual sound level will be higher than expected for a significant proportion of time. This is not only the case for a stable atmosphere, but also, to a lesser degree, for a neutral atmosphere.

The change in wind profile at night also results in lower ambient background levels than expected: at night the wind speed near the ground may be lower than expected from the speed at 10 m and a logarithmic wind profile, resulting in low levels of wind induced sound from vegetation. The contrast between wind turbine and ambient sound levels is therefore more pronounced at night.

Measured sound immission levels at 400 m from the nearest wind turbine almost perfectly match (average difference: 0.1 dB) sound levels calculated from measured emission levels near the turbines. From this it may be concluded that both the emission and immission levels could be determined accurately, even though the emission measurements were not quite in agreement with the recommended method. As both levels can be related through a propagation model, it may not be necessary to measure both; the immission measurements can be used to assess immission as well as emission sound levels.

There is, however, a growing discrepancy with distance; at distances of 1–2 km the calculated level may underestimate the measured level by 3 dB. This is most probably a consequence of the fact that the actual (night-time) atmospheric sound transmission is not adequately modelled in the sound transmission model.

At night the turbines cause a low pitched thumping sound superimposed on a broadband 'noisy' sound, the 'thumps' occurring at the rate at which blades pass a turbine tower. It appears that the characteristic, but usually small 'swishing' pulses that can be heard at the rate at which blades pass a turbine tower, coincide because turbines operate nearly synchronously. Two coinciding pulse trains thus give a 3 dB higher pulse level, three a 5 dB higher pulse level. The measured pulse levels and frequencies agree with values expected from nearly synchronous pulse trains generated by a small number of wind turbines.

The number and severity of noise complaints near the wind park are at least in part explained by the two main findings of this study; actual sound levels are considerably higher than predicted, and wind turbines can produce sound with an impulsive character.

The relatively high wind speeds at turbine hub height at night also have a distinct advantage; the electric power output is higher than predicted and benefits the operator of the wind turbine.

References

[1] Handleiding meten en rekenen industrielawaai (Manual for measuring and calculating industrial noise), Den Haag, 1999 (in Dutch).

[2] TA-Lärm: Technische Anleitung zum Schutz gegen Lärm (Technical guideline for noise protection), 1998 (in German).

[3] A.J. Kerkers, Windpark Rheder Moor, prognose geluidsimmissie vanwege 17 Enercon 66 windturbines (Wind park Rheder Moor: prognosis of sound immission from 17 Enercon 66 wind turbines), Lichtveld Buis & Partners bv raadgevende ingenieurs, 1999 (in Dutch).

[4] S. Ljunggren, Expert group study on 'Recommended practices for wind turbine testing and evaluation', part 10. Measurement of noise immersion from wind turbines at noise receptor locations, Department of Building Science, The Royal Institute of Technology, Sweden, 1994/1997.
[5] IEC International Standard 61400-11, Wind turbine generator systems—Part 11: Acoustic noise measurement techniques, IEC 61400-11:1998(E).
[6] A.A.M. Holtslag, Estimates of diabatic wind speed profiles from near-surface weather observations, *Boundary-Layer Meteorology* 29 (1984) 225–250.
[7] D. Kühner, Excess attenuation due to meteorological influences and ground impedance, *Acustica—Acta Acustica* 84 (1998) 870–883.
[8] TA-Luft, Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz—Technische Anleitung zur Reinhaltung der Luft (First general directive to the federal immission protection act—Technical guideline for clean air), 1986 (in German).
[9] http://www-metdat.llnl.gov/metdat.FAQ.html#stability.class
[10] Climatological data from Dutch stations no. 8: Frequency tables of atmospheric stability, KNMI, De Bilt, 1972 (text part in Dutch).
[11] E. Rudolphi, Wind turbine noise emission. Wind speed measurements below hub height give poor accuracy, *Proceedings of the Nordic Acoustical Meeting*, Stockholm, 1998.
[12] G.P. van den Berg, R. de Graaf, Hoge molens vangen veel wind II—geluidsbelasting door windturbines in de nacht, Natuurkundewinkel RuG (High mills catch strong winds II—sound immission by wind turbines at night, Science Shop for Physics, University of Groningen), December 2002 (in Dutch, a German version is also available).
[13] G.P. van den Berg, Wind turbines at night: acoustical practice and sound research, *Proceedings Euronoise 2003*, Naples, 2003.
[14] A.J. Kerkers, A.J. Koffeman, Beoordeling van windturbinegeluid: technische rapportage—Continu, fluctuerend of impulsachtig (Assessment of wind turbine sound: technical report—continuous, fluctuating or impulsive), Lichtveld, Buis & Partners bv, March 2002 (in Dutch).
[15] E. Pedersen, K. Persson Waye, Perception and annoyance of wind turbine noise in a flat landscape, *Proceedings Internoise 2002*, Detroit, 2002.

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Do wind turbines produce significant low frequency sound levels?

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Summary

Wind turbines produce low frequency sounds, but it has not been shown this is a major factor contributing to annoyance. Sound from wind turbines involves several sound production mechanisms related to different interactions between the turbine blades and the air. Low frequency sound is predominantly the result of the displacement of air by a blade and of turbulence at the blade surface.

An important contribution to the low frequency part of the sound spectrum may be the result of the sudden variation in air flow the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimized for the mean flow.

This effect probably has not been considered important as the blade passing frequency is of the order of one hertz where human hearing is very insensitive. This argument however obscures a very relevant effect: the low blade passing frequency modulates well audible, higher frequency sounds and thus creates periodic sound. This effect is stronger at night because in a stable atmosphere there is a greater difference between rotor averaged and near-tower wind speed. Measurements have shown that more turbines can interact to further amplify this effect.

The effect is confirmed by residents near wind turbines who mention the same common observation: often late in the afternoon or in the evening the turbine sound changes to a more 'clapping' or 'beating' sound, the rhythm in agreement with the blade passing frequency. It is clear from the observations that this is associated to a change to a higher atmospheric stability. The increased annoyance has not been investigated as such, although there are indications from literature this effect is relevant. It is of increasing relevance as the effect is stronger for modern (that is: tall) wind turbines.

Introduction

Modern wind turbines have electric power outputs up to 2 MW (increasing now to 5 MW) and have turbine heights of 80 to 100 meters (increasing to 120 m). In the European Union, producing 74% of the wind power in the world, by the end of 2002 23 GW has been installed, and this should increase to the European target of 40 GW for 2010, but already a capacity of 90 GW has been forecasted for that year [1]. As a result of this growth an increasing number of people are living near (projected) wind parks and have reason to inquire and perhaps be worried about their environmental impact. Visual impact, intermittent reflections on the turbine blades as well as intermittent shadows (sun behind rotating blades), and sound are usually considered potentially negative impacts.

Wind turbines are also suspected to be a cause of low frequency noise, affecting people living nearby. This has been brought forward in the United Kingdom where opponents of wind parks state "current recommendations for noise evaluation near wind turbine sites completely exclude the measurement of low frequency sound" [2]. In a reaction the British Wind Energy Association denies this and accuses the other party "to misunderstand technical information, but be happy to use the material in inappropriate ways. One example of this is their persistent misuse of material on noise". [3].
Yet, a recent review for the British Department for Environment, Food and Rural Affairs states. "Infrasound exposure is ubiquitous in modern life (.....) common in
urban environments, and as an emission from (.....) air movement machinery including wind turbines (. ..). The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness (. ..) compared with other noise." [4]. Also, according to a project proposal from the Swedish Kungl Technical Highschool "there is a risk for low frequency sound from the large wind turbine farms that are planned both in Sweden and in other European countries" [5]. So, those who link wind turbines with low frequency sound are in expert company. But, does it affect nearby residents?
This paper explores the nature of (low frequency) wind turbine sound and explains why low frequencies may be relevant and not relevant at the same time, depending on perspective.

Sources of wind turbine sound

There is a wealth of information on the nature, cause and power of turbine sound. A review resulting from a research programme of the European Union is given by Wagner *et al* [6]. A concise overview of the three sound source mechanisms relevant to this paper will be given here, preceded by an introduction on wind aeroacoustics.

If an air flow is smooth around a (streamlined) body, it will generate little sound. For high speeds and/or over longer lengths the flow in the boundary layer (between body and main flow) becomes turbulent. As this leads to rapid velocity *changes* this will cause more sound with frequencies related to the rate of the velocity changes. A typical size for this turbulence is the boundary layer thickness.
As is the case for aircraft wings or propellor blades, a wind turbine blade is driven by lift generated by the air flow and performs best when lift is maximized and at the same time drag (flow resistance) is minimized. Both are determined by the angle of attack: the angle between the incoming flow and the chord (line between front and rear edge) of the blade. When the angle of attack increases from its optimal value the turbulent boundary layer grows in thickness and turbulence strength, decreasing power performance and increasing sound level. For an increasing angle of attack this eventually leads to stall: a dramatic reduction in lift.
Also, the atmosphere itself is turbulent over a wide range of frequencies and sizes. Atmospheric turbulence energy has a maximum at a frequency that depends on height and atmospheric stability; for wind turbine altitudes this frequency is of an order of magnitude of once per minute (≈ 0.01 Hz), and the associated eddy (whirl) 'diameter' is of the order of magnitude of a several hundreds of meters [7]. Eddy diameter and turbulence strength decrease at increasing frequency and vanish because of viscous friction when they have reached the size of a millimeter.
Turbulent flow is the dominant cause of (audible) sound for modern wind turbines. There are several mechanisms whereby the sound actually is produced.

1. When a blade moves through the air, the air on the forward edge is moved sideways moving back again at the rear edge. So for a periodically moving blade the air is periodically forced, leading to 'thickness noise'. Normally this will not lead to a significant sound production.

However, when a blade passes in front of the turbine tower, it encounters a wind that is influenced by the tower: the wind is slowed down and is forced to move sideways around the tower. This means that quite suddenly the angle of attack changes and lift and drag change abruptly. The change in mechanical load will increase thickness sound at the rate of the blade passing frequency f_B (f_B is the turbine rotation frequency multiplied by the number of blades). As the movement is not purely sinusoidal, there are harmonics with frequencies $k \cdot f_B$ where k is a (small) integer. As f_B typically has a value of approximately 1 Hz and harmonics may occur up to 10 - 20 Hz, this sound is in the infrasound region. Another consequence is that high frequency sound will also increase abruptly because of increased turbulence due to the sub-optimal angle of attack, creating the typical swishes superimposed on the constant noisy sound of a wind turbine.

2. Because of atmospheric turbulence there is a random movement of air superimposed on the average wind speed. The contribution of atmospheric turbulence to wind turbine sound is named 'in-flow turbulence noise' and is broad band sound stretching over a wide frequency range.
   For turbulent eddies larger in size than the blade this may be interpreted as a change in the direction and/or velocity of the incoming flow, equivalent to a deviation of the optimal angle of attack. This leads to the same phenomena as in 1., but changes will usually be less abrupt.
   For turbulent eddies the size of the chord length and less, effects are local and do not occur coherently over the blade. When the blade cuts through the eddies, the movement normal to the wind surface is reduced or stopped, given rise to high accelerations and thus sound.
3. High frequency sound is due to several flow phenomena at the blade itself or in the turbulent wake behind a blade ('airfoil self-noise'). It increases when induced turbulence increases, e.g. because of higher speed or of irregularities (scratches, dirt, insects) on the blade surface. It is essentially broad band sound, but if the turbulence can lock into a fixed length (such as a slit or cut parallel to the trailing edge), a specific frequency can become prominent, resulting in tonal sound.

Sound originating from the generator or the transmission gear has decreased in level in the past decade and has now become irrelevant if considering annoyance for residents.

Measured wind turbine sound spectra

In the summer of 2002 wind turbine sound has been recorded in and near wind park Rhede on the German-Dutch border. The park has a straight row of ten ca. 300 m spaced turbines parallel to the border and a less regular, somewhat uneven spaced row of seven turbines appr. 400 m behind the first row. Each turbine is 100 m high (hub heigth) with a blade length of 35 m, and produces nominally 2 MW electricity. It proved that the sound level, determined by the rotation speed of the turbines, depended on atmospheric stability and was not well predicted at evening and night hours by the usual reference wind speed measured at 10 meter altitude [8].

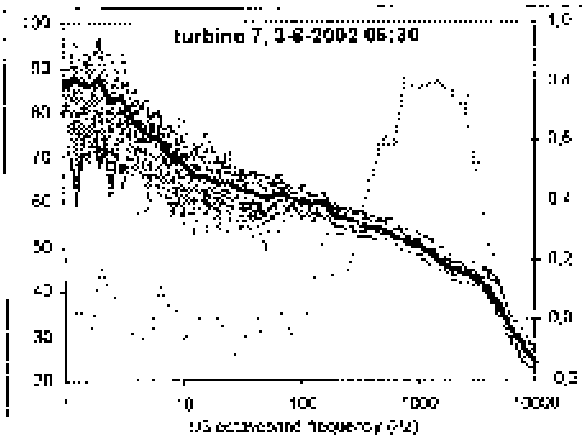
In figure 1 1/3 octave band spectra of the recorded sound have been plotted. The sound was recorded on a TASCAM DA-1 DAT-recorder with a precision Sennheiser microphone. The sound was then sampled in 1-second intervals on a Larson Davis 2800 frequency analyzer. The frequency response of the measurement chain is within 3 dB for frequencies above 4 Hz. From 1 to 4 Hz the frequency response is not accurately known (this has never been a necessity in our work). The spectra were determined from recordings (appr. 5 minutes each) taken with the microphone just above a hard surface at ground level at 100 m from two different turbines (plotted levels are measured Leq minus 6 dB correction for coherent reflection against the surface), and from a recording 1.5 m above a paved terrace and 2 m in

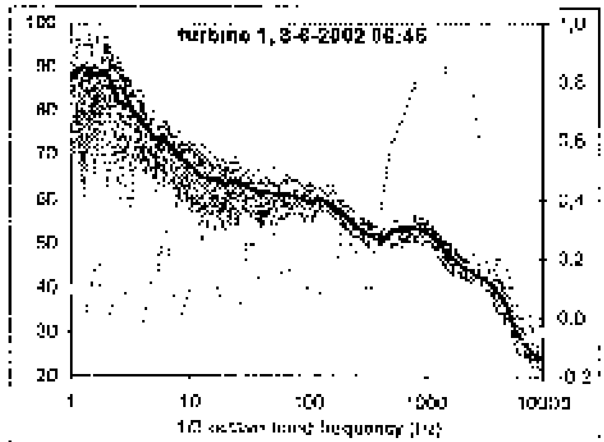
front of the façade of a dwelling at 750 m distance from the nearest row of turbines (measured Leq minus 3 dB correction for incoherent reflection at the façade).
In each part of figure 1 200 spectra (spaced 1 sec) as well as the energy averaged spectrum have been plotted. Also the correlation coefficient σ between all unweighted 1/3 octave band levels and the overall A-weighted sound levels has been plotted for each 1/3 octave band frequency. It is clear from the spectra that most energy is found at lower frequencies. This does not imply it is relevant for hearing as human hearing however is relatively insensitive at low frequencies. Indeed, the correlations show that most audible energy near the turbines is contained in the 1/3 octave band levels with frequencies from 400 through 3150 Hz (where σ > 0.4). For the sound at the façade this is one octave lower (200 - 1600 Hz) because higher frequencies were better absorbed and now contribute less to the sound energy as they do near the turbines.

In figure 2 thirteen more detailed 1-second 1/3 octave band spectra have been plotted from the sound on the façade (see figure 1). Although the bandwidth should be taken smaller to detect the harmonics of the blade passing frequency f_B = 1 Hz, the first harmonic at 2 Hz is clearly visible. A more detailed spectrum form a single turbine is given by Betke *et al* [9].

In figure 3 the three average spectra from figure 1 have been repeated, and the median hearing threshold for otologically selected young adults (according to ISO 226 [10]) has been added as well as the hearing threshold for the best hearing 10% of this group (10 percentile) which is 7 to 8 dB below the median level. It is clear that the sound below appr. 20 Hz must be considered inaudible for even well hearing people, even when one stands close to the turbine. Sound levels above the low frequency range but below appr. 1000 Hz are dominant with respect to audibility.
From figure 3 it is clear that sound levels at 100 m from a turbine (the two upper spectra) and at a location 750 km away from the first row of turbines are of comparable level at infrasonic frequencies; in fact the level differs only 4 dB. Although at the larger distance the sound level of a single turbine decreases, this is counterbalanced by the fact that more turbines contribute. At higher frequencies the same is true, but at increasing distance more sound energy is lost because of absorption.
The spectra in figure 3 are divided in three regions. For frequencies below 10 Hz the sound is dominated by thickness noise associated with the blade passing frequency (and harmonics). Then, in the higher infrasound region and upwards, where the level falls less steeply, in-flow turbulence is the dominant sound producing mechanism. Gradually, at frequencies above 100 Hz, airfoil self-noise is becoming the most dominant source, declining only at high frequencies of several kHz.

Impulsiveness
Wind turbine sound is not usually considered to be impulsive, as it has a more or less constant level due to the essentially random nature of the sound production mechanisms. Although there are periodic audible swishes, these are no equal to 'real impulses' like hammering or gun shots.
However, in a stable atmosphere the periodic swishes are louder than in daytime and residents use words like clapping, beating or thumping to describe the character or the sound. In the case of the Rhede wind park, the beating can be heard clearly at distances of at least up to 1 km and at night one can use it to determine the rotational speed of the turbine. So perhaps wind turbines can produce impulsive sound, but only in specific atmospheric conditions: the atmosphere must be stable. To understand this we must understand the implications of a stable atmosphere with respect to wind, the matter driving wind turbines.





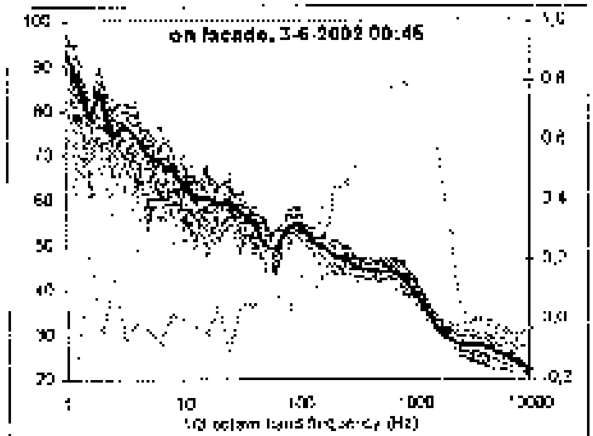


Figure 1:
left axis (in dB): 200 consecutive, unweighted and 1 second spaced 1/3 octave band levels (thin lines), and average spectral level (thick line) near two turbines and near dwelling;

right axis: coefficient of correlation (line with markers) at each 1/3 octave band frequency between all 200 1/3 octave band levels and overall A-weighted levels

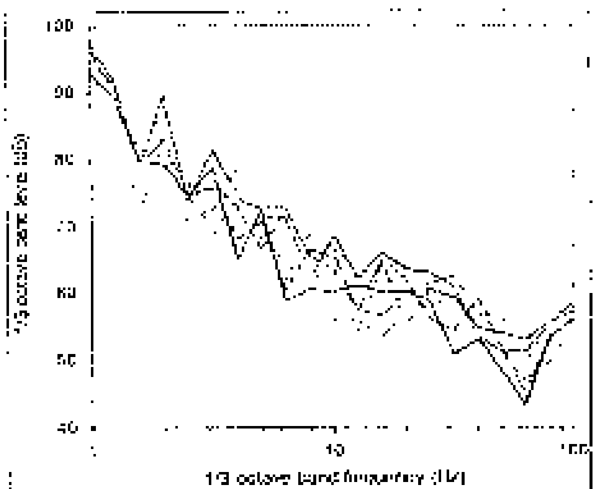


Figure 2:
13 unweighted, 1 second spaced 1/3 octave band levels near a turbine

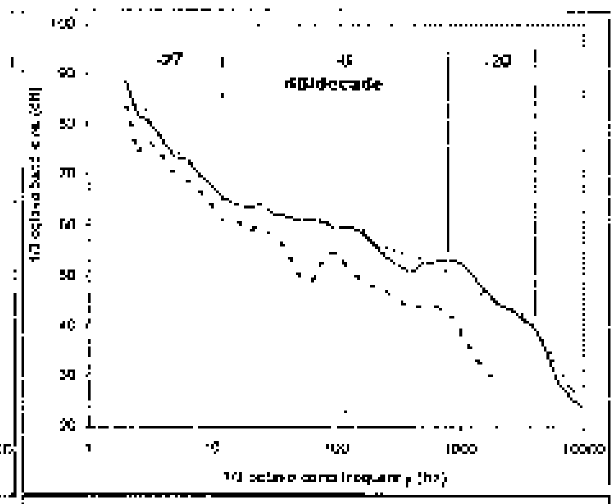


Figure 3: regions in 1/3 octave band spectra near turbines (grey and thin black line) and dwelling (dotted line) with average spectrum slope in dB/decade, and 10 and 50 percentile hearing threshold level for young adults

The wind speed v_h at height h in the atmosphere can be written as:

$$v_h = v_{ref}(h/h_{ref})^m \qquad (1)$$

where v_{ref} is the wind speed at a reference height h_{ref} (usually 10 m). The exponent m depends upon atmospheric stability. For a neutral atmosphere, occurring under heavy clouding and/or in strong winds, air buoyancy dominates thermal effects and m has a value of appr. 0.2. In an unstable atmosphere, as is usual in daytime (if not neutral), m has a value of appr. 0.1. In a stable atmosphere m should theoretically reach values up to a maximum of ½√2, describing a parabolic wind profile corresponding to laminar flow. Our Rhede measurements yielded values of m up to 0.6 [8]. A sample from data from the Royal Dutch Meteorological Institute KNMI [11] shows that indeed this theoretical maximum can be reached: in ten out of twelve midnight half hours (averages over 0:00 – 0:30 GMT) of each first night of the month there was a temperature inversion in the lower 120 m, indicating atmospheric stability. Of these in six cases the temperature increased with more than 1 °C from 10 to 120 m height and the exponent m (calculated from (1): $m = \log(v_{80}/v_{10})/\log(8)$) was 0.43, 0.44, 0.55, 0.58, 0.67 and 0.72 (we expect to do a more thorough analysis on more data to obtain statistically relevant long-term results).
In the following text we will use a value m = 0.1 for an unstable atmosphere and m = 0.6 for a stable atmosphere. These values will be used for altitudes between 10 and 120 m. It is probable that the wind profile above 120 m will not follow formula (1), as eventually a more or less constant wind speed (the geostrophic wind) will be attained, perhaps, in a stable atmosphere, after a decrease when the top of a 'low level jet' at about 100 m height has been reached. Because of this, the optimal height for a windturbine from an energetic point of view will probably be about 100 m.

Effects depend on wind turbine properties (such as speed, diameter and height). We will use typical dimensions of a modern 1.5-2 MW wind turbine: hub height 80 m, rotor diameter 70 m and rotational speed increasing with wind speed to a maximum value of 20 rpm.

Now there are two reasons why the periodic swishes acquire a more impulsive character in a stable atmosphere relative to an unstable or neutral atmosphere.

1- Rotational speed will be determined by a rotor averaged wind speed, but the difference in wind speed between the upper and lower part of the rotor increases. Suppose the wind speed at hub height is v_{80} = 8 m/s. Then in daytime (m = 0.1) the wind speed at the lowest point of the rotor would be v_{45} = 7.6 m/s, at the highest point v_{115} = 8.3 m. The difference in wind speed over the rotor of 0.35 m/s causes a change in angle of attack of only 0.25° (both plus or minus relative to average value). A very slight vertical tilt of the rotor can offset this. In nighttime (m = 0.6) however, at the same wind speed at hub height, v_{45} is 5.7 m/s and v_{115} 9.9 m/s, so the difference in wind speed over the rotor and the change in angle of attack are now 6 times as large: 2.1 m/s and 1.5°, respectively. As a consequence there will be more airfoil self-noise.
A further effect is that there is a greater mismatch between optimum and actual angle of attack when the blade passes the mast (where there was already a mismatch due to the tower), causing higher blade loading and more turbulence. This effect is readily audible when night falls: the blades start clapping or beating at the blade passing frequency. The effect is stronger when stability increases, and also when wind speed at hub height increases up to the point where friction turbulence overrides stability and the atmosphere becomes neutral.

2- As was shown earlier [8], in a stable atmosphere wind turbines can run almost synchronously because the relative absence of turbulence leads to less random motion

superimposed on the constant (average) wind speed at each turbine. Turbines in a wind park therefore experience a wind that is more constant over greater distances. As a result they tend to react the same, that is: their turbine speeds are more nearly equal. This is confirmed by long term measurements by Nanahara *et al* who analysed coherence of wind speeds at locations at increasing distances in two coastal areas [12]. At night hours wind speeds at different locations were found to change more coherently than they did at daytime [13]. The difference between night and day hours was not very strong, probably because just time of day is a helpful, but not sufficient indicator for stability, especially not near sea and over all day lengths in an entire year.
Because of the *near*-synchronicity of several turbines, sometimes two are in phase and the blade passing pulses coincide, and then go out of phase again. The same can happen for three and perhaps more turbines. Exact synchronicity would not give the same effect, because it is improbable that an observer would hear these pulses at the same time. Because of near-synchronicity however, an observer will hear coinciding pulses for part of the time. Synchronicity here refers to the sound pulses of the different turbines at the location of the observer: pulses synchronize when they arrive simultaneously. This does not imply that the rotors are in phase, in that case the pulses would not arrive simultaneously unless the turbines would be at a distance to the observer equal to the distance sound propagates in one pulse repetition time or a multiple.

Both effects, the wind speed gradient and the near-synchronicity, increase the level of the sound heard when the blades pass the tower. The extra blade loading itself is not audible because of the high hearing threshold at the very low blade passing frequency. But the effect of added induced turbulence increases the levels at frequencies that already were dominating the best audible part of the sound, that is, at 750 m distance, at 200 – 1600 Hz (= range with high correlation in figure 1). When the pulses at the Rhede wind park synchronize, the level of the 800 Hz 1/3 octave band (best correlated to audibility: see façade spectrum in figure 1) increases with 10 dB, whereas the total A-weighted level increases with 5 dB. In general the height of the pulse will depend on the change in angle of attack and the distances of the wind turbines relative to the observer: the beat due to several turbines will reach higher pulse levels when more turbines are at approximately equal distances and contribute equal immission levels. The clapping or beating is thus at well-audible frequencies and has a repetition rate equal to the blade passing frequency

Window rattling

Although infrasound levels from large turbines at frequencies below 20 Hz are too low to be audible, they may cause structural elements of buildings to vibrate. The vibrations may produce higher frequency, audible sound.
Windows are usually the most sensitive elements as they move relatively easy because of the low mass per area. Perceptible vibrations of windows may occur at frequencies from 1 to 10 Hz when the incoming 1/3 octave band sound pressure level is at least appr. 52 dB [14]; at higher or lower frequencies a higher level is needed to produce perceptible vibrations. As can be seen in figures 1 – 3 sound pressure levels above 60 dB at frequencies below 10 Hz occur close to a turbine as well as at 750 m distance and further.

A window vibrating at the impinging frequency transmits this frequency to the indoor air. If this does not coincide with a room resonance, the sound will not be louder than outdoors. For rooms in dwellings with a greatest dimension of 10 m, resonance frequencies are higher than appr. 15 Hz and thus cannot coincide with relevant harmonics of f_B, the blade passing frequency.

However, a window pane itself may have a resonant frequency of, e.g., 40 Hz and a frequency of 10 Hz then may sustain a window pane resonance, thus transforming inaudible infrasound to audible higher frequencies. Also, a loosely fitted window may move to and fro and being stopped by the window frame vibrates at higher frequencies radiated into the room.

Conclusion

Infrasonic harmonics of the blad passing frequency from modern, tall wind turbines must be considered inaudible. Low frequency in-flow turbulence sound may be audible, but wind turbine sound is loudest at medium to high frequencies. This readily audible sound is caused by atmospheric and induced turbulence at the blade surface. The level of this medium/high frequency turbulent sound varies at the rate of the blade passing frequency, which causes the typical swishing sound of a modern wind turbine.

When the atmosphere becomes more stable, which is usual at night when there is a partial clear sky and a light to moderate wind (at ground level), there is an important change in wind profile affecting the performance of a modern, tall wind turbine. The airflow around the blade then changes tot less than optimal, resulting in added induced turbulence. This effect is strongest when the blades pass the tower, causing short lasting, higher sound levels at the rate of the blade passing frequency. In a wind park these pulses can synchronize, leading to still higher pulse levels for an observer outside the park. The resulting repetitive pulses change the character of the wind park sound and must be expected to cause added annoyance.

References

1- "Windpower keeps its promises", New and Renewable energies: Wind energy. http://europa.eu.int/comm/energy/res/sectors/wind_energy_en.htm, visited June 16, 2004
2- More attention must be paid to the harmful effects, Western Morning News, 6 january 2004; http://www.countryguardian.net/WMN%20re%20noise.htm
3- http://www.britishwindenergy.co.uk/ref/egnoise.html, visited June 16, 2004
4- Geoff Leventhal: "A Review of Published Research on Low Frequency Noise and its Effects", Report for Defra, 2003
5- H. Bodén, M. Bone, M. Åbom: "Sound from sea based wind turbines (TRANS)", http://www.kth.se/forskning/pocket/project.asp?id=20106, visited June 16, 2004
6- S. Wagner, R. Bareiss, G. Guidati: "Wind turbine noise", Springer, Berlin,1996
7- E.L. Petersen, N.G. Mortensen, L. Landberg, J. Høstrup, H.P. Frank: Wind power meteorology", Wind Energy 1 (1998), pp. 2-22
8- G.P. van den Berg: "Effects of the wind profile at night on wind turbine sound", Journal of Sound and Vibration, in press
9- K. Betke, H. Remmers: "Messung und bewertung von tieffrequentem Schall", presented at DAGA'98, Zürich, 1998
10- ISO: ISO 226: "Acoustics-Equal Loudness contours for otologically normal listeners, part 1"
11- A.P. van Ulden, J.G. van der Vliet en J. Wieringa: "Temperature and wind observations at heights from 2m to 200m at Cabauw in 1973", 1976, De Bilt
12- T. Nanahara, M. Asara, T. Sato, K. Yamaguchi, M. Shibata, T. Maejima: "Smoothing effects of distributed wind turbines, part 1", Wind Energy 2004 (7), pp. 61-74
13- T. Nanahara: personal communication by e-mail, June 14, 2004
14- Figure in [6] taken from D. G. Stephens: "Evaluation human exposure noise large wind turbines", NASA-TM-83288, March 1982

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The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines

by

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The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines

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SUMMARY

Sound from wind turbines involves a number of sound production mechanisms related to different interactions between the turbine blades and the air. An important contribution to the low frequency part of the sound spectrum is due to the sudden variation in air flow which the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimized for the mean flow. Hitherto, low-frequency sound from wind turbines has not been shown to be a major factor contributing to annoyance. This seems reasonable as the blade passing frequency is of the order of one hertz where the human auditory system is relatively insensitive. This argument, however, obscures a very relevant effect: the blade passing frequency modulates well audible, higher-frequency sounds and thus creates periodic sound: *blade swish*. This effect is stronger at night because in a stable atmosphere there is a greater difference between rotor averaged and near-tower wind speed. Measurements have shown that additional turbines can interact to further amplify this effect. Theoretically the resulting fluctuations in sound level will be clearly perceptible to human hearing. This is confirmed by residents near wind turbines with the same common observation: often late in the afternoon or in the evening the turbine sound acquires a distinct 'beating' character, the rhythm of which is in agreement with the blade passing frequency. It is clear from the observations that this is associated to a change toward a higher atmospheric stability. The effect of stronger fluctuations on annoyance has not been investigated as such, although it is highly relevant because a) the effect is stronger for modern (that is: tall) wind turbines, and b) more people in Europe will be living close to these wind turbines as a result of the growth of wind energy projects

1. INTRODUCTION

Modern onshore wind turbines have peak electric power outputs of around 2 Mw and tower heights of 80 to 100 meters. In 2003, 75% of the global wind power peak electric output of 40 Gw was installed in the European Union. The original European target for 2010 was 40 Gw, but the European Wind Energy Association have already set a new target for 2010 of 75 Gw, of which 10 Gw is projected off-shore, while others have forecast a peak output of 120 Gw for that year [1]. Whether this growth will actually occur is uncertain; with the proportional increase of wind energy in total electric power the difficulties and costs of integrating large scale windpower with respect to grid capacity and stability, reserve capacity and CO_2 emission reductions are becoming more prominent (see, e.g., [31, 32]). However, further expansion of wind energy is to be expected, and as a result of this (predominantly on-shore) growth an increasing number of people may face the prospect of living near wind farms, and have reason to inquire and perhaps be worried about their environmental impact. Visual intrusion, intermittent reflections on the turbine blades, as well as intermittent shadows (caused when the rotating blades pass between the viewer and the sun), and sound, are usually considered potentially negative impacts.

Atmospheric stability has hitherto not been considered with respect to wind turbine sound. However, at the heights that are reached by modern, tall wind turbines the effect has become increasingly important, from an energetic as well as acoustical point of view.

In an earlier paper [2] it has been shown that in a stable atmosphere the sound *level* due to wind turbines is higher than is expected from sound production based on simple logarithmic extrapolation from reference wind speeds. The present paper explores the effect of atmospheric stability on the periodic *level changes* known as 'blade swish'. In the next two sections three possibly relevant effects of a change in atmospheric stability are identified and investigated from a theoretical point of view. All effects result in a higher level of blade swish. Then, in section 4, we will turn to measurement results and show that measured results can be explained by these predicted effects. Finally, in section 5, the results are put in the context of human perception. It can now be understood why in a stable atmosphere (but not in an unstable atmosphere) wind turbine sound is perceived as a fluctuating sound.

2. SOURCES OF WIND TURBINE SOUND

There are many publications on the nature and power of turbine sound. See, e.g., the studies by Lowson [3] and Grosveld [4], and the reviews by Hubbard and Shepherd [5] and Wagner *et al* [6]. A short introduction on wind aeroacoustics will be given to elucidate the most important sound producing mechanisms.

If an air flow is smooth around a (streamlined) body, it will generate very little sound. For high speeds and/or over longer lengths the flow in the boundary layer between the body and the main flow becomes turbulent. The rapid turbulent velocity changes at the surface cause sound with frequencies related to the rate of the velocity changes. The turbulent boundary layer at the downstream end of an airfoil produces *trailing edge sound*, which is the dominant audible sound from modern turbines.

As is the case for aircraft wings, the air flow around a wind turbine blade generates lift. An air foil performs best when lift is maximised and drag (flow resistance) is minimised. Both are determined by the angle of attack: the angle (α) between the incoming flow and the blade chord (line between front and rear edge; see figure 1). When the angle of attack increases from its optimal value the turbulent boundary layer on the suction (low pressure) side grows in thickness, thereby decreasing power performance and increasing sound level. For high angles of attack this eventually leads to stall, that is: a dramatic reduction in lift.

Apart from this turbulence inherent to an airfoil, the atmosphere itself is turbulent over a wide range of frequencies and sizes. Turbulence can be defined as changes over time and space in wind velocity and direction, resulting in velocity components normal to the airfoil varying with the turbulence frequency causing *in-flow turbulent sound*. Atmospheric turbulence energy has a maximum at a frequency that depends on height and on atmospheric stability. For wind turbine altitudes this peak frequency is of an order of magnitude of once per minute (0.017 Hz). The associated eddy (whirl) scale is of the order of magnitude of several hundreds of meters [7] in an unstable atmosphere, less in a stable atmosphere. Eddy size and turbulence strength decrease at higher frequency, and vanish due to viscous friction when they have reached a size of approximately one millimetre.

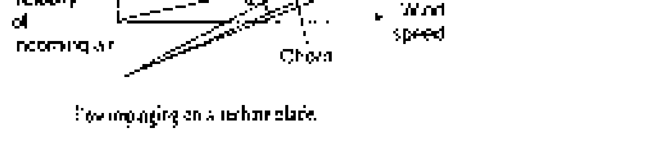

Figure 1 Flow impinging on a turbine blade.

A third sound producing mechanism is the response of the blade to the change in lift when it passes the tower. The wind is slowed down by the tower which changes the angle of attack. The resulting sideways movement of the blade causes *thickness sound* at the blade passing frequency and its harmonics.

A more thorough review of these three sound production mechanisms is given in Appendix I, where frequency ranges and sound levels are quantified in so far as relevant for the present paper. A modern wind turbine sound spectrum can now be divided in (overlapping) regions corresponding to these three mechanisms:

1. Infrasound frequency ($f < 30$ Hz): the *thickness sound* is tonal, the spectrum containing peaks at the blade passing frequency f_B and its harmonics.
2. Low frequency: *in-flow turbulent sound* is broad band noise with a maximum level at approximately 10 Hz and a slope of 3–6 dB per octave.
3. High frequency: *trailing edge (TE) sound* is noise with a maximum level at 500–1000 Hz for the central octave band, decreasing by 11 dB for neighbouring octave bands and more for further octave bands.

Sound originating from the generator or the transmission gear has decreased in level in the past decades and has become irrelevant when considering annoyance for residents. As thickness sound is not relevant for direct perception, turbulent flow is the dominant cause of (audible) sound for modern wind turbines. It is broad-band noise with no tonal components and only a little variation, known as blade swish. Blade swish is sound due to the regular increase in trailing edge sound whenever a blade passes the tower. Trailing edge (TE) sound level is proportional to 50 log M (see equation A4 in appendix), where M is the Mach number of the air impinging on the blade. TE sound level therefore increases steeply with blade speed and is highest at the high velocity blade tips. Swish thus originates predominantly at the tips.

Sound from downwind rotors, i.e. with the rotor downwind from the tower, was considered problematic as it was perceived as a pulsating sound (see appendix). For modern upwind rotors this variation in sound level is weaker. It is not thought to be relevant for annoyance and considered to become less pronounced with increasing distance due to loss of the effect of directivity, due to relatively high absorption at swish frequencies, and because of the increased masking effect of background noise [8]. However, several effects that increase the level of the swishing sound and are related to increasing atmospheric stability have not been taken into account as yet. Possible effects will be considered before we turn to measurement results.

3. EFFECT OF ATMOSPHERIC STABILITY ON WIND TURBINE SOUND

The wind speed v_h at height h in the atmosphere can be written as:

$$v_h = v_{ref}\left(\frac{h}{h_{ref}}\right)^m \qquad (1)$$

where reference height h_{ref} is usually 10 m [2, 7]. The relation is suitable where h is at least several times the roughness length. At high altitudes the wind profile will not follow (1), as eventually a more or less constant wind speed (the geostrophic wind) will be attained. At higher altitudes in a stable atmosphere there may be a *decrease* in wind speed when a nocturnal "jet" develops. The maximum in this jet is caused by a transfer of kinetic energy from the near ground air that decouples from higher air masses as large, thermally induced eddies vanish because of ground cooling. In fact, reversal of the usual near-ground diurnal pattern of low wind speeds at night and higher wind speeds in daytime is a common phenomenon at higher altitudes over land in clear nights [9, 10, 11]. Over large bodies of water the phenomenon may be seasonal as stability occurs more often when the water is relatively cold (winter, spring). This may also be accompanied by a maximum in wind velocity at a higher altitude [12].

In a neutral atmosphere the wind profile can also be modelled with the well known logarithmic or adiabatic profile, where relative wind speed v_h/v_{ref} depends on height and surface roughness. This model is widely (and, as yet, only) used in relation to wind turbine sound (see, e.g., [8] or [14]). With regard to wind *power* more attention is being paid to stability effects and thus to other wind profile models [see, *e.g.*, 10, 11, 12, 15, 16]. Accurate wind speed profiles can be calculated with a diabatic wind speed model where stability corrections are added to the adiabatic profile (see, *e.g.*, [9] or [13]).

Equation (1) has no theoretical basis, but often provides a good fit to the vertical wind profile, especially when the atmosphere is non-neutral. In flat terrain the stability exponent m has a value of 0.1 and more. In daytime or in windy nights ($0.1 < m < 0.2$) equation (1) does not deviate much from the logarithmic wind profile; for altitudes up to 100 m and low vegetation (roughness length < 10 cm), wind velocities calculated with equation 1 agree within 20% with the logarithmic wind profile.

For a neutral atmosphere, occurring under heavy clouding and/or in strong winds, m has a value of approx. 0.1. In an unstable atmosphere -occurring in daytime- thermal effects caused by ground heating are dominant. Then m has a lower value, down to approx. 0.1. In a stable atmosphere vertical movements are damped because of ground cooling. One would then eventually expect a parabolic wind profile, as is found in laminar flow, corresponding to a value of m of $0.7 \approx \sqrt{½}$. Our measurements near the Rhede wind farm (53° 6.2' latitude, 7° 12.6' longitude) at the German-Dutch border [2] yielded values of m up to 0.6. A sample (averages over 0:00–0:30 GMT of each first night of the month in 1973) from data from a 200 m high tower in flat, agricultural land [27] shows that the theoretical value is indeed reached: in ten out of the twelve samples there was a temperature inversion in the lower 120 m, indicating atmospheric stability. In six samples the temperature increased with more than 1 °C from 10 to 120 m height and the exponent m (calculated from (1): $m = \log(v_{80}/v_{10})/\log(8)$) was 0.43, 0.44, 0.55, 0.58, 0.67 and 0.72. Comparable values have been estimated in the US Midwest [15] and at a Spanish plateau [16]. In the following text we will use a value $m = 0.15$ for a daytime atmosphere (unstable – neutral), $m = 0.4$ for a stable, and $m = 0.65$ for a very stable atmosphere. These values will be used for altitudes between 10 and 120 m.

The magnitude of the effects of increasing stability depends on wind turbine properties such as speed, diameter and height. We will use the dimensions of the wind turbines in the Rhede wind farm, that are typical for a modern 1.5-2 MW wind turbine: hub height 100 m, blade length 35 m and rotational speed increasing with wind speed up to a maximum value of $\Omega R = 73$ m/s (at 20 rpm).

There are now three factors influencing blade swish level when the atmosphere becomes more stable: a) the higher wind speed gradient, b) the higher wind direction gradient, and c) the relative absence of large scale turbulence.

a. *Wind speed gradient.* Rotational speed is determined by a rotor averaged wind speed. With increasing atmospheric stability the difference in wind speed between the upper and lower part of the rotor increases. Suppose that the wind speed at hub height is $v_{100} = 14$ m/s, corresponding to $v_{10} = 9.8$ m/s in a neutral atmosphere in flat open grass land (roughness length 4 cm). Then in daytime ($m = 0.15$) the wind speed at the lowest point of the rotor would be $v_{65} = 13.1$ m/s, at the highest point $v_{135} = 14.6$ m/s. As the blade angle does not change with rotation angle, the difference between the low tip and hub height wind speeds causes a change in angle of attack on the blade of $\Delta\alpha = 0.8°$ at 20 rpm (see appendix, equation A7). Between the high tip and hub height the change is smaller: 0.5°. In night-time ($m = 0.4$), at the same wind speed at hub height, v_{65} is 11.8 m/s causing a change in angle of attack at the lower tip relative to hub height of 1.8° (at the high tip: $v_{135} = 15.8$ m/s, $\Delta\alpha = 1.5°$). When the atmosphere is very stable ($m = 0.65$), wind speed $v_{65} = 10.5$ m/s and the angle of attack on the low altitude tip deviates 2.9° from the angle at hub height (at the high tip, $v_{135} = 17.2$ m/s, $\Delta\alpha = 2.5°$).

In fact when the lower tip passes the tower there is a greater mismatch between optimum and actual angle of attack α because there was already a change in angle of attack related to the wind velocity deficit in front of the tower. For a daytime atmosphere and with respect to the situation at hub height, the change in α associated to a blade swish level of 1 ± 0.5 dB is estimated as $2.1 \pm 0.4°$ (see appendix, section C), part of which (0.8°) is due to the wind profile and the rest to the tower. The increase in α due to the stability related wind profile change must be added to this daytime change in α. Thus, relative to the daytime (unstable to neutral) atmosphere, the change in angle of attack when the lower tip passes the mast increases with 1.0° in a stable atmosphere, and with 2.1° in a very stable atmosphere. The associated change in trailing edge (TE) sound level, as calculated from equation A6 in the appendix, is 3.1 ± 0.7 dB for a stable and 5.0 ± 0.8 dB for a very stable atmosphere (compared to 1 ± 0.5 dB in daytime). The corresponding total A-weighted sound level will be somewhat less as trailing edge sound is not the only sound source (but it is the dominant source; see section 4C).

At the high tip the change in angle of attack is smaller than for the low tip as there is no (sudden) tower induced change to add to the wind gradient dependent change. The change in angle of attack at the high tip in a very stable atmosphere (2.5°) is comparable to the change at the low tip in daytime, and this change is more gradual than for the low tip.

Thus we find that, for $v_{10} = 14$ m/s, the 1-2 dB daytime blade swish level increases to approx. 5 dB in a very stable atmosphere. The effect is stronger when wind speed increases up to the point where friction turbulence overrides stability and the atmosphere becomes neutral. The increase in trailing edge sound level will be accompanied by a lower peak frequency (see appendix, equation A2). For $\alpha = 5°$ the shift is one octave.

b. *Wind direction gradient.* In a stable atmosphere air masses at different altitudes are only coupled by small scale turbulence and are therefore relatively independent. Apart from a higher velocity gradient a higher wind direction gradient is also possible, and with increasing height the wind direction may change significantly. This wind direction shear will change the angle of attack with height. Assuming the wind at hub height to be normal to the rotor, the angle of attack will decrease below and increase above hub height (or vice versa). This effect, however, is small: if we suppose a change in wind direction of 20° over the rotor height at a wind velocity of 10 m/s, the change in angle of attack between extreme tip positions at 20 rpm is only 0.25°, which is negligible relative to the wind velocity shear.

c. *Less turbulence.* As was shown in an earlier study [2], in areas near a wind farm an increase in blade swish pulse height (The term 'pulse' is used to indicate the upward variation in sound level.) can be explained by the synchronization of two or three pulse trains coming from the two or three closest turbines. In a stable atmosphere wind turbines can run almost synchronously because the absence of large scale turbulence leads to less variation superimposed on the constant (average) wind speed at each turbine. In unstable conditions the average wind speed at both turbines will be equal, but instantaneous local wind speeds will differ because of the presence of large, turbulent eddies at the scale of the inter-turbine distance. In a stable atmosphere the turbulence scale decreases with a factor up to 10, relative to the neutral atmosphere and even more relative to an unstable atmosphere [17]. In stable conditions turbines in a wind farm therefore experience a more similar wind and as a consequence their instantaneous turbine speeds are more nearly equal. This is confirmed by long term measurements by Nanahara *et al.* [18] who analysed coherence of wind speeds between different locations in two coastal areas. At night wind speeds at different locations were found to change more coherently than they did at daytime [19]. The difference between night and day was not very strong, probably because time of day on its own is not a sufficient indicator for stability. The decay of coherence was however strongly correlated with turbulence intensity, which in turn is closely correlated to stability. (In a coastal location atmospheric stability also depends on wind direction as landwards stability is a diurnal, but seawards a seasonal phenomenon. Also, a fixed duration for all nights in a year does not coincide with the time that the surface cools (between sundown and sunrise), which is a prerequisite for stability.)

Near the Rhede wind farm we found that, because of the *near* synchronicity of several turbines, sometimes two or three were in phase and the blade passing pulses coincided, and then went out of phase again [2]. This would lead to a doubling (+3 dB) or tripling (+5 dB) of pulse height. If in a (very) stable atmosphere individual swish pulse heights are 3–5 dB (see section 3a above), synchronicity at the Rhede wind farm or similar configurations would thus lead to pulse heights of 6–10 dB.

Synchronicity here refers to the sound pulses from the different turbines as observed at the location of the observer. So, pulses synchronise when they arrive simultaneously. This is determined by differences in phase (rotor position) between turbines and in propagation distances of the sound from the turbines. Phase differences between turbine rotors occur because turbines are not connected and because of differences in actual performance. The place where synchronicity is observed will change when the phase difference between turbines changes. With exact synchronicity there would be a fixed interference pattern, with synchronicity at fixed spots. Because of near-synchronicity however, synchronicity will change over time and place and an observer will hear coinciding pulses for part of the time only.

A second effect of the decrease in turbulence strength is that in-flow turbulent sound level also decreases. The resulting decrease in broad band sound level lowers the minimum in the temporal variations, thereby increasing modulation depth.

We conclude that the higher wind speed gradient and (near-) synchronicity increase blade swish levels at some distance from a wind farm. The higher infrasound level due to extra blade loading is not perceptible because of the high hearing threshold at the very low blade passing frequency. However, the effect of added boundary layer turbulence on the blade increases the levels at the higher frequencies that already were dominating the most audible part of the sound. Near a wind farm the variation in sound level will depend on the distances of the wind turbines relative to the observer, the level increase due to several turbines will reach higher levels when more turbines are at approximately equal distances and thus contribute equal immission levels. The increase in level variation, or beating, is thus at well audible frequencies and has a repetition rate equal to the blade passing frequency.

Thus, theoretically it can be concluded that in stable conditions (low ambient sound level, high turbine sound power and higher modulation or swish level) wind turbine sound can be heard at greater distances and is of lower frequency due to absorption and the frequency shift of swish sound. It is thus a louder and more low-frequency 'thumping' sound and less the swishing sound than observed close to a daytime wind turbine.

4. MEASUREMENT RESULTS

4.1. Locations

In the summers of 2002 and 2004 wind turbine sounds have been recorded in and near the Rhede wind farm on the German-Dutch border. The farm (figure 2) has a straight south to north row of ten turbines at approximately 300 m intervals, running parallel to the border, and seven less regularly spaced turbines east of the straight row. Each turbine is 98 m to the hub height, and has a blade length of 35 m, and produces nominally 1.8 MW electric power.

The measurement location at dwelling R is west of the turbines, 625 m from the nearest turbine. The microphone position was at 4 m height and close to the house, but with no reflections except from the ground. The measurement location at dwelling P, 870 m south of R, was 1.5 m above a gravel terrace in front of the façade of the dwelling at 750 m distance from the nearest turbine. The entire area is quiet, flat, agricultural land with some trees close to the dwellings. There is little traffic and there are no significant permanent human sound sources.

A third dwelling Z is in Bourtein in the northern part of the Netherlands, 280 m west of a single, two-speed turbine (45 m hub height, 23 m blade length, 20/26 rpm). The area is again quiet, flat and agricultural. The immission measurement point is at 1.5 m height above gravel near the dwelling. This measurement site is included here to show that the influence of stability on blade swish levels occurs also with

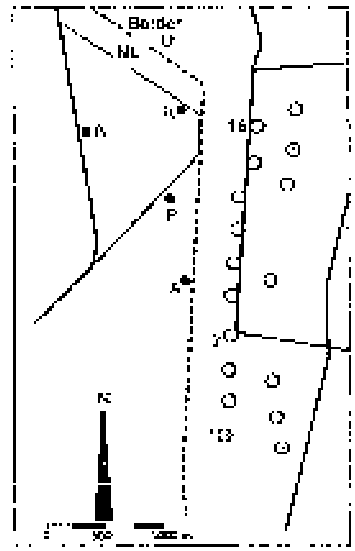

Figure 2 Turbines (grey circles) and measurement locations (A,B,P,R) near the Rhede wind farm; solid lines are roads.

Table 1. Overview of measurement locations and times and of turbine speed and wind

	Measurement		Turbine speed	Wind speed (m/s)		Wind direction
Location	Date	Time	(rpm)	v_{10}	v_{hub}	(° north)
Dwelling P	June 3, 2002	00:45	20	5	14	100
Turbine 7	June 3, 2002	06:30	17	5	15	100
Turbine 1	June 3, 2002	05:45	19	5	15	100
Dwelling R Turbine 16	Sep. 9, 2004	23:07	15	4	13	50
Dwelling Z	Oct. 18, 2003	01:43	26	3	6	40

smaller, single turbines. At all locations near dwellings the microphone was fitted in a 9 cm diameter foam wind screen.

Table 1 gives an overview of measurement (start) times and dates of observed turbine speeds and of wind speed and direction, for situations for which results will be given below. The wind speed at hub height v_{hub} has been determined from turbine rotation speed N or sound power level L_w ([2], the relation v_{hub} – N follows from ref. 5 and 11 in [1]). The wind speed v_{10} at 10 m height was continuously measured at or near location A, except for location Z, where data from several meteorological stations were used showing that the wind was similar and nearly constant in the entire northern part of the Netherlands. In all cases there were no significant variations in wind speed at the time of measurement. Wind speed at the microphone was lower than v_{10} because of the low microphone height and shelter provided by trees nearby. Wind direction is given in degrees relative to north and clockwise (90° is east). The spectra near a turbine were measured with the microphone just above a hard surface at ground level 100 m downwind of a turbine in compliance with IEC 61400 [34] as much as possible (non-compliance did not lead to differences in result [2]; for reasons of non-compliance, see [34]). The levels plotted are immission levels: measured Leq minus 6 dB correction for coherent reflection against the hard surface [16]. The plotted levels near the dwellings are also immission levels: measured Leq minus 3 dB correction for incoherent reflection at the façade for dwelling P, or measured Leq without any correction for dwellings R and Z.

At dwelling P at the time of measurement the beat in the turbine sound was very pronounced. In the other measurements (dwellings R and Z) the beating was not as loud. The measurements near turbine 16 and dwelling R at 23:07 on September 9 were performed simultaneously.

4.2. Frequency response of instruments

For the Rhede measurements sound was recorded on a TASCAM DA-1 DAT recorder with a precision ½ in Sennheiser MKH 20 P48 microphone. The sound was then sampled in 1-second intervals on a Larson Davis 2800 frequency analyser. From 1 to 10 000 Hz the frequency response of the DAT-recorder and LD2800 analyser have been determined with a pure tone electrical signal as input. The LD2800 response is flat (±1 dB) for all frequencies. The DAT-recorder is a first order high pass filter with a corner frequency of 2 Hz. The frequency response of the microphone was of most influence and has been determined relative to a B&K ½ in microphone type 4189 with a known frequency response [20]. Equivalent spectral sound levels with both microphones in the same sound field (approx. 10 cm mutual distance) were compared. For frequencies of 2 Hz and above the entire measurement chain is within 3 dB equivalent to a series of two high pass filters with corner frequencies of f_1 = 4 Hz and f_2 = 9 Hz, or a transfer function equal to $-20\log[1 + (f_1/f)^2] -20\log[1 + (f_2/f)^2]$. For frequencies below 2 Hz this leads to high signal reductions (< −40 dB) and consequentially low signal to (system) noise ratios. Therefore values at frequencies < 2 Hz are not presented.

For the [illegible] measurements sound was recorded on a Sharp MD-MT99 minidisc recorder with a ½ in Sennheiser MT62 microphone. The frequency response of this measurement chain is not known, but is assumed to be flat in the usual audio frequency range. Simultaneous measurements of the broad band A-weighted sound level were done with a precision (type 1) sound level meter. Absolute precision is not required here as the minidisc recorded spectra are only used to demonstrate relative spectral levels. Because of the ATRAC time coding of a signal, a minidisc recording does not accurately follow a level change in a time interval < 11.6 ms. This is insignificant in the present case as the "fast" response time of a sound level meter is much slower (125 ms).

4.3. Measured Emission and Immission Spectra

Recordings were made at evening, night or early morning. On June 2, 2002, sound was recorded at dwelling P at around midnight and early in the morning near two turbines (numbers 1 and 7). At P at these times a distinct beat was audible in the wind turbine sound. In figure 5, 1/3 octave band spectra of the recorded sound at P and at both turbines have been plotted. In each figure A, B and C, 200 sound pressure spectra sampled in one-second intervals, as well as the energy averaged spectrum of the 200 samples have been plotted. The standard deviation of 1/3 octave band levels is typically 7 dB at very low frequencies, decreasing to approx. 3 dB at 1 kHz. The correlation coefficient ρ between all unweighted 1/3 octave band levels and the overall A-weighted sound level has also been plotted for each 1/3 octave band frequency.

For frequencies below approximately 30 Hz the sound is dominated by the thickness sound associated with the blade passing frequency and harmonics. In the rest of the infrasound region and upwards, in-flow turbulence is the dominant sound producing mechanism. Gradually, at frequencies above 100 Hz, trailing edge sound becomes the most dominant source, declining at high frequencies of one to several kHz. Trailing edge sound is more pronounced at turbine 1 (T1) compared to turbine 7 (T7), causing a hump near 1000 Hz in the T1 spectra. At very high frequencies (> 2 kHz) sometimes higher spectral levels occur due to birds.

It is clear from the spectra that most energy is found at lower frequencies. However, most of this sound is not perceptible. To assess the infrasound level relevant to human perception it can be expressed as a G-weighted level [30]. With G-weighting sound above the infrasound range is suppressed. The average infrasound perception threshold is 95 dB(G) [28]. The measured G-weighted levels are 15-20 dB below this threshold: 80.5 and 81.1 dB(G) near turbines 1 and 7 respectively, and 76.4 dB(G) at the façade.

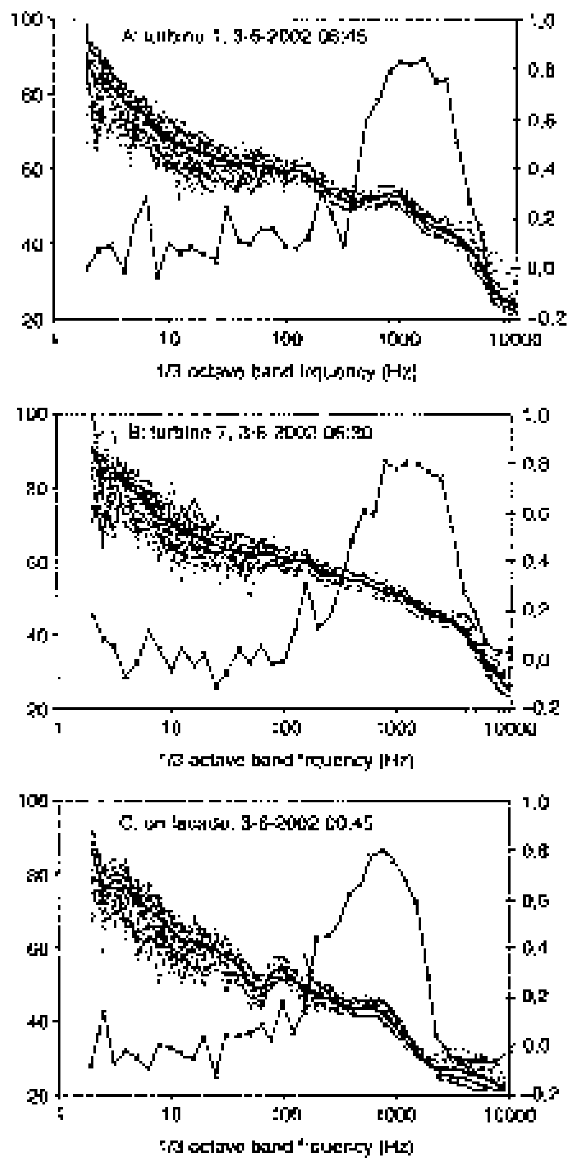

Figure 3 Left axis (in dB): 200 consecutive, unweighted and 1 second spaced 1/3 octave band levels (thin lines), and average spectral level (thick line) near turbines 1 and 7, and near dwelling P; right axis: coefficient of correlation (line with markers) at each 1/3 octave band frequency between all 200 1/3 octave band levels and overall A-weighted levels.

The correlations show that variations in total A-weighted level near the turbines are correlated with the 1/3 octave band levels with frequencies from 400 through 3150 Hz (where $\rho > 0.4$), which is trailing edge sound. This is one octave lower (200 - 1600 Hz) for the sound at the façade: the higher frequencies were better absorbed during propagation through the atmosphere.

The façade spectra in figure 3C show a local minimum at 50-63 Hz, followed by a local maximum at 80-100 Hz. (In a FFT spectrum minima are at 57 and 170 Hz, maxima at 110 and 220 Hz.) This is caused by interference between the direct sound wave and the wave reflected by the façade at 1.5 m from the microphone: for wave lengths of approx. 6 m (55 Hz) this leads to destructive interference, for wave lengths of 3 m (110 Hz) to constructive interference.

In figure 4A the three average spectra at the same locations as in figure 3A-C have been plotted, but now for a total measurement time of approx. 9.5 (façade).

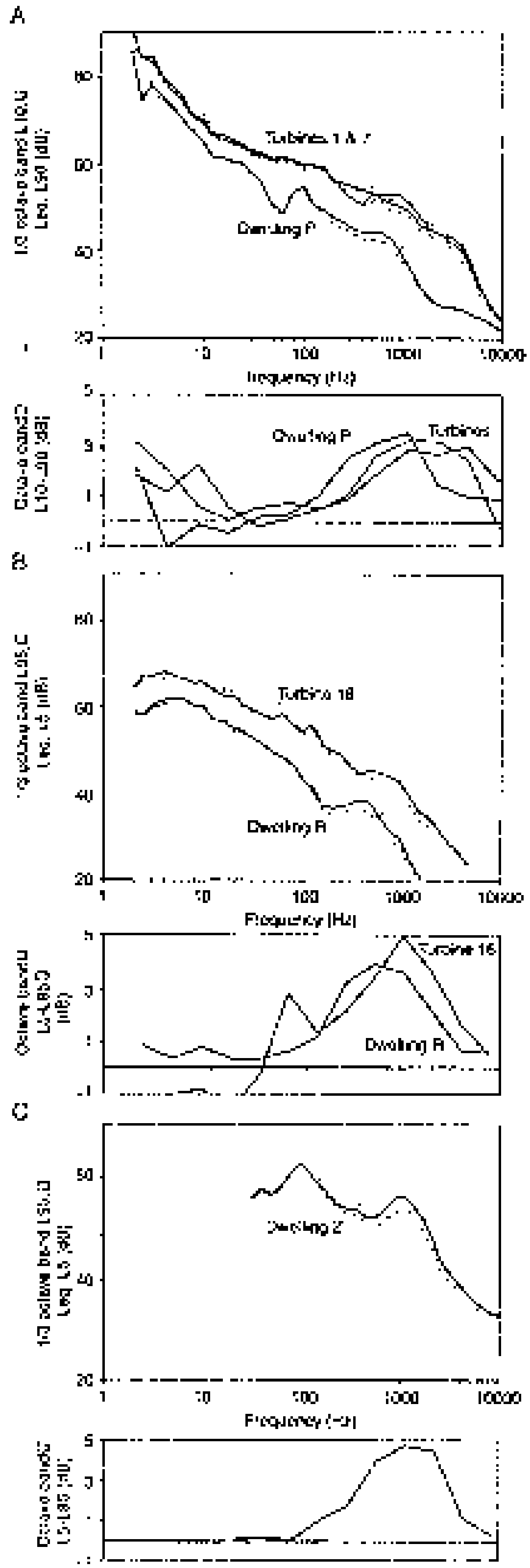

Figure 6 Upper panels A,B,C: 1/3 octave band Leq near windturbines and dwellings (thick lines) and Leq of all samples with resp. 5% highest (thin dotted lines) and 5% lowest values of broad band L_A (thick spaced lines). Lower panels: difference between Leq of 5- and 95-percentile octave band levels.

5 (T7) and 6 (T1) minutes. For each of these measurement periods the average of the 5% of samples with the highest broad band A-weighted sound level (i.e. the equivalent spectral level of the L_{A5} percentile) has also been plotted, as well as the 5% of samples with the lowest broad band level (L_{A95}). The range in A-weighted broad band level can be defined as the difference between the highest and lowest value: $R_{bb} = L_{Amax} - L_{Amin}$. Similarly the range per 1/3 octave or octave band R_f can be defined by the difference in spectral levels corresponding to L_{Amax} and L_{Amin}. The difference between L_{A5} and L_{A95} is a more stable value, avoiding possibly incidental extreme values, especially when spectral data are used. $R_{bb,90}$ is defined as the difference in level between the 5% highest and the 5% lowest broad band sound levels: $R_{bb,90} = L_{A5} - L_{A95}$. For spectral data, $R_{f,90}$ is the difference between spectral levels associated with L_{A5} and L_{A95}. Values of $R_{f,90}$ are plotted in the lower part of figure 4A (here octave bandlevels have been used to avoid the somewhat 'jumpy' behaviour of the 1/3 octave band levels). Close to turbines 1 and 7 R_{bb} is 4.8 and 4.1 dB, respectively. $R_{bb,90}$ is 3.2 and 2.6 dB, which is almost the same as $R_{f,90}$ (3.2 and 3.0 dB) at 1000-4000 Hz. Further away, at the façade, R_{bb} is comparable to the near turbine values: 4.9 dB. $R_{bb,90}$ at the façade is 3.3 dB and again almost the same as maximum $R_{f,90}$ (3.5 dB) at 1000 Hz.

Also, close to the turbine there is a low frequency maximum in $R_{f,90}$ at 2 (or 8) Hz; this is also present at the façade, indicating that the modulation of trailing edge sound is correlated in time with the infrasound caused by the blade movement.

Figure 4B presents similar plots for the average spectra and the L_{A5} and L_{A95} spectra at dwelling R and near turbine T16 over a period of 16 minutes. Close to the turbine the broadband $R_{bb,90}$ is 3.7 dB; octave band $R_{f,90}$ is highest (5.1 dB) at 4000 Hz. Near R broad band $R_{bb,90}$ is also 3.7 dB, and octave band $R_{f,90}$ is highest (4.0 dB) at 500 Hz. The R_{bb} ranges are 2.1–2.5 dB higher than the 90% ranges $R_{bb,90}$. A 25 second part of this 16 min period is shown in figure 5. The broad band level L_A changes with time at T16 and R, showing a more or less regular variation with a period of approximately 1 s (= $1/f_B$). In these measurements the infrasound level was lower than in the previous measurements at dwelling P where beating was more pronounced. G-weighted sound level during the 16 minutes at R was 70.4 dB(G), and at T16 77.1 dB(G).

Finally figure 3C gives average spectra over a period of 16 minutes at dwelling Z. $R_{f,90}$ is now highest (4.8 dB) at 1 kHz, and broadband $R_{bb,90}$ is 4.3 dB (R_{bb} = 5.9 dB). The turbine near Z is smaller and lower, but rotates faster than the Rhede turbines; for a hub height wind speed of 6 m/s the expected calculated increase in trailing edge sound for the lower tip relative to the day time situation is 2.0 ± 0.8 dB for

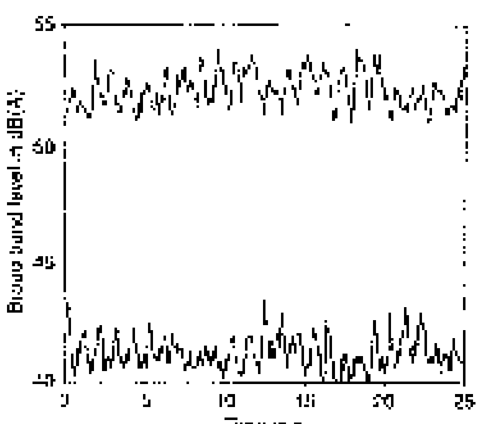

Figure 5 Broad band A-weighted momentary sound level near turbine T16 (upper plot) and close to dwelling R (lower plot).

a stable, and 2.9 ± 0.8 dB for a very stable atmosphere. For this turbine a peak trailing edge sound level is expected (according to equation A2 in appendix) at a frequency of 1550/a Hz = 400 – 800 Hz.

In all cases above the measured sound includes ambient background sound. Ambient background sound level could not be determined separately at the same locations because the wind turbine(s) could not be stopped (it has been shown elsewhere that it is a flaw in noise regulation to make independent noise assessment procedurally impossible because of its dependency on wind turbine owner's consent [34]). However, at audible frequencies it could be ascertained by ear that wind turbine sound was dominant. At infrasound frequencies this could not be ascertained. But if significant ambient sound were present, subtracting it from the measured levels would lead to lower (infrasound) sound levels, which would not change the conclusion, based on the G-weighted level, that measured infrasound must be considered inaudible.

4.4. Beats Caused by Interaction of Several Wind Turbines

In the previous section we saw that measured variations in broad band sound level (R_{bl}) were 4 to 6 dB. Figure 6 presents the time variation of the broad band A-weighted level from the sound level at the façade of dwelling P over a one minute period [2]. In this night stable conditions prevailed (m ≈ 0.45 from the wind speeds in table 1). Turbines 12 and 11 are closest at 710 and 750 m, followed by turbines 9 and 14 at 890 and 910 m. Other turbines are more than 1 km distant and have an at least 4 dB lower immission level than the closest turbine has. The sequence in figure 6 begins when the turbine sound is noisy and constant within 2 dB. After some time (at t = 155 s) regular pulses appear with a maximum height of 3 dB, followed by a short period with louder (5 dB) and steeper (rise time up to 23 dB/s) pulses. The pulse frequency is equal to the blade passing frequency. Then (t > 180 s) the pulses become weaker and there is a light increase in wind speed.

This was one of the nights where a distinct beat was audible: a period with a distinct beat alternating with a period with a weaker or no beat, repeated more or less during the entire night. The pattern is consistent with three pulse trains of slightly different frequencies [2].

In figure 7 the equivalent 1/3 octave band spectrum at the façade of P has been plotted for the period of the beat (165 < t < 175 s in figure 6, spectra sampled at a rate of 20 s^{-1}), as well as the equivalent spectrum associated with the 5% highest (L_{A5} = 52.5 dB(A)) and the 5% lowest (L_{A95} = 47.7 dB(A)) broad band levels and the difference between both. As in the similar spectra in figure 4 we see that the beat corresponds to an increase at frequencies where trailing edge sound dominates: the sound pulses correspond to 1/3 octave band levels between 200 and 1250 Hz and are highest at 800 Hz. In figure 7 also the equivalent 1/3 octave band levels are plotted for the period after beating where the wind was picking up slightly (t > 175 s in figure 6). Here spectral levels above 400 Hz are the same or slightly lower as on average at the time of beating, but at lower frequencies down to 80 Hz (related to in-flow turbulence) levels now are 1 to 2 dB higher. The increase in the 'more wind' spectrum at high frequencies (> 2000 Hz) is probably from rustling tree leaves.

Figure 8 shows sound spectra for a period with a distinct beat (150 < t < 175 s in figure 6), and a period with a weak or no beat (130 < t < 150 s). Each spectrum is

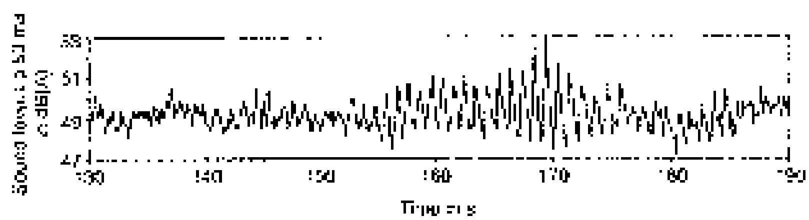

Figure 6 Broad band A-weighted immission sound level at façade of dwelling P

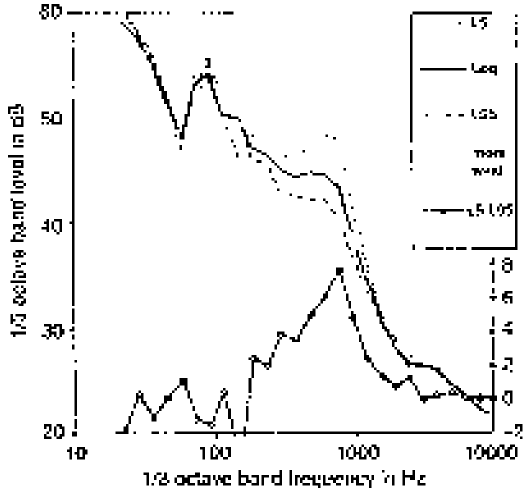

Figure 7 1/3 octave band levels at façade of dwelling P during beating (L_{eq}, L_5 and L_{95}) and when wind speed is picking up (L_{eq}).

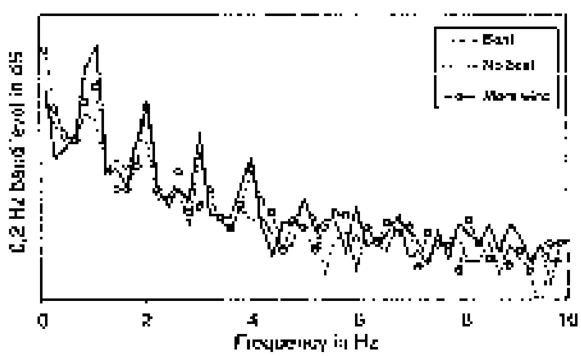

Figure 8 Sound power spectrum of A-weighted broad band immission sound level at façade of dwelling P when beating is distinctly or not audible and with slightly increased wind speed.

an FFT of 0.2 Hz line width from broad band A-weighted immission sound pressure level values. The frequencies are therefore *modulation*, not sound frequencies. The abscissa spans 20 dB. The spectra show that distinct beating is associated with higher total A-weighted levels at the blade passing frequency and its harmonics. As has been shown above, the higher level is related to the frequency range of trailing edge sound, not to infrasound frequencies linked to thickness sound. When beating is weaker but there is more wind (t > 175 s), the level of the odd harmonics (base frequency k = 1, and k = 3) is lower than during 'beat', whereas the first two even harmonics (k = 2, 4) are equally loud, indicating more distorted (less sinusoidal) and lower level pulses. It is important to realize that the periodic variation as represented in figure 8 is the result from a wind farm, not from a single turbine.

In long term measurements near the Rhede wind farm, where average and percentile sound levels were determined over 5 minute periods, periods where wind turbine sound was dominant could be selected with a criterion ($B_{5min} = L_{A5} - L_{A95} < 4$ dB) implying a fairly constant source with less than 4 dB variation for 90% of the time [2]. The statistical distribution of the criterion values has been plotted in 1 dB intervals in figure 9 for the two long term measurement locations A and B (see figure 3). Total measurement times -with levels in compliance with the criterion- were 110 and 135 hours, respectively. Relative to dwellings P and R, one location (A, 400 m from nearest turbine) is closer to the turbines, the other (B, 1500 m) is further. The figure

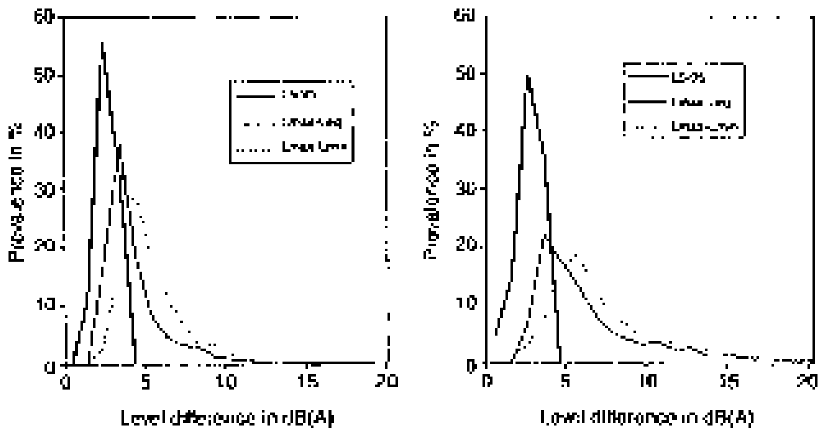

Figure 9 Statistical distribution of level differences (in 1 dB-classes) between high and low sound levels within 5 minute periods at 400 m (left) and 1500 m (right) from the nearest wind turbine.

shows that the criterion value (cut off at 4 dB) at both locations peaks at 2.5 dB. Also plotted in figure 9 is the value of $L_{Amax} - L_{Aeq}$ (while $R_{bs,90} \leq 4$ dB), peaking at 3.5 dB at both locations. Finally, the difference between maximum and minimum level within 5 minute periods, $L_{Amax} - L_{Amin} = R_{5m}$, peaks at 4.5 dB (location A) and 5.5 dB (B). Where $R_{5m} > 7$ dB, the distributions are influenced by louder (non-turbine) sounds, such as from birds. Extrapolation of the distribution from lower values suggests that the maximum range R_{bs} due to the wind farm is 8.5 dB (location A) to 9.5 dB (B). This is 4 dB more than the most frequently occurring ranges at both locations.

4.5. Summary of Results

In table II the level variations due to blade swish as determined in the previous sections have been summarised. Some values not presented in the text have been added. The ranges are presented as R_{bs} and $R_{bs,90}$. The latter is of course a lower value as it leaves out high and low excursions occurring less than 10% of the time. The time interval over which these level differences occur differ from several up to 16 minutes for the short term measurements, where wind conditions can be presumed constant, up to over 100 hours at locations A and B.

5. PERCEPTION OF WIND TURBINE SOUND

In a review of literature on wind turbine sound Pedersen concluded that wind turbine noise was not studied in sufficient detail to be able to draw general conclusions, but that the available studies indicated that at relatively low levels wind turbine sound was more annoying than other sources of community noise such as traffic [21]. In a field study by Pedersen and Persson Waye [22] 8 of 40 respondents living in dwellings with (calculated) maximum outdoor immission levels of 37.5 - 40.0 dB(A) were very annoyed by the sound, and at levels above 40 dB(A) 9 of 25 respondents were very annoyed. The correlation between sound level (in 2.5 dB classes) and annoyance was significant (p < 0.001). In this field study annoyance was correlated to descriptions of the sound characteristics, most strongly to swishing with a correlation coefficient of 0.72 [22]. A high degree of annoyance is not expected at levels below 40 dB(A), unless the sound has special features such as a low-frequency components or an intermittent character [23]. Psychoacoustic characteristics of wind turbine sound have been investigated by Persson-Waye *et al.* in a laboratory setting with naive listeners (students not used to wind turbine sound): the most annoying sound recorded from five different turbines were described as 'swishing', 'lapping' and 'whistling', the least annoying as 'grinding' and 'low frequency' [24]. People living close to wind turbines, interviewed by Pedersen *et al.*, felt irritated

Table II. Level variation in modern wind turbine[1] sound due to blade swish, in dB

Location		Reference	Atmospheric condition	R_{50} $L_{Amax} - L_{Amin}$	L_{5-95} $L_5 - L_{95}$
Calculated results					
Single turbine		Section 3a	neutral	1.5 ± 0.5	
		Section 3a	stable	3.1 ± 0.7	
		Section 3a	very stable	5.0 ± 0.8	
Two turbines			(very) stable	single + 3	
Measured results					
Single turbine		[8]	unspecified	< 3	
Single turbine	Near T1	Fig. 2A		4.8	3.2
	Near T7	Fig. 2A		4.1	2.6
	Near T16	Fig. 2B		6.0	3.7
	dwelling E	Fig. 2C	stable	5.9[2]	4.3
Multiple turbines	dwelling A	Fig. 2B		6.2	3.7
	façade dwelling P	Fig. 3A		4.9	3.3
	façade P + beat	Fig. 5		5.4	
	Location A	Fig. 6A		4.5 (most frequent)	
				8.5 (maximum)	
			long term, stable		
	Location B	Fig. 6B		5.5 (most frequent)	
				9.5 (maximum)	

notes:
1 hub height ≥ 90 m, rotor diameter ≥ 70 m, ≥ 20 rpm
2 for this turbine (hub height 40 m, diameter 46 m, 25 rpm) R_{50} = 3.7 dB was calculated

because of the intrusion of the wind turbines in their homes and gardens, especially the swishing sound, the blinking shadows and constant rotation [25].

Our experience at distances of approx. 700 to 1500 m from the Rhede wind farm, with the turbines rotating at high speed in a clear night and pronounced beating audible, is that the sound resembles distant pile driving. When asked to describe the sound of the turbines in this wind farm, a resident compares it to the surf on a rocky coast. Another resident near a set of smaller wind turbines, likens the sound to that of a racing rowing boat (where rowers simultaneously draw, also creating a periodic swish). Several residents near single wind turbines remark that the sound often changing to clapping, thumping or beating when night falls: 'like a washing machine'. It is common in all descriptions that there is noise ('like a nearby motorway', 'a B747 constantly taking off') with a periodic increase superimposed. In all cases the sound acquires this more striking character late in the afternoon or at night, especially in clear nights and downwind from a turbine.

Part of the relatively high annoyance level and the characterisation of wind turbine sound as lapping, swishing, clapping or beating may be explained by the increased fluctuation of the sound [2, 21]. Our results in table 2 show that in a stable atmosphere measured fluctuation levels are 4 to 6 dB for single turbines, and in long term measurements (over many 5 minute periods) near the Rhede wind farm fluctuation levels of approx. 5 dB are common but may reach values up to 9 dB.

The level difference associated with an amplitude modulation (AM) factor mf is $\Delta L = 20 \log((1+mf)/(1-mf))$. The modulation factor mf is the change in sound pressure amplitude due to modulation, relative to the average amplitude. For $\Delta L < 9$ dB a good approximation (±5%) is $mf = 0.055\,\Delta L$. Now when ΔL rises from 3 dB, presumably a maximum value for a daytime (unstable or neutral) atmosphere, to 6 dB, mf rises from 17% to 33%. For a maximum value of $\Delta L = 9$ dB, mf is 50%.

Fluctuations are perceived as such when the modulation frequencies are less than 20 Hz. Human sensitivity for fluctuations is highest at $f_{mod} = 4$ Hz, which is the frequency typical for rhythm in music and speech [26], and for frequencies of the modulated sound close to 1 kHz. For wind turbines we found that a typical modulation frequency is 1 Hz, modulating the trailing edge sound that itself is at frequencies of 500 – 1000 Hz. So human sensitivity for wind turbine sound fluctuations is relatively high.

Fluctuation strength can be expressed in a percentage relative to the highest perceptible fluctuation strength (100%) or in the unit vacil [26]. The reference value for the absolute fluctuation strength is 1 vacil, equalling a 60 dB, 1 kHz tone, 100% amplitude-modulated at 4 Hz [26].

For an AM pure tone as well as AM broad band noise, absolute fluctuations strength is zero until $\Delta L = 3$ dB, then increases approximately linearly with modulation depth for values up to 1 vacil. For a broad band noise level L_A the fluctuation strength F_{bb} can be written as [26]:

$$F_{bb} = \frac{5.8(1.25\,mf - 0.25)(0.05\,L_A - 1)}{(f_{mod}/5\text{Hz})^2 + (4\text{Hz}/f_{mod}) + 1.5} \qquad \text{vacil} \qquad (2)$$

With typical values of $f_{mod} = 1$ Hz and $L_A = 40$ dB(A), this can be written as $F_{bb} = 1.31(mf-0.2)$ vacil or, when $\Delta L < 9$ dB:

$$F_{bb} \approx 0.072(\Delta L - 3.6) \qquad \text{vacil} \qquad (3)$$

When ΔL increases from 3 to 6 dB, F_{bb} increases from negligible to 0.18 vacil. For the high fluctuation levels found at locations A and B ($\Delta L = 8 - 9$ dB), F_{bb} is 0.32 to 0.39 vacil.

It can be concluded that, in a stable atmosphere, the fluctuations in modern wind turbine sound can be readily perceived. However, as yet it is not clear how this relates to possible annoyance. It can however be likened to the rhythmic beat of music: pleasant when the music is appreciated, but distinctly intrusive when the music is unwanted.

The hypothesis that these fluctuations are important, is supported by descriptions of the character of wind turbine sound as 'lapping', 'swishing', 'clapping', 'beating' or 'like the surf'. Those who visit a wind turbine in daytime will usually not hear this and probably not realise that the sound can be rather different in conditions that do not occur in daytime. This may add to the frustration of residents: "Being highly affected by the wind turbines was hard to explain to people who have not had the experiences themselves and the informants felt that they were *not being believed*" [25]. Persson-Waye *et al.* observed that, from five recorded different turbine sounds "the more annoying noises were also paid attention to for a longer time". This supported the hypothesis that awareness of the noise and possibly the degree of annoyance depended on the content (of intrusive character) of the sound [24].

Fluctuations with peak levels of 3 – 9 dB above a constant level may have effects on sleep quality. The Dutch Health Council [33] states that "at a given L_{night} value, the most unfavourable situation in terms of a particular direct biological effect of night-time noise is not, as might be supposed, one characterised by a few loud noise events per night. Rather, the worst scenario involves a number of noise events all of which are roughly 5 dB(A) above the threshold for the effect in question." For transportation noise (road, rail, air traffic) the threshold for motility (movement), a direct biological effect having a negative impact on sleep quality, is a sound exposure level per sound event of SEL = 40 dB(A) in the bedroom [33]. The pulses in figure 6 have SEL-values up to 50 dB(A), but were measured on the façade. With an open window facing the wind turbines indoor SEL-values may exceed the threshold level. In other situations this of course depends on distance to and sound power of the turbines and on the attenuation between façade and bedroom. It is not clear whether the constant and relatively rapid repetition of wind turbine sound beats will have more or less effect on sleep quality, compared to vehicle or airplane passages. Pedersen and Persson Waye found that at dwellings where the (outdoor) sound level due to wind turbines exceeded 35 dB(A), 16% of 128 respondents reported sleep disturbance by this sound, of whom all but two slept with a window open in summer [22].

6. DISCUSSION AND CONCLUSION

Atmospheric stability has a significant effect on wind turbine sound, especially for modern, tall turbines.

First, it is related to a change in wind profile causing strong, higher altitude, winds while at the same time wind close to the ground may become relatively weak. High sound immission levels may thus occur at low ambient sound levels, a fact that has not been recognised in noise assessments where a neutral or unstable atmosphere is usually implied. As a result, wind turbine sound that is masked by ambient wind-related sound in daytime, may not be masked at night time. This has been dealt with elsewhere [2].

Secondly, the change in wind profile causes a change in angle of attack on the turbine blades. This increases the thickness (infra) sound level as well as the level of trailing edge (TE) sound, especially when a blade passes the tower. TE sound is modulated at the blade passing frequency, but it is a high frequency sound, well audible and indeed the most dominant component of wind turbine noise. The periodic increase in sound level when the blade passes the turbine tower, blade swish, is a well known phenomenon. Less well known is the fact that increasing atmospheric stability creates greater changes in the angle of attack over the rotor plane that add up with the change near the tower. This results in a thicker turbulent TE boundary layer, in turn causing a higher swish level and a shift to somewhat lower frequencies. It can be shown theoretically that for a modern, tall wind turbine in flat, open land the angle of attack at the blade tip passing the tower changes by approx. 2° in daytime, but this value increases by 2° when the atmosphere becomes very stable. The calculated rise in sound level during swish then increases from 1–2 dB to 4–6 dB. This value is confirmed by measurements at single turbines in the Rhede wind farm where maximum sound levels rise 4 to 6 dB above minimum sound levels within short periods of time.

Thirdly, atmospheric stability involves a decrease in large scale turbulence. Large fluctuations in wind speed (at the scale of a turbine) vanish, and the coherence in wind speed over distances as great as or larger than the size of an entire wind farm increases. As a result turbines in the farm are exposed to a more constant wind and rotate at a more similar speed with less fluctuations. Because of the near-synchronicity, blade swishes may arrive simultaneously for a period of time and increase swish level. The phase difference between turbines determines where this amplification occurs: whether the swish pulses will coincide at a location depends on this phase difference and the propagation time of the sound. In an area where two or more turbines are comparably loud the place where this amplification occurs will sweep over the area with a velocity determined by the difference in rotational frequency. The magnitude of this effect thus depends on stability, but also on the number of wind turbines and the distances to the observer. This effect is in contrast to what was expected, as it seemed reasonable to suppose that turbines would behave independently and thus the blade swish pulses from several turbines would arrive at random, resulting in an even more constant level than from one turbine. Also, *within* a wind farm the effect may not be noticed, since comparable positions in relation to two or more turbines are less easily realised at close distances.

Sound level differences $L_{max} - L_{min}$ (corresponding to swish pulse heights) within 5 minute periods over long measurement periods near the Rhede wind farm show that level changes of approximately 5 dB occur for an appreciable amount of time and may less often be as high as 8 or 9 dB. This level difference did not decrease with distance, but even increased 1 dB when distance to the wind farm rose from 400 m to 1500 m. The added 3-5 dB, relative to a single turbine, is in agreement with simultaneously arriving pulses from two or three approximately equally loud turbines.

The increase in blade swish level creates a new percept, fluctuating sound, that is absent or weak in neutral or unstable atmospheric conditions. Blade passing frequency is now an important parameter as a modulation frequency (not as an infra-sound frequency). Human perception is most sensitive to modulation frequencies close to 4 Hz of sound with a frequency of approx. 1 kHz. The hypothesis that fluctuations are important is supported by descriptions given by naïve listeners as well as residents: turbines sound like 'lapping', 'swishing', 'clapping', 'beating' or 'like the surf'. It is not clear to what degree this fluctuating character determines the relatively high annoyance caused by wind turbine sound and to a deterioration of sleep quality. Further research is necessary into the perception and annoyance of wind turbine sound, with correct assumptions on the level and character of the sound. Also the sound exposure level of fluctuations in the sound in the bedroom must be investigated to be able to assess the effects on sleep quality.

It is obvious that in wind turbine sound measurements atmospheric stability must be taken into account. When the impulsive character of the sound is assessed, this should be carried out in relation to a stable atmosphere, as that is the relevant condition for impulsiveness. Also sound immission should be assessed for stable conditions in all cases where night time is the critical noise period. Wind speed at low heights is not a sufficient indicator for wind turbine performance. Specifically, when ambient sound level is considered as a masker for wind turbine sound, neither sounds should be related to wind speed at reference height via a (possibly implicit) neutral wind profile. In stable conditions wind induced sound on a microphone is not as loud as is usually thought (creating a high background level lowering the 'signal to noise ratio'), as in these conditions hub height wind speeds are accompanied by relatively low microphone height wind speeds. So, wind turbine sound measurements are easier when performed in a stable atmosphere, which agrees well with the night being the sensitive period for noise immission.

7. REFERENCES

1. European Wind Energy Association (EWEA), European Commission's Directorate General for Transport and Energy (DG TREN): "Wind Energy - The Facts: An Analysis of Wind Energy in the EU-25" (2004).

2. G.P. van den Berg: "Effects of the Wind Profile at Night on Wind Turbine Sound", J. Sound Vib. 277 (4-5), 955-970 (2004).

3. M.V. Lowson: "A New Prediction Model for Wind Turbine Noise", Wind Engineering **18** (2), 51-62 (1995).

4. F.W. Grosveld. "Prediction of Broadband Noise from Horizontal Axis Wind Turbines", J. Propulsion 1 (4), 292-299 (1985).

5. H.H. Hubbard and K.P. Shepherd: "Aeroacoustics of Large Wind Turbines", J. Acoust. Soc. Am 89 (6), 2495-2508 (2004).

6. S. Wagner, R. Bareiss and G. Guidati: "Wind Turbine Noise", Springer, Berlin, 1996.

7. E.L. Petersen, N.G. Mortensen, L. Landberg, J. Højstrup and H.P. Frank: "Wind Power Meteorology: Part I: Climate and Turbulence", Wind Energy 1 2-22 (1998)

8. The Working Group on Noise from Wind Turbines: "The Assessment & Rating of Noise from Wind Farms" (ETSU-R-97), Department of Trade and Industry, United Kingdom (1996).

9. J.R. Garratt: "The Atmospheric Boundary Layer", Cambridge University Press, 1992.

10. C.L. Archer and M.Z. Jacobson: "Spatial and Temporal Distributions of U.S. Winds and Wind Power at 80 m Derived from Measurements", J. Geophys. Res. 108 (D9), (2003).

11. S. Baidya Roy, S.W. Pacala and R.L. Walko: "Can Large Wind Farms Affect Local Meteorology?", Journal of Geophysical Research, Vol. 109, D19101 (2004).

12. A. Smedman, U. Högström and H. Bergstrom: "Low Level Jets – A Decisive Factor for Off-Shore Wind Energy Siting in the Baltic Sea", Wind Engineering 20 (3), 137-147 (1996).

13. K. Smith, G. Randall, D. Malcolm, N. Kelly and B. Smith: "Evaluation of Wind Shear Patterns at Midwest Wind Energy Facilities" (preprint), National Renewable Energy Laboratory NREL/CP-500-32492, USA (2002)

14. J.A. Pérez, M.A. García, M.L. Sánchez and B. de Torre: "Analysis and parameterisation of wind profiles in the low atmosphere", Solar Energy, in press (2004)

15. A.A.M. Holtslag: "Estimates of Diabatic Wind Speed Profiles from Near-Surface weather observations", Boundary-Layer Meteorology 29, 225-250 (1984).

16. IEC International Standard 61400-11, Wind Turbine Generator Systems—Part 11: Acoustic Noise Measurement Techniques, IEC 61400-11:1998(E).

17. F.V. Hutcheson and T.F. Brooks: "Effects of Angle of Attack and Velocity on Trailing Edge Noise", proc. 42nd Aerospace Sciences Meeting, Reno, January 2004.

18. T. Nanahara, M. Asari, T. Sato, K. Yamaguchi, M. Shibata and T. Maejima: "Smoothing Effects of Distributed Wind Turbines, Part 1", Wind Energy 2004 (7), pp. 61-74.

19. T. Nanahara: personal communication, June 14, 2004.

20. B&K: "Microphone Handbook", Bruel & Kjaer, Denmark, 1995.

21. E. Pedersen: "Noise annoyance from wind turbines - a review", Swedish Environmental Protection Agency (2003).

22. E. Pedersen and K. Persson Waye: "Perception and Annoyance due to Wind Turbine Noise - a Dose-Response Relationship", J. Acoust. Soc. Am 116 (6), 3460-3470 (2004)

23. WHO: "Guidelines for Community Noise", World Health Organization (Geneva) and Institute of Environmental Epidemiology (Singapore), 2000.

24. K. Persson Waye and E. Ohstrom: Psycho-acoustic characters of relevance for annoyance of wind turbine noise - J. Sound Vib. 250(1), 65-73 (2002).

25. E. Pedersen, K. Persson Waye and I.R.M. Hallberg: "Living Close to Wind Turbines–A Qualitative Approach to a Deeper Understanding", proc. Internoise2004, Prague (2004).

26. E. Zwicker and H. Fastl: "Psycho-Acoustics, Facts and Models", Springer Verlag, Berlin (1999).

27. A.P. van Ulden, J.G. van der Vliet en J. Wieringa: "Temperature and Wind Observations at Heights from 2m to 200m at Cabauw in 1973", 1976, De Bilt.

28. J. Jakobsen: "Low Frequency Sound from Wind Turbines", proc. Low Frequency Noise and Vibration, Maastricht (2004).

29. T.F. Brooks, D.S. Pope and M.A. Marcolini: "Airfoil Self-Noise and Prediction", NASA reference publication 1218, USA (1989).

30. ISO: "Acoustics – Frequency-Weighting Characteristic for Infrasound Measurements" (ISO 7196), International Organization of Standardization (1995).

31. E. On: Wind Report 2004", E.ON Netz GmbH, Bayreuth, Germany (2004).

32. ESB: "Impact of Wind Power Generation in Ireland on the Operation of Conventional Plant and the Economic Implications", ESB National Grid, Ireland (2004).

33. Health Council of the Netherlands: "Effects of Noise on Sleep and Health", Health Council of the Netherlands, publication no. 2004/14, The Hague (2004).

34. G.P. van den Berg: "Wind Turbines at Night: Acoustical Practice and Sound Research", Proc. Euronoise 2003, Naples (2003).

LIST OF SYMBOLS

Symbol: definition [unit]

α: angle of attack [radian or degree]
δ_t^*: displacement thickness of turbulent boundary layer [m]
ν: kinematic viscosity of air [$m^2 s^{-1}$]
ρ: correlation coefficient (here: between (1/3) octave band level and L_A)
Ω: turbine rotor angular velocity [rad s^{-1}]
σ: correction factor for boundary layer thickness (value: 2 – 4)
c: velocity of sound in air [m s^{-1}]
C: blade chord length [m]
D_h: directivity function [-]
f: frequency [Hz]
f_{mod}: modulation frequency [Hz]
$f_{peak,TE}$: peak frequency of trailing edge sound [Hz]
$f_{peak,IT}$: peak frequency of in-flow turbulence sound [Hz]
f_B: blade passing frequency [Hz]
f_t: α-dependent factor for boundary layer thickness [-]
F_{fl}: fluctuation strength [vacil]
h: height [m]
H: turbine height [m]
h_{ref}: reference height for wind speed (and direction) [m]
k: integer number (of harmonic frequency)
K_1: constant (128.5 dB)
K_α: α dependent increase in trailing edge sound level [dB]
M: Mach number (at radius R: $M = \Omega R/c$) [-]
ΔL: increase in sound level [dB]
L_A: broad band sound level [dB(A)]
L_{A5}: 5-percentile of broad band sound levels over a time period [dB(A)]
L_{A95}: 95-percentile of broad band sound levels over a time period [dB(A)]
m: stability exponent [-]
mf: modulation factor [-]
N: number of blades [-]

r:	distance [m]
R:	rotor radius = blade length [m]
ΔR:	increment in R [m]
R_X:	range between maximum and minimum sound levels (X= bb or f) [dB]
$R_{X,90}$:	range between 5- and 95-percentile of sound levels (X= bb or f) [dB]
Re:	chord based Reynolds number (Re = ΩRC/ν) [-]
v_h:	wind speed at height h [m s^{-1}]
v_{ref}:	wind speed at reference height [m s^{-1}]
v_{xx}:	wind speed at height xx m [m s^{-1}]
Sp_i:	1/3 octave band weighing function for TE sound [dB]
SPL_i:	sound pressure level [dB]
St:	Strouhal number [-]

Subscripts:

A:	A-weighted
bb:	broad band
f:	at frequency of (1/3) octave band
i:	component of TE sound (i = p, s, α)
if:	in-flow
p:	pressure side
s:	suction side
TE:	trailing edge

APPENDIX I

Dominant Sources of Wind Turbine Sound

With modern wind turbines there are three important mechanisms that produce sound. These will be reviewed here up to a detail that is relevant to this paper.

A. Infrasound: thickness sound.

When a blade moves through the air, the air on the forward edge is pushed sideways, moving back again at the rear edge. For a periodically moving blade the air is periodically forced, leading to 'thickness sound'. Usually this will not lead to a significant sound production as the movement is smooth and thus accelerations are relatively small.

When a blade passes the turbine tower, it encounters wind influenced by the tower: the wind is slowed down, forced to move sideways around the tower, and causes a wake behind the tower. For a downwind rotor (i.e. the wind passes the tower first, then the rotor) this wake causes a significant change in blade loading.

The change in wind velocity near the tower means that the angle of attack of the air on a blade changes and lift and drag on the blade change more or less abruptly. This change in mechanical load increases the sound power level at the rate of the blade passing frequency, f_B. For modern turbines $f_B = N\,\Omega/(2\pi)$ typically has a value of approximately 1 Hz. As the movement is not purely sinusoidal, there are harmonics with frequencies $k f_B$, where k is an integer. Harmonics may occur up to 30 Hz, so thickness sound coincides with the infrasound region (0–30 Hz). Measured levels at 92 m from the two-bladed 2 MW WTS-4 turbine showed that measured sound pressure levels of the individual blade harmonics were less than 75 dB, and well predicted by calculations of wind-blade interaction near the turbine tower [5, 6]. The envelope of the harmonics peaks at the fifth harmonic (k = 5 with f_B = 1 Hz), indicating a typical pulse time of (5 Hz)$^{-1}$ = 0.2 s which is 20% of the time between consecutive blade passages. The WST-4 is a downwind turbine with an 80 m tubular tower, where the wind velocity deficit was estimated to be 40% of the free wind velocity [5]. For modern, upwind rotors the velocity deficit in front of the tower is smaller. As a consequence blade-tower wake interaction is weaker than for downwind turbines. From data collected by Jakobsen it appears that the infrasound level at 100 m from an upwind turbine is typically 70 dB(G) or lower, near downwind turbines 10 to 30 dB higher, where 95 dB(G) corresponds to the average infrasound hearing threshold [28]. Infrasound from (upwind) wind turbines thus does not appear to be so loud that it is directly perceptible.

B. *Low frequencies: in-flow turbulent sound.*
Because of atmospheric turbulence there is a random movement of air superimposed on the average wind speed. The contribution of atmospheric turbulence to wind turbine sound is named 'in-flow turbulence sound' and is broad band sound stretching over a wide frequency range. For turbulent eddies larger in size than the blade this may be interpreted as a change in the direction and/or velocity of the oncoming flow, equivalent to a deviation of the optimal angle of attack. This leads to the same phenomena as in *A*, but changes will be random (not periodic) and less abrupt. For turbulent eddies the size of the chord length and less, effects are local and do not occur coherently over the blade. When the blade cuts through the eddies, the movement normal to the wind surface is reduced or stopped, given rise to high accelerations and thus sound.

In-flow turbulence sound has a maximum level in the 1/3 octave band with frequency:

$$f_{peak,if} = (St \cdot 0.7R\Omega)/(H - 0.7R) \qquad (A1)$$

where Strouhal number St is 16.6 [4, 6]. Most sound is produced at the high velocity, outer parts of the blades. For a modern, tall, three-bladed wind turbine with hub height H = 100 m, blade length R = 35 m and angular velocity $\Omega = 2\pi f_B/3 = 2$ rad s^{-1} (20 rpm), $f_{peak,if}$ = 11 Hz which is in the infrasound region. Measured fall off from $f_{peak,if}$ is initially approx. 3 dB per octave, increasing to 12 dB per octave at frequencies in the audible region up to a few hundreds of hertz [4, 6].
C. High frequencies: trailing edge sound.
Several flow phenomena at the blade itself or in the turbulent wake behind a blade cause high frequency sound ('airfoil self-noise'). Most important for modern turbines is the sound from the turbulent boundary layer at the rear of the blade surface where the boundary layer is thickest and turbulence strength highest. Trailing edge sound has a maximum level in the 1/3 octave band with frequency

$$f_{peak,TE} = 0.02\,\Omega R/(\delta^* M^{0.6}) \qquad (A2)$$

where Mach number M is based on airfoil velocity. The displacement thickness of the turbulent layer is:

$$\delta^* = a\,0.37\,C\,Re^{-0.2}/8 \qquad (A3)$$

for a zero angle of attack. Re is the chord based Reynolds number [29]. The experimental factor a accounts for the empirical observation that the boundary layer is a factor 2 to 4 thicker than predicted by theory [3, 6]. For air of 10 °C and atmospheric pressure, a typical chord length C = 1 m, and other properties as given above (section *B*), $f_{peak,TE}$ = 1700/a Hz. With a = 2 to 4, $f_{peak,TE}$ is 450 - 900 Hz. The spectrum (see Sp_i below) is symmetrical around $f_{peak,TE}$ and decreases with 3 dB for the first octave, 13 dB for the next, the contribution from further octave bands is negligible [29].

According to Brooks *et al.* [29] trailing edge sound level can be decomposed in components SPL_p and SPL_s due to the pressure and suction side turbulent boundary layers with a zero angle of attack of the incoming flow, and a component SPL_α that accounts for a non-zero angle of attack α. For an edge length ΔR each of the three components of the immission sound level at distance r can be written as [29]:

$$SPL_i = 10\log\left(\delta_i^* M^5 \Delta R\, D_h / r^2\right) + Sp_i + K_i - 3 + K \qquad (A4)$$

and total trailing edge immission sound level as:

$$SPL_{TE} = 10\log\left(\Sigma_i\, 10^{SPL_i/10}\right) \qquad (A5)$$

where the index i refers to the pressure side, suction side or angle of attack part (i = p, s, α). The directivity function D_h equals unity at the rear of the blade (θ = 180°) and falls off with $\sin^2(\theta/2)$. Because of the strong dependence on

Table A1. Increase of trailing edge sound level with angle of attack α

α	1	2	3	4	5
$SPL_{TE}(\alpha) - SPL_{TE}(\alpha=0)$ (dB)	0.4	1.4	2.9	4.6	6.4

M ($\sim M^5$) trailing edge sound is dominated by sound produced at the high velocity parts: the blade tips.

Sp_i gives the symmetrical spectral distribution of the trailing edge sound spectrum centered on $f_{peak,TE}$ and is maximum (0 dB) at this centre frequency. The constant $K_1 - 3 = 125.5$ dB applies when the chord based Reynolds number exceeds 8×10^5 and the pressure-side turbulent boundary displacement thickness $\delta_p^* > 1$ mm, as is the case for modern tall turbines. K_i is non-zero only if $i = \alpha$.

For small non-zero angles of attack ($\alpha < 5°$) the boundary layer thickness shrinks δ^* with a factor $f_p = 10^{-0.042\alpha}$ at the pressure-side and grows with a factor $f_s = 10^{0.068\alpha}$ at the suction side, $\delta_{\alpha}^* = \delta_s^*$, so $f_\alpha = f_s$.

K_α has a large negative value for $\alpha = 0$. For $1° < \alpha < 5°$ and $M = 0.2$ it can be approximated by $K_\alpha = 3.6\alpha - 12.1$ ([29], formula 49 with $K_\alpha = K_2 - K_1 + 3$).

With equation A4, equation A5 can be rewritten as:

$$SPL_{TE} = 10 \log\left(\delta^* M^5 \Delta R\, D_h / r^2\right) + K_1 - 3 + 10 \log\left(\Sigma_i\, 10^{(20 \log(f_i) + Sp_i + K_i)/10}\right) \qquad (A6)$$

The last term in A6 is the α-dependent part. For the peak frequency 1/3 octave band level ($Sp_i = 0$) the last term in equation A6 is 3 dB for $\alpha = 0$, and 4.4 dB at $\alpha = 2°$, then increasing with approx. 1.7 dB per degree to 9.4 dB at $\alpha = 5°$. The level increase relative to the level at $\alpha = 0$ is given in table A1.

The swishing sound that one hears when a blade passes the tower is less than 3 dB (in daytime) [8]. It must correspond to a change in sound level of 1 dB to be heard at all. An increase of 1 dB corresponds to an increase in α from zero to a value of 1.7° (0.03 radians), an increase of 2 dB corresponds to 2.5° (0.04 radians). So we estimate the change in α at the tower passage as $2.1 \pm 0.4°$. Part of this is due to the lower wind velocity at the lower blade tip relative to the rotor average (0.8°, see section 3 of main text), the rest is due to the slowed down of the wind by the tower.

For small angles the change of wind speed with angle of attack α at radius R is:

$$dV_{wind}/d\alpha = \Omega R \qquad (A7)$$

So for a modern turbine ($\Omega R = 70$ m/s at tip at 20 rpm) the wind speed deficit where the blade tip passes the tower and $\alpha = 2.1°$ (0.037 radians) is 2.6 m/s. In a (rotor averaged) 14 m/s wind this is 20%. This deficit is due to the influence of the tower as well as the (daytime) wind profile.

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RIJKSUNIVERSITEIT GRONINGEN

The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise

Proefschrift

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Godefridus Petrus van den Berg
geboren op 7 januari 1952
te Rotterdam

* This is a copy of GP (Frits) van den Berg's doctoral thesis, from the University of Groningen, Netherlands, completed May 2006. Dr. van den Berg kindly sent this to me earlier this month.

-- Calvin Luther Martin, PhD
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The sound of high winds:

the effect of atmospheric stability on wind turbine sound and microphone noise

G.P. van den Berg

Contents

I WIND POWER, SOCIETY, THIS BOOK: an introduction

Bobby asks: 'Do you ever hear the windmills?'
'What sound do they make?'
'It's a clanking metal noise, but when the wind is really strong
the blades blur and the air starts screaming in pain' He shudders
'What are the windmills for ?'
'They keep everything running.
If you put your ear to the ground you can hear them.'
'What do you mean by everything?'
'The lights, the factories, the railways. Without the windmills it all stops.'[1]

This is the story of the discovery of a new phenomenon: why wind turbines sound different at night time. This discovery was related to a problem in society, namely that of perceived noise by residents living close to such turbines..

This introduction sketches the context in which my work proceeded: how the questions came up, why noise is an inseparable part of wind power development, and that being critical does not need to imply a negative attitude towards wind power. Let's start at the beginning.

I.1 A 'new' phenomenon

The discovery was modest: I have not found a new law of nature or a new way to make money. It was rather the idea to apply existing knowledge in a new context: the application of atmospheric physics to solve the mystery why people complained about noise from wind turbines that according to wind developers and acoustic consultants they should not even be able to hear. In principle it was not very difficult to find out why. When Walter Flight (a very Dutch citizen despite his name) told me he could see the wind turbines near his house rotating at high speed while at the same time his garden was completely calm, I thought: oh yes, I know that, that's

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[1] 'The suspect', by Michael Robotham, Time Warner Paperbacks, 2005 (p. 151)

because at night, especially on nice summer evenings, the atmosphere becomes stable. I teach this in a course, Environmental Techniques. The phenomenon is treated extensively in this book, but for now it is sufficient to know that, due to strong winds at greater heights coupled with very light winds at ground level, wind turbines can be a lot noisier in a night time atmosphere than they are in daytime. This was why Walter and his neighbours complained. Also the nature of the sound changes: a thumping character can become very pronounced at night.

In this book I will often use the terms 'day' and 'night', though the distinction is more accurately stated as the atmosphere being unstable (which is usually in daytime, that is: sun up) or stable (night time, sun down). The heat coming in from the sun or radiated out at night is the real cause of the difference in stability. In between is another state, namely neutral, where heating or cooling are unimportant beacause of heavy clouding and/or strong wind and which can occur in day as well as night time, though not very often in a temperate climate and over land. Atmospheric stability means that vertical movements in the air are damped and as a consequence horizontal layers of air can have a greater difference in velocity: close to the ground the wind can be weak while higher up there is a strong wind.

Though in principle the explanation is simple and easily understood, it of course had to be shown from solid theory and with sufficient data that the explanation was correct. The first steps were extensive measurements in Bellingwolde, where severe complaints had arisen about noise from the nearby Rhede wind farm. This I did together with Richard de Graaf, then a physics student.

After this simple discovery, a new mystery (to me) was why this did not play a role in the assessment of wind turbine noise? Every meteorologist knows about atmospheric stability, so why had none of the experts dealing with wind turbine sound ever come across it? Wind turbines have been built for several decades and since the 1980's in ever larger numbers, so there should be a lot of accumulated experience. Had no one (except some residents) noticed the discrepancy between predicted and real noise exposure?

There are probably several reasons. One of them is that for a long time wind turbines were not big enough for the effects of atmospheric stability to be clearly noticeable. Since wind turbines have grown taller the effect manifests itself more clearly. Secondly, as the more distant locations have become scarce, more and more turbines are being built closer to where people live, so more people now experience the sound of wind turbines. Thirdly, atmospheric stability over flat land is easier to understand and quantify than in a mountainous or coastal area where the atmosphere is more complex so the effect on wind turbines may be less easily recognizable.

Wind turbines as such have not become that much noisier, despite their increase in height and blade span (the sound power depends more on speed than on physical dimensions of the towers). Earlier machines could be quite noisy due to whining or severe thumping, and modern designs are certainly better. The point is they now reach into less familiar parts of the atmosphere.

Finally, an important reason to not recognize the unexpected high sound levels certainly is the fact that it impedes commercial interests and national policy. The positive ring of the term 'sustainability' helps investors in wind energy and local authorities (applying national policy) to counterbalance objections concerning possible disadvantages of new projects. As these objections are sometimes strong enough to torpedo projects, investors and authorities don't welcome more negative news. Though the population widely supports sustainable energy, reactions are less positive when a new project adversely affects their lives. This 'contradictory behaviour' is in fact quite understandable: when a new project is planned in an area, residents for the first time have to balance the positive social consequences to the negative local impact: visual impact, flickering shadows, noise and possibly ice throw from turbine blades.

The first reaction of wind energy proponents, represented by the Windkoepel ('Wind dome'), to our research results was to pay a consultant to comment on our report [Van den Berg *et al* 2002]. This consultant boasted of having advised a large number of wind farm projects, so he clearly understood the position of the wind power industry. In the resulting 'second opinion' [Kerkers 2003] no material critique was presented, only procedural arguments were used to declare our results inaccurate and thus irrelevant. The Windkoepel issued a press statement concluding that we had made a lot of fuss, but had not contributed any new insights.[1] They could get back to business.

I.2 Digging deeper

I too went back to my business, which can be summarized as helping citizen groups to defend their position by objective arguments using known principles of physics. In 2004 an article about my research was published in a scientific journal [Van den Berg 2004a] lending my results the respectability of peer review and triggering an international e-mail influx from interested consultants as well as worried residents, as our first report had done earlier on a national scale.

What still puzzled me at that time was how a single turbine could start thumping at night. I thought I understood how the modest blade swish of a single turbine could evolve into louder thumping: the small sound variations due to blade swish from several turbines could add up to louder pulses. But with a single turbine there is nothing to add! Apart from this, in news media in the UK there were complaints that low frequency wind turbine noise had been underestimated and had been making people sick.[2]

Some thoughts about this were presented at a conference in Maastricht [Van den Berg 2004b]. I agreed with delegate Jørgen Jakobsen, who presented a paper on low frequency wind turbine noise [Jakobsen 2004],

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[1] Press statement February 2, 2003 "Onlangs is opschudding ontstaan .....," ("Recently an upheaval was caused..."), De Windkoepel, Arnhem

[2] Catherine Milner: "Wind farms make people sick who live up to a mile away", online Telegraph, filed January 25, 2004 (http://news.telegraph.co.uk/news/ main.jhtml?xml=/ news/2004/01/25/ nwind25.xml, consulted December 10, 2005)

that even though wind turbines did produce an appreciable amount of infrasound, the level was so far below the average human hearing threshold that it could not be a large scale problem. But it was possible that complaints had been expressed in a way not understood by experts. Perhaps people bothered by the endless thumping of a relatively low pitched sound (such as I had heard myself on several occasions), thought that 'low frequency sound' was a term to use, as official sounding jargon. They might not be aware that the term 'low frequency sound' makes acousticians think of frequencies below 100 to 200 hertz, and in that range the sound level was not considered to be problematic. A classical misunderstanding perhaps, that could be clarified. After the Maastricht conference I wanted to quantify my ideas on the origin of the night time thumping of wind turbines and the relevance of low frequencies. This resulted in a second scientific article [Van den Berg 2005a] in which I tried to put these ideas together.

What had surprised me from early on was that people in the wind power business seemed to know so little about their raw material, the wind. In the Windkoepel press statement (see footnote previous page) a wind turbine manufacturer's spokesman argued that if the hub height wind velocity indeed was structurally higher at night, this must be visible in production statistics. This indeed seems plausible, so why not investigate that? If the wind industry had done so, they might have come up with results I found from measured wind profiles at Cabauw over an entire year [Van den Berg 2005b]. Indeed for an 80 m high turbine the night time yield is significantly higher than expected, whereas the daytime yield is lower. The net result was that in the real atmosphere at Cabauw annual production was 14% to 20% (depending on wind turbine power settings) higher than in an atmosphere extrapolated from 10-m wind velocities with a perpetual neutral wind profile. For wind power production forecasting there is a method that incorporates a correction for atmospheric stability [Troen *et al* 1989], but such knowledge has never been used for sound exposure forecasting.

I.3 Commercial and policy implications

So from an energy point of view a stable atmosphere is very attractive. The challenge is to use that potential, but not put the burden on those living nearby. One solution is to build wind farms offshore where no people are affected if enough distance is kept (and calculation models are used that accurately model long range sound propagation over water). Over large bodies of water seasonal, not diurnal atmospheric stability will boost production in part of the year but lower it when the water has warmed. Another solution is to improve turbine design from two perspectives: decreasing sound power without substantially decreasing electric power, and reducing annoyance by minimizing fluctuations in the sound. Part of any solution is to respect complainants and try to achieve a better balance between national benefits and local costs.

Oblivious of any research, residents had already noticed a discrepancy between predicted and real noise exposure. Opponents of wind farms have organized themselves in recent years in the Netherlands and elsewhere, and word had spread that noise exposure in some cases was worse than predicted. Though atmospheric stability and sometimes a malfunctioning turbine could explain this, most wind farm developers and their consultants relied on the old prediction methods. An energy firm's spokesman complained that each and every new project attracted complaints (from local groups) and called this "a new Dutch disease".[1] This is a very narrow view on the problem, denying the detrimental effects for residents. If their real concerns are denied it is not unreasonable for residents to oppose a new project, because practical experience shows that once the wind farm is there (or any other noise producer) and problems do arise, complaints will very probably not alter the situation for at least several years. Social scientists are familiar with such situations and suggest better strategies such as being honest and respectful, treating residents as equal partners, and not being arrogant: already in 1990 Wolsink mentioned this in a study on acceptance of wind energy and warned that it was wrong to label opposition as NIMBY (Not In My Back Yard) and refuse to recognize

[1] NRC Handelsblad, August 26 2005: "Verzet tegen windmolens succesvol" ("Opposition to wind mills succesful")

legitimate problems [Wolsink 1990]. It is sad that most of the proponents still emanate a WARYDU attitude (We Are Right but You Don't Understand).

When real complaints are not addressed seriously, the "new Dutch disease" may well become an Australian, British, Chinese or any nation's disease. In the Netherlands assessment of wind turbine noise still is according to the old standard procedure (with one exception, see chapter VII), assuming a neutral atmosphere at all times, even though this has been admitted to be wrong for more than a year now.[1] Consultants apparently are afraid to be critical, perhaps because they don't want to jeopardize new assignments or because a change in assessment implies they were not correct before (they were not correct, but we were wrong collectively). Though most consultants claim to be impartial, the problem of 'not biting the hand that feeds' is more subtle, as I concluded in an earlier desk study on the quality of acoustic reports [Van den Berg 2000]. *E.g.*, it involves authorities who do not question the position of paid experts, and a society hiding political decisions behind the demand for more research.

I hope other countries do not to follow the Dutch way: first denying the consistency and legitimacy of the complaints, then being late in addressing them and in the end finding this has created more opposition. It is evident that also in the UK there are (a few?) serious complaints from honest people that are not dealt with adequately. In at least some cases atmospheric stability again seems to offer an explanation for observations of unpleasant wind turbine noise by residents (see example in box on next page), but the matter has not been investigated correctly.

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[1] In March 2004 I showed in an article in 'Geluid', a Dutch professional journal, how to deal with non-neutral atmospheric conditions within the existing legal procedures [Van den Berg 2004c]; in July 2004 the Ministry of Housing, Environment and Spatial Planning advised to investigate the 'wind climate' at new wind farm locations (letter on "Beoordeling geluidmetingen Natuurkundewinkel RUG bij De Lethe, gem. Bellingwedde" to Parliament by State Secretary van Geel, June 21, 2004); in the 2005 Annual report of BLOW, a union of local, provincial and national authorities to promote wind energy development, it is recognized that the effect of wind shear still should be addressed, but no action is announced (Annual report BLOW 2005, January 2006).

NOISE FROM WINDFARM MAKING LIFE A MISERY

A recent settler in Caithness claimed yesterday his life is being blighted by ghostly noises from his new neighbours, the county's first large-scale windfarm. (.....) Mr Bellamy said: "The problem is particularly bad at night when I try to get to sleep and there's a strong wind coming from the direction of the turbines. "They just keep on droning on. It's a wooh wooh type of sound, a ghostly sort of noise. It's like torture and would drive anyone mad."

Mr Bellamy believes the noise is being transmitted through the ground since it seems to intensify when he lies down. He said he has got nowhere with complaints to the wind company and environmental health officers. "I feel I'm just getting fobbed off and can't get anyone to treat me seriously," he said. Mr Bellamy has been asked to take noise readings every 10 minutes during problem times, something he claims is unrealistic to expect him to do. He said the company's project manager Stuart Quinton-Tulloch said they could not act until it had proof of unacceptable noise levels. Mr Bellamy said: "I'm not the moaning type and I have no problem with the look of the windmills. I'm not anti-windfarm. It's just the noise which is obviously not going to go away." (....)

Highland Council's principal environment officer Tom Foy who has been dealing with Mr Bellamy's complaint was unavailable for comment. His colleague David Proudfoot said he was aware of noise complaints about the Causewaymire turbines being lodged by two other residents, but said he had gone out several times and found no evidence to support the concerns.

Part of an article in *Press and Journal* of Aberdeen, 25 May 2005

Thinking that this could perhaps be solved by the Sustainable Development Commission (SDC), the UK government's 'independent advisory body on sustainable development', I wrote to the SDC about remarks on wind turbine noise in their report "Wind power in the UK" [SDC 2005], which was in my opinion too positive and somewhat overly optimistic regarding wind turbine noise. The SDC replied, on authority of its (unknown) consultants, that they had no detailed knowledge of atmospheric conditions in the UK but still thought an impulsive character of the noise 'likely to be very rare'. After I presented some examples the SDC preferred to close the discussion.

The situation in the Netherlands is not very different. In the latest annual report of the body of national, provincial and local authorities responsible for wind energy development it is acknowledged that the problem of underrated noise has justly been brought to the policy agenda.[1] Nevertheless, no activity is undertaken to remedy this.

I.4 Large scale benefits and small scale impact

Though wind turbine noise is the main topic of this book, it is not the main problem in wind power development. Visual impact is usually considered the most important and most discussed local or regional effect. It is often presented as a matter of individual taste, though there are some common factors in 'public taste'. One such factor is the perceived contrast of a wind turbine (farm) and its environment: a higher contrast will have more impact, either in a positive or negative way. A peculiarity of turbines is that the rotational movement makes them more conspicuous and thus enhances visual impact. This common notion suggests that wind turbines in a built up area will have less impact relative to a remote natural area (though this may be overruled by the number of people perceiving the impact).

A second factor is attitude: e.g. farmers usually have a different attitude to the countryside than 'city folk' have, and hence they differ in judgments on the appropriateness of a building, construction or activity in the

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[1] Jaarverslag BLOW (Bestuursovereenkomst Landelijke Ontwikkeling Windenergie), 2005 (Annual report BLOW 2005; in Dutch), January 2006

countryside. It is predictable that when residents have a positive association with a neighbouring wind farm they will experience less annoyance from the visual impact. For a wind turbine owner the sound of each blade passing means another half kWh is generated[1] and is perhaps associated with the sound of coins falling into his lap, a lullaby. The very same rhythm, like the proverbial leaking faucet tap, might prevent his neighbour from falling asleep.
Other issues have gained attention in the public discussion, such as the modest contribution of wind energy to total energy consumption and the problematic variability of wind power. This is not the place to discuss these issues, except that they partially depend on a person's world view and expectations of the future. But I would like to show my personal position here. I find it astounding to realize that *all* wind turbine energy generated in the Netherlands in one year (2004) is equal to two months' *growth* of the total Dutch energy consumption. And even though wind turbine energy now provides about 2% of the total Dutch electricity consumption, this is only 0.2% of our total energy consumption.[2] This is also true on a global scale as is clear from figure 1.1: wind power is now negligible and expected to supply 0.5% in 2030.

Despite the disappointingly low percentages I still think that wind energy need not be insignificant. In my view the problem is rather that we use such vast amounts of energy and keep on using ever more, which is a problem that no source, including wind power, can solve. Society will need to find a stand in the variety of opinions that have been brought forward since the 1970's. In a recent newspaper discussion about the liberalization of the energy market an opinion maker stated: "It is now generally appreciated that the end of the rich era of energy approaches rapidly, and the competition has begun for the last stocks", whilst his opponent the Minister of Economic Affairs wrote: "The lights must be kept burning, the

[1] when the turbine generates 2 MW at 20 rpm

[2]: the percentages are based on data from Statistics Netherlands (Centraal Bureau voor Statistiek) for the Netherlands for the year 2004: wind energy production: 1.9 TWh; total electricity consumption: 108.5 TWh; total energy consumption: 919 TWh. Growth in total energy consumption in period 1995 – 2004: + 100 TWh or 1.7 TWh per two months. Growth in total electricity consumption 1995 - 2004: ~23 TWh or 2.3 TWh per year.

gas must keep flowing" .[1] I do not agree with the Minister: I think that a limited resource should require limited consumption, even at the cost of some discomfort to our spoiled society. If we can curb our Joule addiction, wind power may help us to produce part of the sustainable energy we need to satisfy basic needs

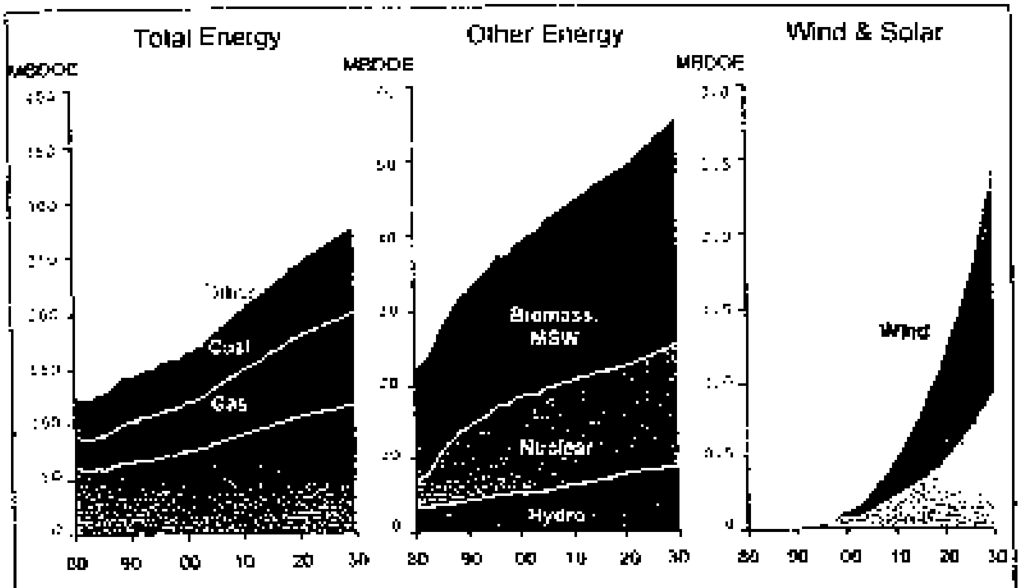

Figure I.1: history since 1980 and forecast until 2030 of global energy production (adapted from the ExxonMobil 2004 Energy Outlook); MBDOE = million barrels per day oil-equivalent = 620 TWh per year

Wind turbine noise is a problem that may grow due to neglect by wind energy proponents and thus it may be another reason for part of the public, with politicians following, to turn away from wind power. This problem can be solved when it is also addressed at the level of local impact: sustainability must also apply at the local level. Some technical possibilities for noise reduction are given in this book and more competent, hardware oriented people may come up with better solutions. In addition to this, the social side of the problems must not be neglected. In a recent study [Van As *et al* 2005] it was concluded that "growing public resistance

[1] NRC Handelsblad 8-11-2005, articles "Bezinning nodig over energiebeleid" ("Energy policy needs reflection" by W. van Dieren) and "Nieuw debat schept slechts onzekerheid" ("New debate only creates uncertainty" by Laurens Jan Brinkhorst); my translations

to onshore wind turbines" obstructs wind energy development in the Netherlands. According to the report this opposition is now the main bottle-neck: local communities and residents are faced with the disadvantages whilst others (proponents, society at large) reap the benefits. The report recommends that the former share in the benefits too.

I.5 Microphone wind noise

In contrast to the impact my wind turbine research has had in society, the same knowledge of atmospheric physics helped me solve a non-controversial problem of interest to only a few: what is the nature of the noise that wind creates in a microphone? It occurred to me that if atmospheric turbulence was the cause, then one must be able to calculate the level of this noise. I was delighted when I found out how well theoretical considerations fitted hitherto only vaguely understood measurement results. Eureka!, such is the joy of work in science.

Somewhat unexpectedly this second discovery turns out to be related to wind turbine sound, which is why it is in this book. Originally it was considered difficult to measure wind turbine sound, because the strong winds that were supposed to cause high wind turbine sound levels, also were believed to be responsible for a lot of microphone wind noise. Solutions to this problem were either to put the microphone out of the wind on the ground or use several microphones and decrease microphone noise by averaging over all microphone signals. A new solution offered in this book is to take measurements in a stable atmosphere where near-ground wind velocity is so low that microphone noise is far less of a problem. One can measure sound at distances from a wind farm most researchers would not now believe to be possible.

The relationship is even stronger. In some countries the level of ambient background sound determines (part of) the limit imposed on sound exposure. To measure the level of this background sound the microphone must be put up in a place where residents stay outdoors, also in stronger winds. In this case it is important to discriminate between real ambient sound and the noise that wind produces in the microphone. With the calculation methods in this book it is now possible to do so.

I.6 Research aims

The issues raised above concerning wind turbine noise and its relationship to altitude dependent wind velocity led to the following issues to be investigated:

- what is the influence of atmospheric stability on the speed and sound power of a wind turbine?
- what is the influence of atmospheric stability on the character of wind turbine sound?
- how widespread is the impact of atmospheric stability on wind turbine performance: is it relevant for new wind turbine projects?; how can noise prediction take this stability into account?
- what can be done to deal with the resultant higher impact of wind turbine sound?

Apart from these directly wind turbine related issues, a final aim was to address a measurement problem:

- how does wind on a microphone affect the measurement of the ambient sound level?

I.7 Text outline and original work

This book gives an overview of results of the wind turbine noise research that has been presented in the international arena in the last few years, as well as some opinions on this topic in the Introduction and Epilogue. Most of the text in this book has been published in scientific journals or presented at conferences. However, the texts have been adapted somewhat so as to form a continuous story without too much overlap. Other changes have been listed below.

- *Chapter II* is a reflection on some problems I encountered in doing research and presenting the results, most of it concerning wind turbine noise, but set against a more general background. It corresponds to a paper presented at Euronoise 2003 [Van den Berg 2003], but some overlap with later chapters is taken out and some new information concerning the variation of wind turbine sound has been added (last paragraph in II.2). The remaining text has been edited slightly.

- *Chapter III* gives some numbers on wind energy development in the European Union, as well as an introduction on atmospheric wind gradients and the origins of aerodynamic wind turbine sound. It corresponds to sections of two published papers [Van den Berg 2004a and 2005a] to which remarks on the local wind speed at the turbine blade (section III.3) and on the spectrum of thickness sound (footnote in III.4) has been added. Also a description of sound and effects as given by a residential group with practical experience is added (box at end of chapter) and a remark on constant speed and variable speed wind turbines (in III.4).
- *Chapter IV* corresponds to my first paper on this topic [Van den Berg 2004a] on measurements at the Rhede wind farm. The section on Impulsive Sound has been taken out here and transferred to the next chapter. A new section (IV.10) has been added describing previously unpublished measurements at the Rhede wind farm as well as a comparison with calculated sound levels. Chapter IV demonstrates the fact that sound levels due to wind turbines have been systematically underestimated because hub height wind velocities were not correctly predicted. This effect is becoming more important for modern, tall wind turbines particularly when the atmosphere is 'non standard' (*i.e.* diverging from neutrality).
- In *chapter V* a second effect of atmospheric stability is investigated. Not only has the sound level been underestimated, but also the effect on the sound character: when the atmosphere turns stable, a more pronounced beating sound evolves. Most of the data are from the Rhede wind farm, complemented by data from a smaller single turbine elsewhere and theoretical calculations. In a section on the perception of fluctuating sound, it is explained how an apparently weak sound level variation can indeed turn into audibly pronounced beating. This chapter corresponds to a published paper [Van den Berg 2005a], but the section on interaction of several turbines (V.2.4) has been

combined with the corresponding section of the first paper [Van den Berg 2004a]. In this chapter the fact that wind velocity in the rotor is not equal to the free wind velocity, which was neglected in the paper, has been taken into account.

- In *chapter VI* data on atmospheric stability and wind statistics are presented. The raw data are from a location in the mid west of the Netherlands and have been provided by the KNMI. The analysis and application to a reference wind turbine help us to understand the behaviour of wind turbines and, together with research results from other countries, show that the atmospheric conditions found at the Rhede wind farm certainly were no exception. This chapter is the text of a paper presented at the WindTurbineNoise2005 conference [Van den Berg 2005b], with some results from other presentations at that conference added (in section VI.6).
- In *chapter VII* some possibilities are discussed to cope with the effects of atmospheric stability on wind turbine noise, either by controlling wind turbine performance or by new designs. In part this is derived from a project in the town of Houten where the town council wants to permit a wind farm, taking into account the effect on residents, especially at night. This chapter is a somewhat expanded version (a concluding section has been added) of a second paper presented at the WindTurbineNoise2005 conference [Van den Berg 2005c].
- In *chapter VIII* a new topic is introduced: how does wind affect sound from a microphone? It shows that atmospheric turbulence, closely related to again- atmospheric stability, is the main cause of wind induced microphone noise. The chapter corresponds to a published article [Van den Berg 2006].
- In *Chapter IX* all results are summarized. Based on these general conclusions recommendations are given for a fresh look at wind turbine noise.
- Finally, in *chapter X*, some thoughts are given to conclude the text. After that the appendices give additional information.

II ACOUSTICAL PRACTICE AND SOUND RESEARCH

II.1. *Different points of view*

In 2001 the German wind farm Rhede was put into operation close to the Dutch border. Local authorities as well as residents at the Dutch side had opposed the construction of the 17 wind turbines because of the effects on landscape and environment: with 98 m hub height the 1.8 MW turbines would dominate the skyline of the early 20th century village of Bellingwolde and introduce noise in the quiet area.
With the turbines in operation, residents at 500 m and more from the wind farm found the noise (and intermittent or flicker shadow, which will not be dealt with here) worse than they had expected. The wind farm operator declined to take measures as acoustic reports showed that German as well as Dutch noise limits were not exceeded. When the residents brought the case to a German court, they failed on procedural grounds. For a Dutch court they had to produce arguments that could only be provided by experts.

Science Shops are specifically intended to help non-profit groups by doing research on their behalf. For the Science Shop for Physics in Groningen noise problems constitute the majority of problems that citizens, as a group or individually, come up with. Although the aim of our research is the same as for acoustic consultants –to quantify sound levels relevant for annoyance- the customers are different: consultants mostly work for the party responsible for the sound production, whereas the Science Shop mostly works for the party that is affected by the sound. This may lead to different research questions. In the case of wind farm Rhede a consultancy will check the sound production of the turbines and check compliance of the calculated sound immission level with relevant limits. However, the Science Shop, taking the strong reaction from the residents as a starting point, wanted to check whether the real sound immission agrees with the calculated one and whether sound character could explain extra annoyance.

In the Dutch professional journal 'Geluid' it was shown, on the basis of 30 acoustic reports, that acoustic consultants tend to rely too much on information from their customers, even when they had reason to be critical about it [Van den Berg 2000]. As consultants' customers are usually noise producers and authorities, the point of view of those that are affected by noise is not usually very prominent. This book shows that for wind turbines a similar case can be made.

II.2 Results from our wind turbine research

The results of the investigation of the sound from the wind farm Rhede are given in the next chapters. Here the results will be dealt with briefly. The main cause for the high sound level perceived by residents is the fact that wind velocities at night can, at 100 m height, be substantially higher than expected. As a consequence a wind turbine produces more sound. As measured immission levels near the wind farm Rhede show, the discrepancy may be very large: sound levels are up to 15 dB higher than expected at 400 m from the wind farm. The important point is not so much that the maximum measured sound level is higher than the maximum expected sound level (it was, around +2 dB, but this was not an effect of the wind velocity profile). The point is that this maximum does not only occur at high wind velocities as expected, accompanied by high wind induced ambient sound levels, but already at relatively low wind velocities (4 m/s at 10 m height) when there is little wind at the surface and therefore little wind induced background sound. Thus, the discrepancy of 15 dB occurs at quiet nights, but yet with wind turbines at almost maximum power. This situation occurs quite frequently.

A second effect that adds to the sound annoyance is that the sound has an impulsive character. The primary factor for this appeared to be the well known swishing sound one hears close to a turbine. For a single turbine these 1 – 2 dB broad band sound pressure fluctuations would not classify as impulsive, but at night this swish seems to evolve into a less gentle thumping. Also, when several turbines operate nearly synchronously the pulses may occur in phase increasing pulse strength further. At some distance from the wind farm this sound characteristic, described as thumping or beating, can be very pronounced though in the wind farm, close to a turbine, we never heard this impulsiveness.

Indeed, close to a turbine it seems that most sound is coming from the downgoing blade, not when it passes the tower. One has to be careful in estimating blade position, as an observer at, say, 100 m from the foot of the tower is 140 m from a 100 m hub and therefore hears the sound from a blade approximately half a second after it was produced, in which time a blade may have rotated over some 30°. At the Berlin WindTurbineNoise conference Oerlemans [2005] explained this phenomenon: when the blade comes down and heads towards the observer, the observer is at an angle to the blade where most sound is radiated (see remark on directivity just below equation B.5 in Appendix B). On top of that the high tip velocity (70 m/s) causes a Doppler amplification. Both effects increase the sound level for our observer. However, this observation cannot be used for a distant turbine as in that case the observer sees the rotor sideways. Then the change due to the directivity of the sound is small, and also the Doppler effect is nil as the change in the velocity component towards the observer is negligible.

II.3 Early warnings of noisy wind turbines?

One may wonder why the strong effect of the nightly wind profile or the thumping was not noticed before. In the 1998 publication IEC 16400 only the neutral logarithmic wind profile is used [IEC, 1998]. As recent as 2002 it was stated that wind turbine sound is not impulsive [Kerkers *et al* 2002], which was concluded from assumed, not from measured sound level variations.

There have been some warnings, though. In 1998 Rudolphi concluded from measurements that wind velocity at 10 m height is not a good measure for the sound level: at night the (58 m hub height) turbine sound level was 5 dB higher than expected [Rudolphi 1998]. This conclusion was not followed by more thorough investigation. Since several years residential groups in the Netherlands and abroad complained about

annoying turbine sound at distances where they are not even expected to be able to hear the sound. Recently Pedersen *et al* [2003, 2004] found that annoyance was relatively high at calculated maximum sound immission levels below 40 dB(A) where one would not expect strong annoyance.
As wind turbines become taller, the discrepancy between real and expected levels grows and as more tall wind turbines are constructed complaints may become more widespread. In the Netherlands residents near the German border were the first Dutch to be acquainted with turbines of 100 m hub heights.

It may be that earlier discrepancies between real and projected sound immission were not sufficient to evoke strong community reactions and that only recently turbines have become so tall that the discrepancy now is intolerable.
There are other reasons that early warnings perhaps did not make much impression. One is that sound emission measurements are usually done in daytime. It is hard to imagine the sound would be very different at night time, so (almost) no one did. Until some years ago, I myself could not imagine how people could hear wind turbines 2 km away when at 300 to 400 m distance the (calculated) immission level was, for a given wind velocity, already equal to the ambient background sound level (L_{95}). But it proved I had not listened in a relevant period: an atmospherically stable night.
What is probably also a reason is the rather common attitude that 'there are always people complaining'. Complaints are a normal feature, not as such a reason to re-investigate. Indeed Dutch noise policy is not to prevent any noise annoyance, but to limit it to acceptable proportions. Added to this is a rather general conviction of Dutch authorities and consultants that routine noise assessment in compliance with legal standards must yield correct results. If measurements are performed it is to check actual emission levels –usually in normal working hours, so in daytime. It is quite unusual to compare the calculated sound immission from a wind turbine (farm) with measured immission levels (so unusual that it is likely that we were the first to do so).

A third reason may be partiality to the outcome of the results. Wind turbine operators are not keen on spending money that may show that sound levels do not comply with legal standards. And if, as expected, they do comply, the money is effectively wasted. Apart from this, we have the experience that at least some organisations that advocate wind energy are not interested in finding out why residents oppose wind farms.

II.4 The use of standard procedures

Although our objective was to measure immission sound levels, we also wanted to understand what was going on: if levels were higher than expected, was that because emission was higher or attenuation less? Could there be focussing or interference? We therefore also measured sound emission as a function of rotational speed of the variable speed turbines. An interesting point that came up with the emission measurement was that compliance with the recommended standard [Ljunggren 1997 or IEC 1998] was impossible. As the farm operator withdrew the co-operation that was previously agreed upon, we had to measure emission levels with the full wind farm in operation, as we obviously did not have the means to stop all turbines except the one to be measured, as the standard prescribes. To measure ambient background sound level, even the last turbine should be stopped.

According to the recommended standard the sound emission should be measured within 20% of the distance to the turbine equal to hub height + blade length. However, to prevent interference from the sound from other turbines the measurement location had to be chosen closer to the turbine.

The primary check on the correctness of the distance (i.e. not too close to other turbines) was by listening: the closest turbine should be the dominant source. If not, no measurement was done, and usually a measurement near another turbine was possible. Afterwards we were able to perform a second check by comparing the measured sound immission of the wind farm at a distance of 400 m with the level calculated with a sound propagation model with the measured emission level of all (identical) turbines as input. The calculated difference between a single turbine sound power level and the immission level was 58.0 dB (assuming a constant spectrum this is independent from the power level itself). The measured average difference

was 57.9 dB, with a maximum deviation of individual measurement points of 1.0 dB. So our measurements proved to be quite accurate, deviating only 0.1 ± 1.0 dB from the expected value! In fact, from our measurements one may conclude that, to determine turbine sound power level, it is easier and cheaper to determine total sound emission by measurements at some distance from a wind farm than measuring separate turbines. The wind induced ambient sound, that easily spoils daytime measurements, is not an important disturbance in many nights!
Using a 1 m diameter round hard board, again to comply with the standard, was quite impractical and sometimes impossible. *E.g.* at one place potato plants would have to be cleared away, at another place one would have to create a flat area in clumps of grass in a nature reserve, both unnecessarily. Instead of the large board we used the side (30·44 cm^2) of a plastic sound meter case. We convinced ourselves that (in this case) this was still a good procedure by comparing at one location sound levels measured on the case on soft ground with sound levels measured on a smooth tarmac road surface a few meters away, both at the same distance to the turbine as in the other measurements: there was no difference.

Whether a turbine produces impulsive sound is usually determined by listening to and measuring the sound near a single turbine (along with measurements to determine sound power and spectral distribution). In the Netherlands impulsivity is judged subjectively (by ear), not by a technical procedure as in Germany, though judgement can be supported with a sound registration showing the pulses. Interestingly, in Dutch practice only an acoustician's ear seems reliable, though even their opinions may disagree. From our measurements the impulsive character can be explained by the wind profile and the interaction of the sound of several turbines. Even at a time the impulsive character can be heard near residents' dwellings, it cannot clearly be heard close to the turbines in the wind farm (as explained in section II.2). So here also there was need to do measurements where people are actually annoyed, and not to rely on source measurements only, certainly not from a single turbine.

When noise disputes are brought to court, it is clearly advantageous to have objective procedures and standards to assure that the technical quality, which can hardly be judged by non experts, is sufficient and therefore the results are reliable. In the case made here however, a standard may be non-applicable for valid reasons. Nonetheless, the emission measurements have been contested on procedural grounds (*viz.* we have not complied to the standard [Kerkers 2003]), even though the immission sound levels were the primary research targets and we did not really need the sound emission measurement results (which, however, proved very accurate).

The tendency to put all noise assessment into technical standard procedures has the disadvantage that when there is a flaw in a legally enforced standard, still the standard is followed, not reality. It is hardly possible for non experts, such as residents, to bring other arguments to court. They, the annoyed, will have to hire an expert to objectify their annoyance. This is not something every citizen can afford.

II.5 Modelling versus measurements

Being able to calculate sound levels from physical models is a huge advantage over having to do measurements (if that, indeed, is possible) especially as in practical situations conditions keep changing and other sounds disturb the measurements. Because of its obvious advantages models have become far more important for noise assessment than measurements. In the Netherlands usually sound emission measurements are carried out close to a source to determine sound power levels. Then, with the sound power level, the immission level is calculated, usually on façades of residences close to the sound source. It is not common to measure immission levels in the Netherlands; in some cases (e.g. railway, aircraft noise) there is not even a measurement method (legally) available to check calculated levels.

However, a physical model is never the same as reality. As will be shown in this book, the widely used standard to quantify sound emission from wind turbines is implicitly based on a specific wind profile. This profile is not correct at night, although the night is the critical period for wind turbine noise assessment.

Even a perfect physical model will not reproduce reality if input values are not according to reality. An example is to apply sound power levels from new sources (cars, road surfaces, aeroplanes, mopeds, vacuum cleaners, etc.), maybe acquired in a specific test environment, to real life situations and conditions. Another example is a wind farm south of the Rhede wind farm where a turbine produced a clearly audible and measurable tonal sound, probably caused by damage on a blade. It is very hard for residents to convince the operator and authorities of this annoying fact, partly because most experts say that modern wind turbines do not produce tonal sound.

Incorrect models and incorrect input may well occur together and be difficult to separate. It is important that calculation models are checked for correctness when they are used in new applications. Situations where (strong) complaints arise may indicate just those cases where models do not cover reality.

II.6 Conclusion

In modelling wind turbine sound very relevant atmospheric behaviour has been 'overlooked'. As a consequence, at low surface wind velocities such as often occur at night, wind turbine noise immission levels may be much higher than expected. The discrepancy between real and modelled noise levels is greater for tall wind turbines. International models used to assess wind turbine noise on dwellings should be revised for this atmospheric effect, at least by giving less attention to the 'standard' neutral atmosphere.

A discrepancy between noise forecasts and real noise perception, as a result of limited or even defective models, cannot always be avoided, even not in principle. However, its consequences can be minimised if immission levels are measured at relevant times and places. This relevancy is also determined by observations of those affected. It should always be possible to check noise forecasts by measurement.

For wind turbine noise (and other noise sources) standard measurement procedures require co-operation of the operator to be able to check emission sound levels. This introduces an element of partiality to the advantage of the noise producer. This is also generally a weak point in noise assessment: the source of information is usually the noise producer. Hence there should always be a procedure to determine noise exposure independently of the noise producer.

Standard technical procedures have the benefit of providing quality assurance: when research has been conducted in compliance with a standard procedure lay persons should be able to rely on the results. It may however also have a distinct disadvantage for lay people opposing a noise source: when an assessment does not comply with a standard procedure it is not accepted in court, regardless of the content of the claim. A consequence is they have to depend on legal as well as acoustical expertise. If citizens are forced to use expert knowledge, one may argue that they should be given access to that knowledge. An important obstacle is the cost of that access.

III BASIC FACTS: wind power and the origins of modern wind turbine sound

III.1 Wind energy in the EU

Modern onshore wind turbines have peak electric power outputs up to 3 MW and tower heights of 80 to 100 meters. In 2003, 75% of the global wind power peak electric output of 40 GW was installed in the European Union. The original European target for 2010 was 40 GW, but the European Wind Energy Association have already set a new target for 2010 of 75 GW, of which 10 GW is projected off-shore, while others have forecasted a peak output of 120 GW for that year [EWEA 2004]. Whether this growth will actually occur is uncertain; with the proportional increase of wind energy in total electric power the difficulties and costs of integrating large scale windpower with respect to grid capacity and stability, reserve capacity and CO_2 emission reductions are becoming more prominent [see, *e.g.*, E.On 2004, ESB 2004]). However, further expansion of wind energy is to be expected, and as a result of this (predominantly on-shore) growth an increasing number of people may face the prospect of living near wind farms, and have reason to inquire and perhaps be worried about their environmental impact. Visual intrusion, intermittent reflections on the turbine blades, as well as intermittent shadows (caused when the rotating blades pass between the viewer and the sun), and sound, are usually considered potentially negative impacts.

III.2 Wind profiles and atmospheric stability

Atmospheric stability has a profound effect on the vertical wind profile and on atmospherical turbulence strength. Stability is determined by the net heat flux to the ground, which is a sum of incoming solar and outgoing thermal radiation, and of latent and sensible heat exchanged with the air and the subsoil. When incoming radiation dominates (clear summer days) air is heated from below and rises: the atmosphere is unstable. Thus, thermal turbulence implies vertical air movements, preventing large variations in the vertical wind velocity gradient (*i.e.* the change in time averaged wind velocity with height). When outgoing radiation dominates (clear nights) air is cooled from below; air density will increase closer to the ground, leading to a stable configuration where vertical movements are damped. The 'decoupling' of horizontal layers of air allows a higher vertical wind velocity gradient. A neutral state occurs when thermal effects are less significant, which is under heavy clouding and/or in strong winds.

Wind velocity at altitude h_2 can be deduced from wind velocity at altitude h_1 with a simple power law function:

$$V_{h2}/V_{h1} = (h_2/h_1)^m \qquad \text{(III.1)}$$

Equation III.1 is an engineering formula used to express the degree of stability in a single number (the shear exponent *m*), but has no physical basis. The relation is suitable where h is at least several times the roughness height (a height related to the height of vegetation or obstacles on the ground). Also, at high altitudes the wind profile will not follow (III.1), as eventually a more or less constant wind velocity (the geostrophic wind) will be attained. At higher altitudes in a stable atmosphere there may be a *de*crease in wind velocity when a nocturnal 'jet' develops. The maximum in this jet is caused by a transfer of kinetic energy from the near-ground air that decouples from higher air masses as large, thermally induced eddies vanish because of ground cooling. In fact, reversal of the usual near-ground diurnal pattern of low wind velocities at night and higher wind velocities in daytime is a common phenomenon at higher altitudes over land in clear nights as will be shown further below (Chapter VI). Over large bodies of water the phenomenon may be seasonal as atmospheric stability occurs more often when the water is relatively cold (winter, spring). This may also be accompanied by a maximum in wind velocity at a higher altitude [Smedman *et al* 1996].

In flat terrain the shear exponent *m* has a value of 0.1 and more. For a neutral atmosphere *m* has a value of approximately 1/7. In an unstable atmosphere -occurring in daytime- thermal effects caused by ground heating are dominant. Then *m* has a lower value, down to approximately

0.1. In a stable atmosphere vertical movements are damped because of ground cooling and *m* has a higher value. One would eventually expect a parabolic wind profile, as is found in laminar flow, corresponding to a value of *m* of 0.7 = $\sqrt{½}$. Our measurements near the Rhede wind farm yielded values of *m* up to 0.6. A sample (averages over 0:00–0:30 GMT of each first night of the month in 1973) from data from a 200 m high tower in flat, agricultural land [Van Ulden *et al* 1976] shows that the theoretical value is indeed reached: in ten out of the twelve samples there was a temperature inversion in the lower 120 m, indicating atmospheric stability. In six samples the temperature increased with more than 1 °C from 10 to 120 m height and the exponent *m* (calculated from (III.1): $m = \log(V_{80}/V_{10})/\log(8)$) was 0.43, 0.44, 0.55, 0.58, 0.67 and 0.72. More data from this site (Cabauw) and other areas will be presented in chapter VI.

A physical model to calculate wind velocity V_h at height h is ([Garrat 1992], p. 53):

$$V_h = (u_*/\kappa)\cdot[\ln(h/z_0) - \Psi] \qquad \text{(III.2)}$$

where $\kappa = 0.4$ is von Karman's constant, z_0 is roughness height and u_* is friction velocity, defined by $u_*^2 = \sqrt{(\langle uw\rangle^2 + \langle vw\rangle^2)} = \tau/\rho$, where τ equals the momentum flux due to turbulent friction across a horizontal plane, ρ is air density and u, v and w are the time-varying components of in-wind, cross-wind and vertical wind velocity, with $\langle x\rangle$ the time average of x. The stability function $\Psi = \Psi(\zeta)$ (with $\zeta = h/L$) corrects for atmospheric stability. Here Monin-Obukhov length L is an important length scale for stability and can be thought of as the height above which thermal turbulence dominates over friction turbulence; the atmosphere at heights $0 < h < L$ (if L is positive and not very large) is the stable boundary layer. The following approximations for Ψ, mentioned in many text books on atmospheric physics (*e.g.* [Garrat 1992]), are used:

- in a stable atmosphere ($L > 0$) $\Psi(\zeta) = -5\zeta < 0$.
- in a neutral atmosphere ($|L|$ large $\rightarrow 1/L \approx 0$) $\Psi(0) = 0$.
- in an unstable atmosphere ($L < 0$) $\Psi(\zeta) = 2\cdot\ln[(1+x)/2] + \ln[(1+x^2)/2] - 2/\tan(x) + \pi/2 > 0$, where $x = (1-16\cdot\zeta)^{1/4}$.

For $\Psi = 0$ equation (III.2) reduces to $V_{h,log} = (u_*/\kappa)\cdot\ln(h/z_0)$, the widely used logarithmic wind profile. With this profile the ratio of wind velocities at two heights can be written as:

$$V_{h2,log}/V_{h1} = \log(h_2/z_0)/\log(h_1/z_0) \qquad \text{(III.3)}$$

For a roughness length of z_0 = 2 cm (pasture) and m = 0,14, the wind profiles according to equations III.1 and III.3 coincide within 2% for h < 100 m. In figure III.1 wind profiles are given as measured by Holtslag [1984], as well as wind profiles according to formulae (III.1) and (III.3).

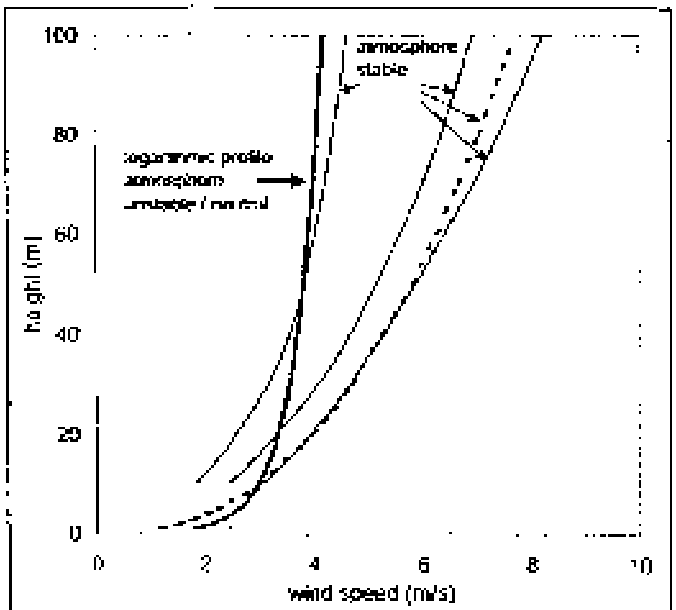

Figure III.1: wind profiles

Formula III.3 is an approximation of the wind profile in the turbulent boundary layer of a neutral atmosphere, when the air is mixed by turbulence resulting from friction with the surface of the earth. In daytime thermal turbulence is added, especially when there is strong insolation. At night time a neutral atmosphere, characterized by the adiabatic temperature gradient of -1 °C per 100 m, occurs under heavy clouding and/or at relatively high wind velocities. When there is some clear sky and in the absence of strong winds the atmosphere becomes stable because of radiative cooling of the surface; the wind profile changes and can no longer be adequately described by (III.3). The effect of the change to a stable atmosphere is that, relative to a given wind velocity at 10 m height in daytime, at night there is a higher wind velocity at hub height and thus a higher turbine sound power level; also there is a lower wind velocity below 10 m and thus less wind-induced sound in vegetation.

With regard to wind *power* some attention is being paid to stability effects and thus to other wind profile models such as the diabatic wind velocity model (III.2) [see, *e.g.*, Archer *et al* 2003, Baidya Roy *et al* 2004, Pérez *et al* 2004, Smedman *et al* 1996, Smith *et al* 2002]. In relation to wind turbine *sound*, much less attention has been given to atmospheric stability (see section II.3).

Stability can also be categorized in Pasquill classes that depend on observations of wind velocity and cloud cover (see, *e.g.*, [LLNL 2004]). They are usually referred to as classes A (very unstable) through F (very stable). In a German guideline [TA-Luft 1986] a closely related classification is given (again closely related to the international Turner classification [Kühner 1998]). An overview of stability classes with the appropriate value of m is given in table III.1.

Table III.1: stability classes and shear exponent *m*

Pasquill class	name	comparable stability class [TA-Luft 1986]	*m*
A	very unstable	V	0.09
B	moderately unstable	IV	0.20
C	neutral	IV2	0.22
D	slightly stable	IV1	0.28
E	moderately stable	II	0.37
F	(very) stable	I	0.41

According to long-term data from Eelde and Leeuwarden [KNMI 1972], two meteorological measurement sites of the KNMI (Royal Netherlands Meteorological Institute) in the northern part of the Netherlands, a stable atmosphere (Pasquill classes E and F) at night occurs for a considerable proportion of night time: 34% and 32% respectively.

From formula (III.3) the ratio of wind velocities at hub height (98 m) and reference height, over land with low vegetation (z_o = 3 cm), is f_{log} = V_{98}/V_{10} = 1.4. According to formula (III.1) and table III.1 this ratio would be $f_{unstable} = 1.2 = 0.85 \cdot f_{log}$ in a very unstable atmosphere and $f_{stable} = 2.5 = 1.8 \cdot f_{log}$ in a (very) stable atmosphere.

The shear exponent m can be determined from the measured ratio of wind velocities at two heights (V_{h2}/V_{h1}) using equation III.1:

$$m_{h1,h2} = \ln(V_{h2}/V_{h1})/\ln(h_2/h_1) \tag{III.4}$$

III.3 Air flow on the blade

As is the case for aircraft wings, the air flow around a wind turbine blade generates lift. An air foil performs best when lift is maximised and drag (flow resistance) is minimised. Both are determined by the angle of attack: the angle (α) between the incoming flow and the blade chord (line between front and rear edge; see figure III.2). The optimum angle of attack for turbine blades is usually between 0 and 4°, depending on the blade profile.

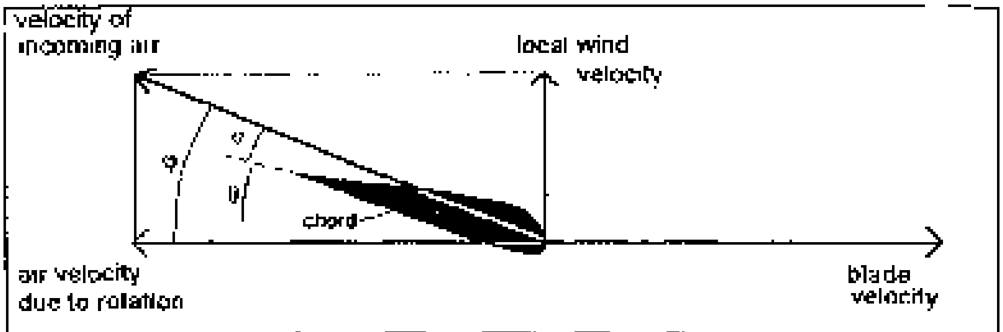

Figure III.2: flow impinging on a turbine blade with flow angle φ, blade pitch angle θ and angle of attack on blade $\alpha = \varphi - \theta$

The local wind at the blade is not the unobstructed wind velocity. The rotor extracts energy from the air at the cost of the kinetic energy of the wind. The velocity of the air passing through the rotor is thus reduced to $V_b = (1 - a)V_\infty$, where a is the induction factor. The highest efficiency of a wind turbine is reached at the Betz limit: at this theoretical limit the induction factor is 1/3 and the efficiency is 16/27 (≈ 60%) [Hansen 2000]. The wind velocity at the blade is thus:

$$V_b = V_\infty \cdot 2/3 \tag{III.5}$$

III.4 Main sources of wind turbine sound

There are many publications on the nature and power of turbine sound: original studies [*e.g.* Lowson 1985, Grosveld 1985] and reviews [*e.g.* Hubbard *et al* 2004, Wagner *et al* 1996]. A short introduction on wind aeroacoustics will be given to elucidate the most important sound producing mechanisms.

If an air flow is smooth around a (streamlined) body, it will generate very little sound. For high velocities and/or over longer lengths the flow in the boundary layer between the body and the main flow becomes turbulent. The rapid turbulent velocity changes at the surface cause sound with frequencies related to the rate of the velocity changes. The turbulent boundary layer at the downstream end of an airfoil produces *trailing edge sound*, which is the dominant audible sound from modern turbines. When the angle of attack increases from its optimal value the turbulent boundary layer on the suction (low pressure) side grows in thickness, thereby decreasing power performance and increasing sound level. For high angles of attack this eventually leads to stall, that is: a dramatic increase of drag on the blades. Apart from this turbulence inherent to an airfoil, the atmosphere itself is turbulent over a wide range of frequencies and sizes.

Figure III.3: 15 m blades for Altamont Pass, Ca (photo: Alex Haag)

Turbulence can be defined as changes over time and space in wind velocity and direction, resulting in velocity components normal to the airfoil varying with the turbulence frequency causing *in-flow turbulent sound*. Atmospheric turbulence energy has a maximum at a frequency that depends on altitude and on atmospheric stability. For wind turbine altitudes this peak frequency is of an order of magnitude of once per minute (0.017 Hz). The associated eddy (whirl) scale is of the order of magnitude of several hundreds of meters [Petersen *et al* 1998] in an unstable atmosphere, less in a stable atmosphere. Eddy size and turbulence strength decrease at higher frequency, and vanish due to viscous friction when the eddies have reached a size of approximately one millimetre.[1]

A third sound producing mechanism is the response of the blade to the change in lift when it passes the tower. The wind is slowed down by the tower which changes the angle of attack on the blade; as a result the lift and drag forces on the blade suddenly change. The resulting sideways movement of the blade causes *thickness sound* at the blade passing frequency and its harmonics.[2] Thickness sound is also mentioned as sound originating from the (free) rotating blade pushing the air sideways. However, the associated air movement is relatively smooth and is not a relevant source of sound.

A more thorough review of these three sound production mechanisms is given in appendix B, where frequency ranges and sound levels are quantified in so far as relevant for this book.

Sound originating from the generator or the transmission gear has decreased in level in the past decades and has become all but irrelevant if considering annoyance for residents.

To summarize, a modern wind turbine sound spectrum can be divided in (overlapping) regions corresponding to the three mechanisms mentioned:

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[1] for more information on atmospheric turbulence: see chapter VIII

[2] a thickness sound pulse has a length t_{pulse} with an order of magnitude of (tower diameter/tip speed =) 0.1 s, so its spectrum has a maximum at $1/t_{pulse} \approx 10$ Hz. The spectrum of a periodic series of Dirac pulses (unit energy 'spikes' with, here, a period of T_{blade}) is a series of spikes at frequencies n/T_{blade} (n = 1, 2, 3, 4, ...). When periodic thickness sound is considered as a convolution of the single sound pulse with a series of Dirac pulses, the Fourier transform is the product of the transforms of both, that is: the product of the sound pulse spectrum centered at $1/t_{pulse}$ and spikes at n/T_{blade}. The result is a series of spikes with the single sound pulse spectrum as an envelope, determining each spike level. In practice $1/T_{pulse}$ usually has a value of 4 to 8 Hz (see e.g. [Wagner 1996]) and the harmonic closest to this frequency carries most energy.

- High frequency: *trailing edge (TE) sound* is noise with a maximum level at 500–1000 Hz for the central octave band, decreasing with 11 dB for neighbouring octave bands and more for further octave bands.
- Low frequency: *in-flow turbulent sound* is broad band noise with a maximum level of approximately 10 Hz and a slope of 3–6 dB per octave.
- Infrasound frequency ($f < 30$ Hz): the *thickness sound* is tonal, the spectrum containing peaks at the blade passing frequency f_B and its harmonics.

As thickness sound is not relevant for direct perception, turbulent flow is the dominant cause of (audible) sound for modern wind turbines. It is broad band noise with no tonal components and only a little variation, known as blade swish. Trailing edge sound level is proportional to 50·logM (see equation B.4 in appendix B), where M is the Mach number of the air impinging on the blade. TE sound level, the dominant audible sound source in a modern turbine, therefore increases steeply with blade speed and is highest at the high velocity blade tips. Writing Mach number at the blade tip as $M = V_{tip}/c$, wind turbine sound level strongly depends on blade tip speed V_{tip}:

$$L_{TE} \sim 50 \cdot \log(V_{tip}/c) \qquad \text{(III.6)}$$

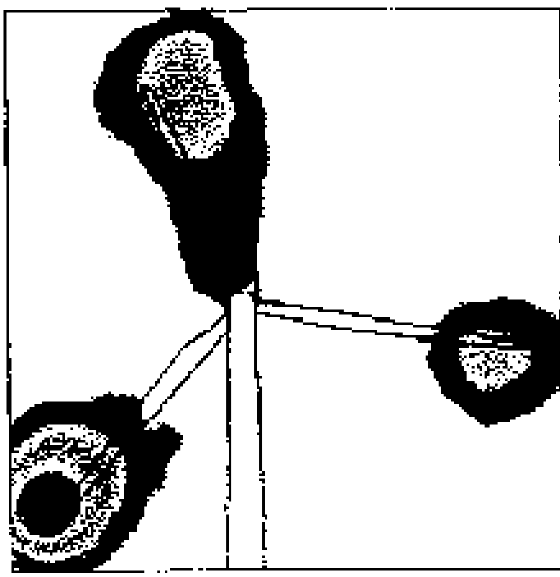


Figure III.1: an 'acoustic photograph' showing the high speed tips of a wind turbine radiate most sound; colors from centre to outside contour indicate an decreasing sound level (photo: Acoustic Camera, GFaI, Berlin)

Swish, which is the variation in TE sound, thus also originates predominantly at the tips.

This book deals with modern variable speed turbines where the angle of attack is constant over a wide range of wind speeds. Keeping blade pitch (the angle between the blade chord and the rotor plane) constant, the rotational speed increases with wind speed usually up to a rated wind speed of some 14 m/s. At higher wind speeds the pitch angle is decreased at constant rotational speed to keep a constant angle of attack until for safety reasons the rotor is stopped. The effect on sound production is that first the sound power level increases up to the rated wind speed, then remains almost constant at higher wind speeds.

In a constant speed turbine the rotational speed has a fixed value, though usually a turbine then has two speeds to accommodate for low and high wind speeds. Here the blade pitch is set to optimize the angle of attack up to the rated power. Above rated power, a situation that will not occur very often, the pitch angle is kept constant, so the angle of attack increases with wind speed and the turbine becomes less efficient. The result is that the sound power at low speed is almost constant, then increases sharply at the change to the higher speed. After that it is again almost constant, increasing again above the rated power when the angle of attack drifts away from the optimum value.

Sound from downwind rotors, *i.e.* with the rotor downwind from the tower, was considered problematic as it was perceived as a pulsating sound (see appendix B). For modern upwind rotors this variation in sound level is weaker. It is not thought to be relevant for annoyance and considered to become less pronounced with increasing distance due to loss of the effect of directivity, due to relatively high absorption at swish frequencies, and because of the increased masking effect of background noise [ETSU 1996]. However, an increase in the level of the swishing sound related to increasing atmospheric stability has not been taken into account as yet. In this context the periodic change in angle of attack near the tower proves to be important, not in relation to thickness sound but as a modulation period.

So, what's the sound like...?

(....) Our experience is that mechanical noise is insignificant compared to the aerodynamic noise, or 'blade thump' as we call it. At "our" windfarm the mechanical noise is usually only audible when within about 100 metres of the turbine, but the blade thump can be heard at distances of up to 1.5 Km away.

(....)

Some residents describe this noise as an old boot in a tumble dryer, others as a Whumph! Whumph! Whumph! Either way its not particularly loud at 1.5 km distance but closer than that and it can be extremely irritating when exposed to it for any period of time. Some residents have even resorted to stuffing chimney stacks with newspaper as the sound reverberates down the stack.

Because it is generally rhythmic, it's not the kind of noise that you can shut out of your mind, like, say, distant road noise - this is why we think the noise level stipulation on the planning conditions of such a windfarm development is woefully inadequate for protecting local residents from the noise effects of a windfarm.

All of us agree that the most disturbing aspect of the noise is the beat that we think is caused by the blades passing the tower of the turbine. As the rotational speed of the 3 bladed turbines is about 28 rpm "on full song" this results in a sound of about 84 beats per minute from each turbine.

The sound rises and falls in volume due to slight changes in wind direction but the end result for those in the affected area is a feeling of anxiety, and sometimes nausea, as the rate continually speeds and slows - we think that is maybe because this frequency of the pulses is close to the human heart rate and some residents feel that their own pulse rate is trying to match that of the turbines. (.....)

When does it strike?

The windfarm makes a noise all the time it is operating, however there are times when it becomes less of a nuisance:

When the wind is very strong, the background noise created by the wind whistling around trees etc. drowns out the noise of the turbines and the problem is reduced. (....)

In this area we all agree that the worst conditions are when the wind is blowing lightly and the background noise is minimal. Under these conditions residents up to 1 kilometre have complained to the Environmental Health department about the drone from the turbines. Unfortunately these are just the sort of weather conditions that you would wish to be outside enjoying your garden. (....)

During the summer nights it is not possible for some residents, even as far away as 1000 metres, to sleep with the window open due to the blade thump. (.....)

Excerpts describing wind turbine sound and its effects, from a page of the website of MAIWAG (consulted December 3 2005), a group of residents in three villages in the south of Cumbria (UK)

IV LOUD SOUNDS IN WEAK WINDS: effect of the wind profile on turbine sound level

IV.1 The Rhede wind farm

In Germany several wind turbine farms have been and are being established in sparsely populated areas near the Dutch border. One of these is the Rhede wind farm in northwestern Germany (53° 6.2' latitude, 7° 12.6' longitude) with seventeen Enercon E-66 1.8 MW turbines of 98 m hub height and with 3-blade propellers of 35 m blade length. The turbines have a variable speed increasing with wind velocity, starting with 10 rpm (revolutions per minute) at a wind velocity of 2.5 m/s at hub height up to 22 rpm at wind velocities of 12 m/s and over.

At the Dutch side of the border is a residential area along the Oude Laan and Veendijk in De Lethe (see figure IV.2): countryside dwellings surrounded by trees and agricultural fields. The dwelling nearest to the wind farm is some 500 m west of the nearest wind turbine (nr. 16). According to a German noise assessment study a maximum immission level of 43 dB(A) was expected, 2 dB below the relevant German noise limit. According to a Dutch consultancy immission levels would comply with Dutch (wind velocity dependent) noise limits.

After the farm was put into operation residents made complaints about the noise, especially at (late) evening and night. The residents, united in a neighbourhood group, could not persuade the German operator into mitigation measures or an investigation of the noise problem and brought the case to court. The Science Shop for Physics had just released a report explaining a possible discrepancy between calculated and real sound immission levels of wind turbines because of changes in wind profile, and was asked to investigate the consequences of this discrepancy by sound measurements. Although at first the operator agreed to supply measurement data from the wind turbines (such as power output, rotation speed, axle direction), this was withdrawn after the measurements had started. All relevant data therefore had to be supplied or deduced from our own measurements.

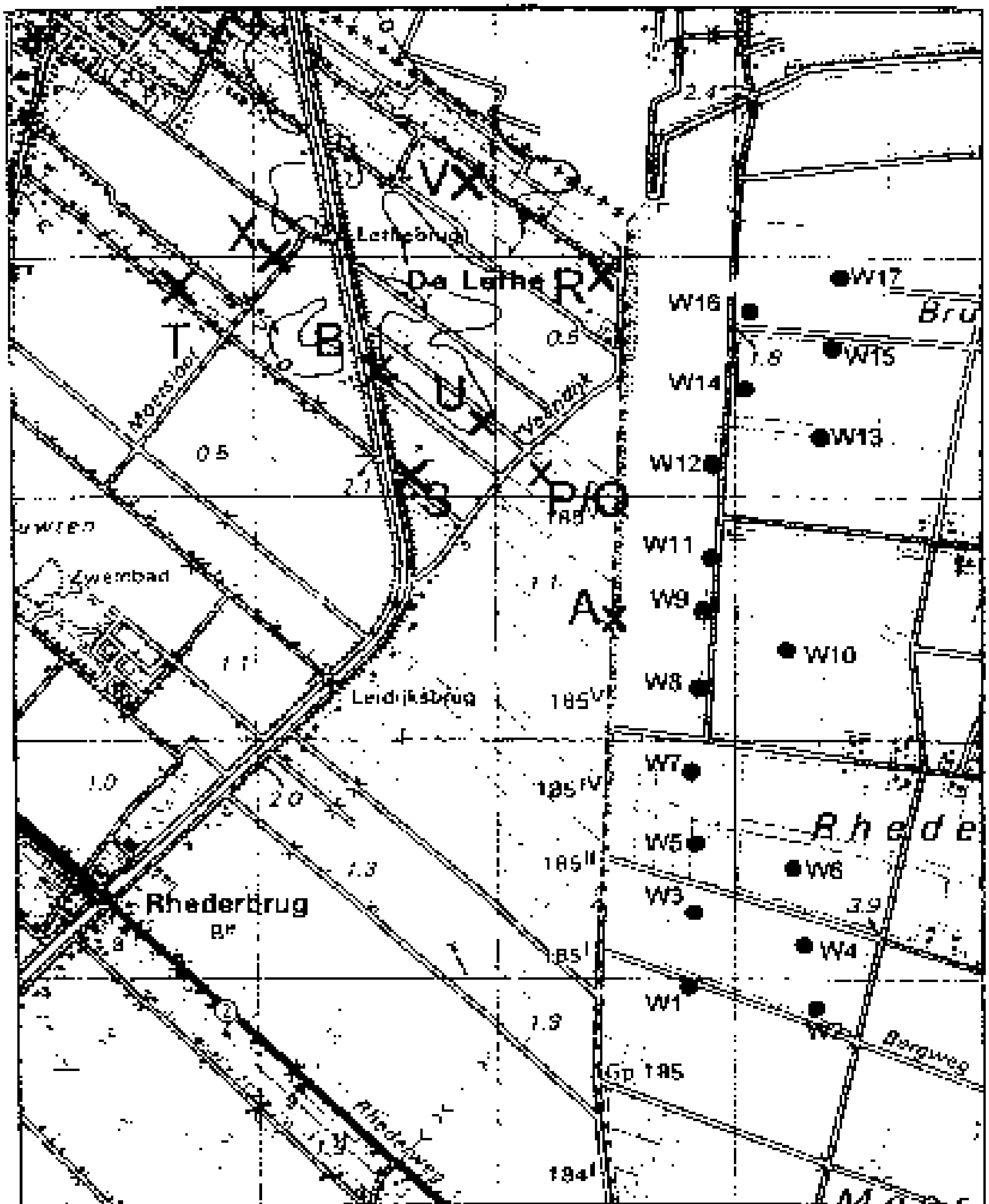


Figure IV.2: turbines (dots W1 ... W17) in and measurement locations (crosses A ... X) near the Rhede wind farm; Duch – German border indicated by line of + - + (through A); grid lines are 1 km apart, north is at top

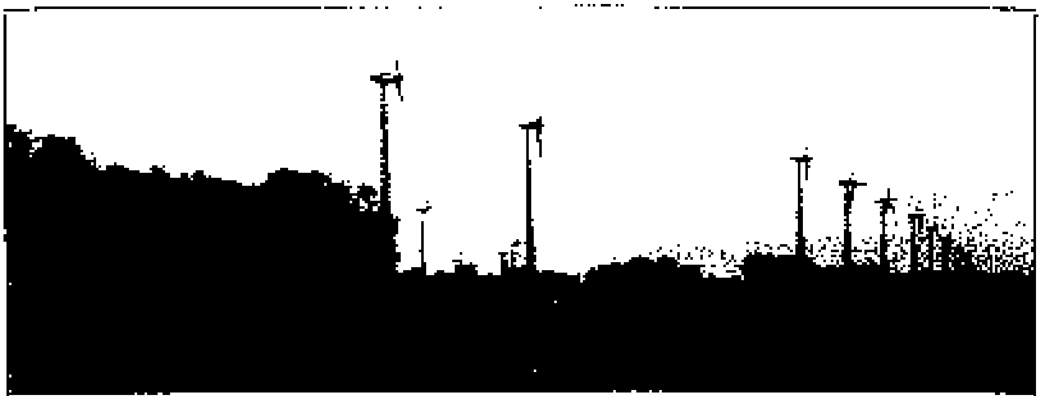


Figure IV.1: the Rhede wind farm, view from the north-northwest

IV.2 Noise impact assessment

In the Netherlands and Germany noise impact on dwellings near a wind turbine or wind farm is calculated with a sound propagation model. Wind turbine sound power levels L_W are used as input for the model, based on measured or estimated data. In Germany a single 'maximum' sound power level (at 95% of maximum electric power) is used to assess sound impact. In the Netherlands sound power levels related to wind velocities at 10 m height are used; the resulting sound immission levels are compared to wind velocity dependent noise limits (see figure VII.1). Implicitly this assessment is based on measurements in daytime and does not take into account atmospheric conditions affecting the wind profile, especially at night.

In the Netherlands a national calculation model is used [VROM 1999] to assess noise impact, as is the case in Germany [TA-Lärm 1998]. According to Kerkers [Kerkers 1999] there are, at least in the case of these wind turbines, no significant differences between both models.
In both sound propagation models the sound immission level L_{imm} at a specific observation point is a summation over j sound power octave band levels L_{Wj} of k sources (turbines), reduced with attenuation factors $D_{j,k}$:

$$L_{imm} = 10 \cdot \log [\Sigma_j \Sigma_k \, 10^{0.1(LWj - Dj,k)}] \qquad (IV.1)$$

L_{Wj}, assumed identical for all k turbines, is a function of rotational speed. D_j is the attenuation due to geometrical spreading (D_{geo}), air absorption ($D_{j\text{-}air}$) and ground absorption ($D_{j\text{-}ground}$): $D_{j,k} = D_{geo,k} + D_{j\text{-}air,k} + D_{j\text{-}ground,k}$.
Formula (IV.1) is valid for a downwind situation. For long term assessment purposes a meteorological correction factor is applied to (IV.1) to account for 'average atmospheric conditions'. When comparing calculated and measured sound immission levels in this study no such meteo-correction is applied because measurements were always downwind of a turbine or the wind farm.

IV.3 Wind turbine noise perception

There is a distinct audible difference between the night and daytime wind turbine sound at some distance from the turbines. On a summer's day in a moderate or even strong wind the turbines may only be heard within a few hundred meters and one might wonder why residents should complain of the sound produced by the wind farm. However, in quiet nights the wind farm can be heard at distances of up to several kilometers when the turbines rotate at high speed. In these nights, certainly at distances from 500 to 1000 m from the wind farm, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broad band 'noisy' sound. A resident living at 1 km from the nearest turbine says it is the rhythmic character of the sound that attracks attention: beats are clearly audible for some time, then fade away to come back again a little later. A resident living at 2.3 km from the wind farm describes the sound as 'an endless train'. In daytime these pulses are usually not audible and the sound from the wind farm is less intrusive or even inaudible (especially in strong winds because of the then high ambient sound level).
In the wind farm the turbines are audible for most of the (day and night) time, but the thumping is not evident, although a 'swishing' sound –a regular variation in sound level is readily discernible. Sometimes a rumbling sound can be heard, but it is difficult to assign it, by ear, to a specific turbine or to assess it's direction.

IV.5 Measurement instruments and method

Sound immission measurements were made over 1435 hours, of which 417 hours at night, within four months on two consecutive locations with an unmanned Sound and Weather Measurement System (SWMS) consisting of a sound level meter (type 1 accuracy) with a microphone at 4.5 m height fitted with a 9 cm diameter foam wind shield, and a wind meter at 10 m as well as at 2 m height. Every second wind velocity and wind direction (at 10 m and at 2 m height) and the A-weighted sound level were measured; the measured data were stored as statistical distributions over 5 minute intervals. From these distributions all necessary wind data and sound levels can be calculated, such as average wind velocity, median wind direction or equivalent sound level and any percentile (steps of 5%) wind velocity, wind direction or sound level, in intervals of 5 minutes or multiples thereof.

Also complementary measurements were done with logging sound level meters (type 1 and 2 accuracy) and a spectrum analyser (type 1) to measure immission sound levels in the residential area over limited periods, and emission levels near wind turbines. Emission levels were measured according to international standards [IEC 1998, Ljunggren 1997], but for practical purposes they could not be adhered to in detail: with respect to the recommended values a smaller reflecting board was used for the microphone (30·44 cm2 instead of a 1 m diameter circular board) and a smaller distance to the turbine (equal to tower height instead of tower height + blade length); reasons for this were given in Chapter II. Also it was not possible to do emission measurements with only one turbine in operation.

IV.6 Results: sound emission

Emission levels L_{eq} measured very close to the centre of a horizontal, flat board at a distance R from a turbine hub can be converted to a turbine sound power level L_W [IEC 1998, Ljunggren 1997]:

$$L_W = L_{eq} - 6 + 10 \cdot \log(4\pi \cdot R^2/A_o) \qquad \text{(IV.2)}$$

where A_o is a unit surface (1 m^2). From earlier measurements [Kerkers 1999] a wind velocity dependence of L_W was established as given in table

IV.1. As explained above, the wind velocity at 10 m height was not considered a reliable single measure for the turbine sound power, but rotational speed was a better measure.

Emission levels have been measured, typically for 5 minutes per measurement, at nine turbines on seven different days with different wind conditions. The results are plotted in figure IV.3; the sound power level is plotted as a function of rotational speed N. N is proportional to wind velocity at hub height and could be determined by counting, typically during one minute, blades passing the turbine mast. This counting procedure is not very accurate (accuracy per measurement is ≤ 2 counts, corresponding to 2/3 rpm) and is probably the dominant reason for the spread in figure IV.3. The best logarithmic least squares fit to the data points in figure IV.3 is:

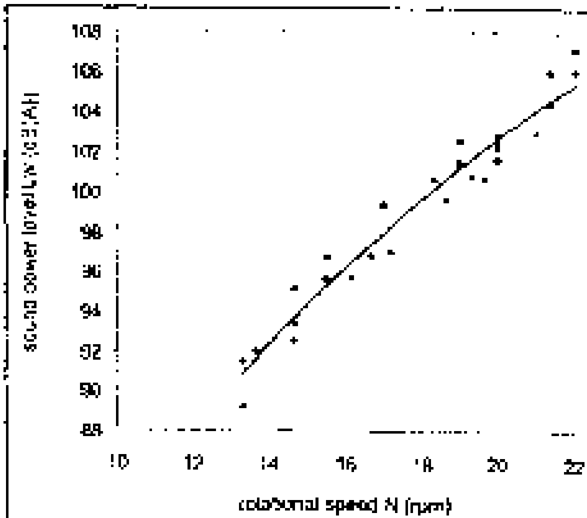


Figure IV.3: measured wind turbine sound power level L_W as a function of turbine rotational speed N

$$L_W = 67.1 \cdot \log(N) - 15.4 \text{ dB(A)} \tag{IV.3}$$

with a correlation coefficient of 0.98. The standard deviation of measurement values with respect to this fit is 1.0 dB.

Table IV.1: sound power level of wind turbines [Kerkers 1999]

wind velocity V_{10}	m/s	5	6	7	8	9	10
sound power level L_W	dB(A)	94	96	98	101	102	103

Table IV.2: octave band spectra of wind turbines at L_W = 103 dB(A)

frequency	Hz	63	125	250	500	1000	2000	4000	L_W
this report	dB(A)	82	92	94	98	98	93	88	103
[Kerkers 1999]	dB(A)	85	91	95	98	98	92	83	103

At the specification extremes of 10 rpm and 22 rpm the (individual) wind turbine sound power level L_W is 82.8 dB(A) and 105.7 dB(A), respectively. In table IV.2 earlier measurement results [Kerkers 1999] are given for the octave band sound power spectrum. Also in table IV.2 the results of this study are given: the logarithmic average of four different spectra at different rotational speeds. In all cases spectra are scaled, with formula IV.3, to the same sound power level of 103 dB(A).
To calculate sound immission levels at a specific rotational speed (or vice versa) the sound power level given in formula (IV.3), and the spectral form in table IV.2 ('this report') have been used

IV.7 Results: sound immission

The sound immission level has been measured with the unmanned SWMS on two locations. From May 13 until June 22, 2002 it was placed amidst open fields with barren earth and later low vegetation at 400 meters west of the westernmost row of wind turbines (location A, see figure IV.2). This site was a few meters west of the Dutch-German border, visible as a ditch and a 1.5 to 2 m high dike. From June 22 until September 13, 2002 the SWMS was placed on a lawn near a dwelling at 1500 m west of the westernmost row (location B), with low as well as tall trees in the vicinity. On both locations there were no reflections of turbine sound towards the microphone, except via the ground, and no objects (such as trees) in the line of sight between the turbines and the microphone. Apart from possible wind induced sound in vegetation relevant sound sources are traffic on rather quiet roads, agricultural activities, and birds. As, because of the trees, the correct (potential) wind velocity and direction could not be measured on location B, wind measurement data provided by the KNMI were used from their Nieuw Beerta site 10 km to the north. These data fitted well with the measurements on location A.

At times when the wind turbine sound is dominant, the sound level is relatively constant within 5 minute intervals. In figure IV.4 this is demonstrated for two nights. Thus measurement intervals with dominant turbine sound could be selected with a criterion based on a low variation in sound level: $L_5 - L_{95} \leq 4$ dB, where L_5 and L_{95} are the 5 and 95 percentile sound level in the measurement interval. In a normal (Gaussian) distribution this would equal σ ≤ 1.2 dB, with σ the standard deviation.

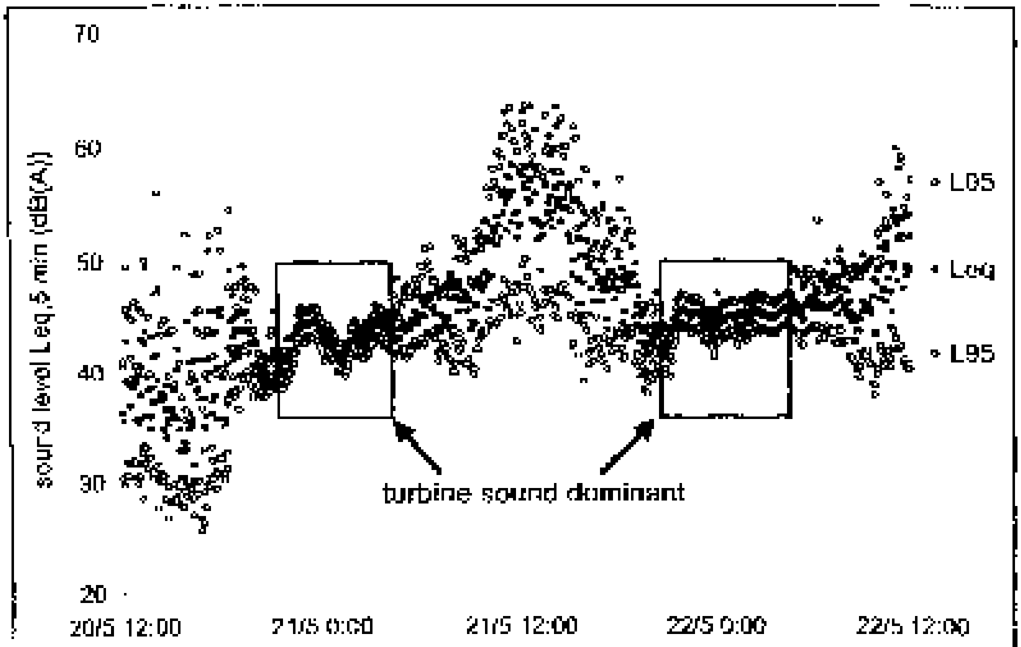


Figure IV.4: 48 hour registration of immission level (L_5, L_{eq} and L_{95}) per 5 minutes at location A; turbines are considered the dominant sound source if L_5-L_{95} ≤ 4 dB

On location A, 400 m from the nearest turbine, the total measurement time was 371 hours. In 25% of this time the wind turbine sound was dominant, predominantly at night (23:00 - 6:00 hours: 72% of all 105 nightly hours) and hardly in daytime (6:00 - 19:00 hours: 4% of 191 hours). See table IV.3.

On location B, 1500 m from the nearest turbine, these percentages are almost halved, but still the turbine sound is dominant for over one third of the time at night (38% of 312 hours). The trend in percentages agree with complaints concerning mostly noise in the (late) evening and at night and their being more strongly expressed by residents closer to the wind farm.

Table IV.3: total measurement time in hours and selected time with dominant wind turbine sound

Location	total time (hours and % of total measurement time at location)	Night 23:00-6:00	Evening 19:00-23:00	Day 6:00-19:00
A: total	371 h	105	75	191
A: selected	92 h 25%	76 72%	9 12%	7 4%
B: total	1064 h	312	183	569
B: selected	136 h 13%	119 38%	13 7%	4 0,7%

In figure IV.5 the selected (L_5-L_{95} ≤ 4 dB) 5 minute equivalent immission sound levels $L_{eq,5min}$ are plotted as a function of wind direction (left) and of wind velocity (right) at 10 m height, for both location A (above) and B (below). The KNMI wind velocity data (used for location B) were given as integer values of the wind velocity.
Also the wind velocity at 10 m and 2 m height on location A are plotted (in IV.5A and IV.5B, respectively), and the local wind velocity (influenced by trees) at 10 m on location B (IV.5C). The immission level data points are separated in two classes where the atmosphere was stable or neutral, according to observations of wind velocity and cloud cover at Eelde. Eelde is the nearest KNMI site for these observations, but it is 40 km to the west, so not all observations will be valid for our area.

In figure IV.5B a grey line is plotted connecting calculated sound levels with sound power levels according to table IV.1 (the lowest value at 2.5 m/s is extrapolated [Van den Berg *et al* 2002]), implicitly assuming a fixed logarithmic wind profile according to formula (III.2). If this line is compressed in the direction of the abscissa with a factor 2.6, the result is a (black) line coinciding with the maximum one hour values ($L_{eq,1h}$). Apparently for data points on this line the sound emission corresponds to a wind velocity at hub height that is 2.6 times higher than expected. In figure IV.6 this is given for one hour periods: all 5 minute measurement periods

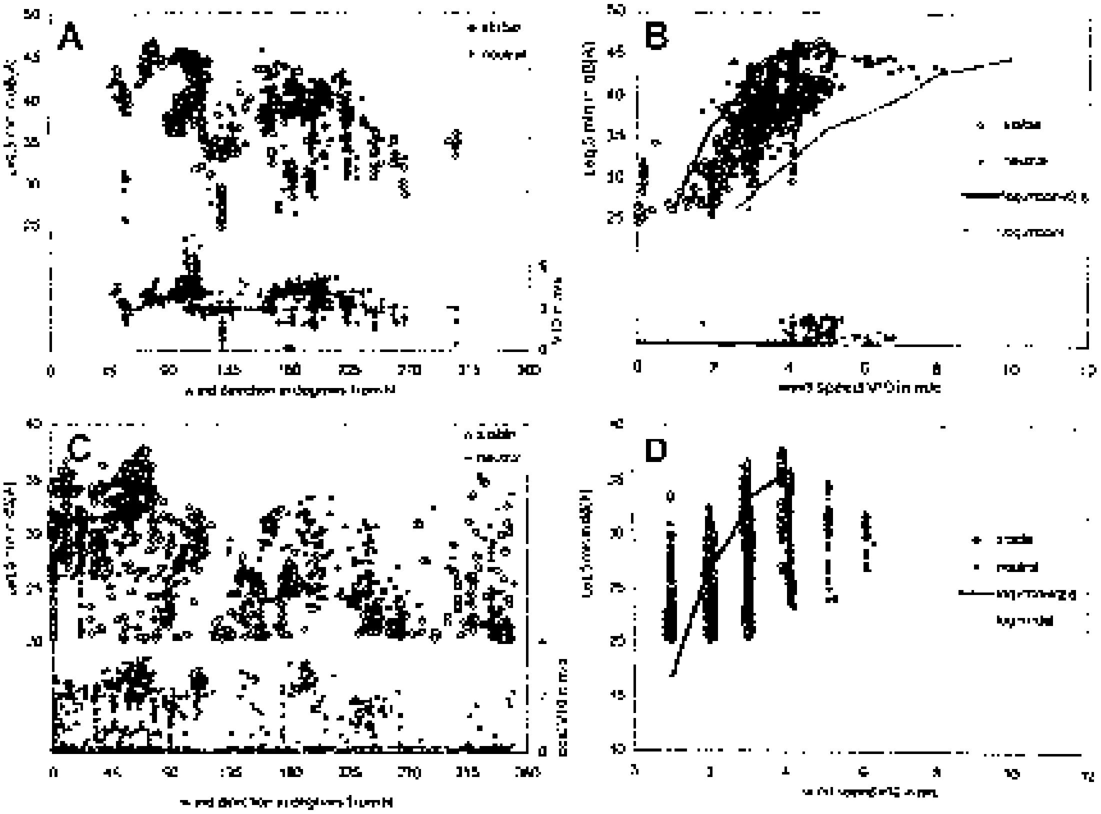


Figure IV. 5: measured sound levels $L_{eq,5\,min}$ at locations A (above) and B (below) as a function of median wind direction (left) and average wind speed (right) at reference height (10 m), separated in classes where the atmosphere at Eelde was observed as stable (open diamonds) or neutral (black dots). Also plotted are expected sound levels according to logarithmic wind profile and wind speed at reference height (grey lines in B and D), and at a 2.6 times higher wind speed (black lines in B and D). Figures A, B and C also contain the wind speed $v_{10}(A)$, v_2 (B), and the local v_{10} (C) disturbed by trees, respectively.

that satisfied the L_5-L_{95}-criterion, with at least 4 periods per hour, were taken together in consecutive hourly periods and the resulting $L_{eq,T}$ (T = 20 to 60 minutes) was calculated. The resulting 83 $L_{eq,T}$-values are plotted against the average wind velocity V_{10}. Also plotted in figure IV.6 are the expected immission levels assuming a logarithmic wind profile calculated from (III.4), with $f_{log} = (V_{98}/V_{10})_{log} = 1.4$ (for f_{ca}, see text above equation III.4); the immission levels assuming a stable wind profile with $m = 0.41$, so $f_{stable} = 2.5 = 1.8 \cdot f_{log}$; the maximum immission levels assuming $f_{max} = 3.7$

= 2.6·f_{log}, in agreement with a wind profile (III.2) with m = 0.57. The best fit of all data points ($L_{eq,T}$) in figure IV.6 is L_{eq} = 32·log(V_{10}) + 22 dB (correlation coefficient 0.80) with 1 < V_{10} < 5.5 m/s. This agrees within 0.5 dB with the expected level according to the stable wind profile. The best fit of all 5 minute data-points in figure IV.5B yields the same result.

Thus on location A the highest one hour averaged hub height wind velocities at night are 2.6 times the expected values according to the logarithmic wind profile in formula (III.4). As a consequence, sound levels at (in night-time) frequently occurring wind velocities of 3 and 4 m/s are 15 dB higher than expected, 15 dB being the vertical distance between the expected and highest one-hour immission levels at 3- 4 m/s (upper and lower lines in figures 5B and 6).

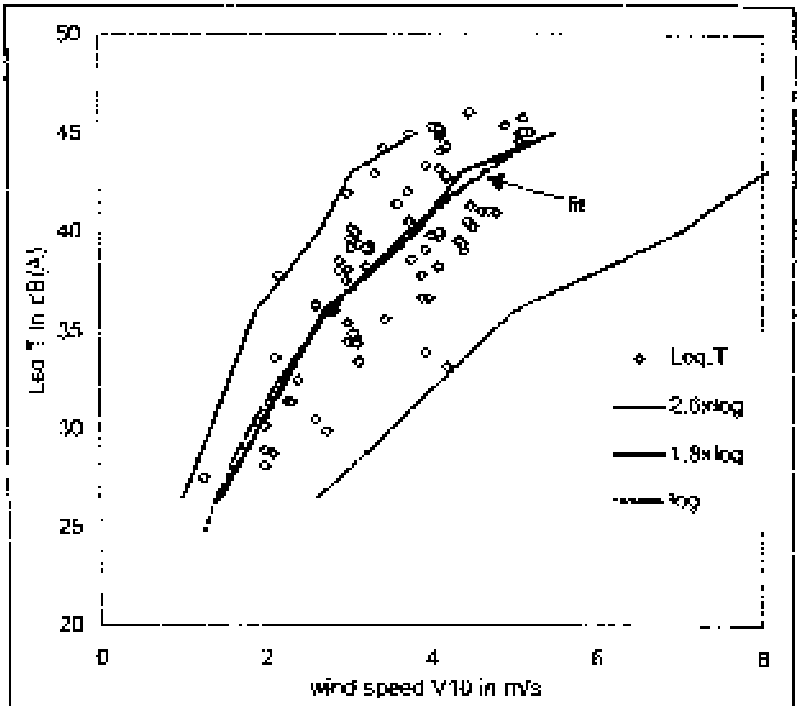


Figure IV.6: selected measured sound levels $L_{eq,T}$ (T = 20 – 60 min) at location A with best fit; and expected sound levels according to a logarithmic wind profile (v_{hh}/v_{10} = f_{log} = 1.4), a stable wind profile (v_{hh}/v_{10} = 1.8·f_{log}) and with the maximum wind speed ratio (v_{hh}/v_{10} = 2.6·f_{log})

The same lines as in figure IV.5B, but valid for location B, are plotted in figure IV.5D; immission levels here exceed the calculated levels, even if calculated on the basis of a 2.6 higher wind velocity at hub height. An explanation may be that a lower ambient sound level is necessary compared to location A to allow wind turbine sound to be dominant at location B (as selected with the $L_5 - L_{95}$ -criterion), implying a lower near ground wind velocity and thus a higher stability. It may also be caused by an underestimate of actual sound level in the calculation model for long distances, at least for night conditions (this issue will be addressed in section IV.10).

As is clear from the wind velocity at 2 m height plotted in figure IV.5B, there is only a very light wind near the ground even when the turbines rotate at high power. This implies that in a quiet area with low vegetation the ambient sound level may be very low. The contrast between the turbine sound and the ambient sound is therefore at night higher than in daytime.

Although at most times the wind turbine sound dominates the sound levels in figure IV.5, it is possible that at low sound levels, *i.e.* at low rotational speeds and low wind velocities, the L_5-L_{95}-criterion is met while the sound level is not entirely determined by the wind turbines. This is certainly the case at levels close to 20 dB(A), the sound level meter noise floor. The long term night-time ambient background level, expressed as the 95-percentile (L_{95}) of all measured night-time sound levels on location B, was 23 dB(A) at 3 m/s (V_{10}) and increasing with 3.3 dB/m·s^{-1} up to V_{10} = 8 m/s [Van den Berg *et al* 2002]. Comparing this predominantly non-turbine background level with the sound levels in figure IV.5B and 5D, it is clear that the lowest sound levels may not be determined by the wind turbines, but by other ambient sounds (and instrument noise). This wind velocity dependent, non-turbine background sound level L_{95} is, however, insignificant with respect to the highest measured levels. Thus, the high sound levels do not include a significant amount of ambient sound not coming from the wind turbines. This has also been verified in a number of evenings and nights by personal observation.

IV.8 Comparison of emission and immission sound levels

From the 30 measurements of the equivalent sound level $L_{eq,T}$ (with T typically 5 minutes) measured at distance R from the turbine hub (R typically 100√2 m), a relation between sound power level L_W and rotational speed N of a turbine could be determined: see formula (IV.3).
This relation can be compared with the measured immission sound level $L_{imm,T}$ (T = 5 minutes) at location A, 400 m from the wind farm (closest turbine), in 22 cases where the rotational speed was known. The best logarithmic fit for the data points of the immission sound level L_{imm} as a function of rotational speed N is:

$$L_{imm} = 57.6 \cdot \log(N) - 30.6 \text{ dB(A)} \qquad \text{(IV.4)}$$

with a correlation coefficient of 0.92 and a standard deviation of 1.5 dB with respect to the fit. Both relations from formulae (IV.3) and (IV.4) and the datapoints are given in figure IV.7. The difference between both relations is $L_W - L_{imm} = 9.5 \cdot \log(N) + 46.0$ dB. For the range 14 – 20 rpm, where both series have data points, the average difference is 57.9 dB, the maximum deviation from this average is 0.8 dB (14 rpm: 57.1 dB(A); 20 rpm: 58.6 dB(A); see lower part of figure IV.7). It can be shown by calculation that about half of this deviation can be explained by the variation of sound power spectrum with increasing speed N.

The sound immission level can be calculated with formula (IV.1). For location A, assuming all turbines have the same sound power L_W, this leads to $L_W - L_{imm} = 58.0$ dB. This is independent of sound power level or rotational speed, as it is calculated with a constant spectrum averaged over several turbine conditions, *i.e.* turbine speeds. The measured difference (57.9 dB) matches very closely the calculated difference (58.0 dB).

The variation in sound immission level at a specific wind velocity V_{10} in figures IV.5B and IV.5D is thus seen to correspond to a variation in rotational speed N, which in turn is related to a variation in wind velocity at hub height, not to a variation in V_{10}. At location A, N can be calculated from the measured immission level with the help of formula (IV.4) or its inverse form: $N = 3.4 \cdot 10^{L_{imm}/57.6}$.

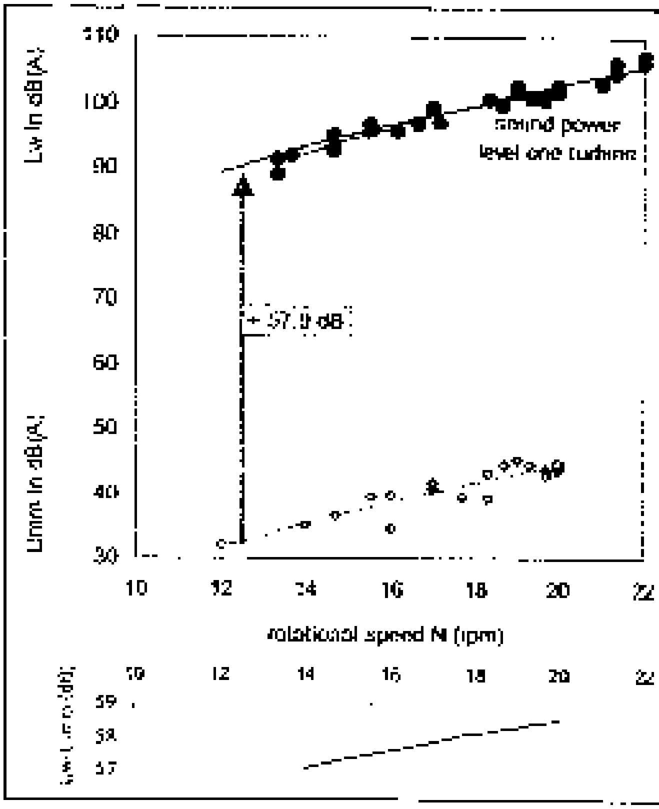


Figure IV.7: turbine sound power levels L_W measured near wind turbines and immission levels L_{imm} measured at 400 m from wind farm: averages differ 57.9 dB; (below) increase of difference L_W - L_{imm} with rotational speed

(L_W data points taken from figure IV.3)

IV.9 Atmospheric stability and Pasquill class

In figure IV.5 measurement data have been separated in two sets according to atmospheric stability in Pasquill classes, supplied by KNMI from their measurement site Eelde, 40 km to the west of our measurement site. Although the degree of stability will not always be the same for Eelde and our measurement location, the locations will correlate to a high degree in view of the relatively small distance between them. For night-time conditions 'stable' refers to Pasquill classes E and F (lightly to very stable) and corresponds to $V_{10} \leq 5$ m/s and cloud coverage $C \leq 50\%$ or $V_{10} \leq 3.5$ m/s and $C \leq 75\%$, 'neutral' (class D) corresponding to all other situations. Although from figure IV.5 it is clear that the very highest sound levels at an easterly wind (≈ 80°) do indeed occur in stable conditions, it is also clear that in neutral conditions too the sound level is higher than expected for most of the time, the expected values corresponding to the grey lines in figures IV.5B and D, derived from daytime conditions. According to this study the sound production, and thus wind velocity at 100 m height is at night often higher than expected, in a stable, but also in a neutral atmosphere. On the other hand, even in stable conditions sound levels may be lower than expected (i.e. below the grey lines), although this occurs rarely. It may be concluded from these measurements that a logarithmic wind profile based only on surface roughness does not apply to the night-time atmosphere in our measurements, not in a stable atmosphere and not always in a neutral atmosphere when determined from Pasquill classes.

IV.10 Additional measurements

In several nights in the period that the SMWS was measuring at location A, manual measurements were performed at a number of locations in the area between 0.6 and 2.3 km west of the wind farm. The locations are plotted in figure IV.2. Most locations were close to dwellings, but two (locations U and X) were in open fields. Locations P and Q are close and at the same distance from the western row of turbines and can be considered equal with respect to the turbines (Q was chosen instead of P as P was at the verge of a garden with a loud bird chorus in the early morning). The surface of most of the area is covered with grass and low crops, with trees at some places.
For these measurements one or more logging sound level meters (accuracy type 1 or 2) were used simultaneously, storing a broad band A-weighted sound pressure level every second. Before and after measurement the meters were calibrated with a 94.0 dB, 1000 Hz calibration source, and as a result measurement accuracy due to the instruments is within 0.2 dB. On every location the microphone was in a 10 cm spherical foam wind screen approximately 1.2 m above the surface. There were no reflections of the wind turbine sound to the microphone, except via the ground.

IV.10.1 Measured and calculated immission sound levels

Figure IV.8 gives a simultaneous registration from just before midnight on May 17, 2002, till noon on May 18, of the equivalent sound pressure levels per 5 minutes at locations A (from the SWMS), P/Q and U (from the manual meters) at distances to the westernmost row of turbines of 400, 750 and 1050 m, respectively. In the night hours the sound of the turbines was dominant at each of these locations, apart from an occasional bird or car. Also plotted in figure IV.8 are the wind velocity at 2 and 10 m heights at location A.

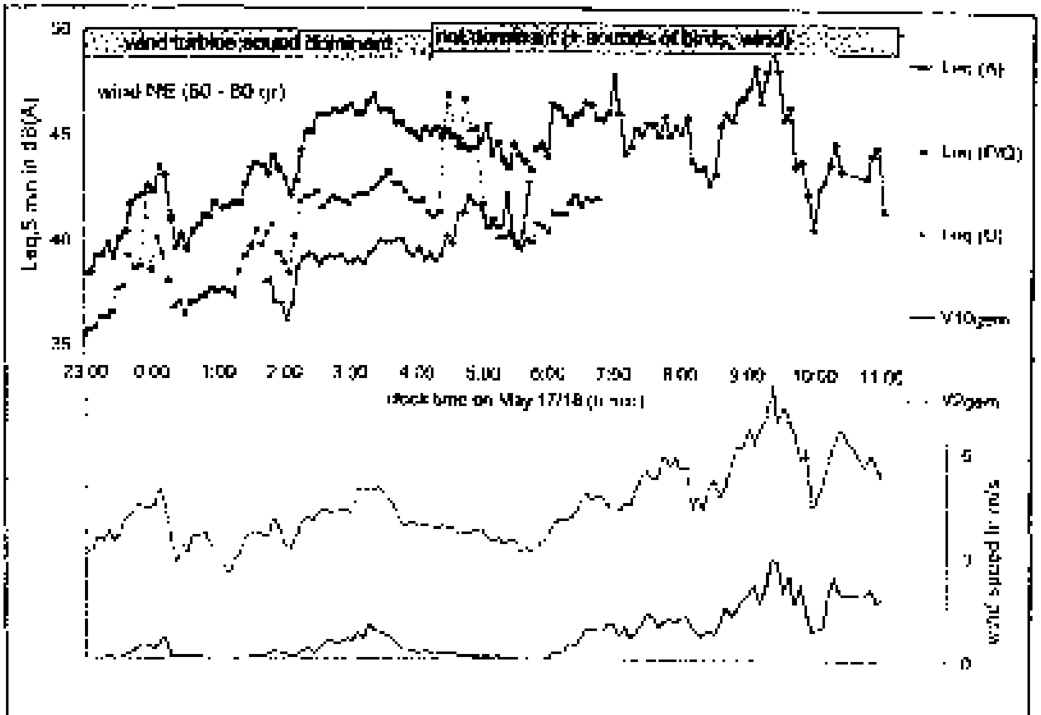


Figure IV.8: measured sound immission level ($L_{eq,5min}$) at locations A, P/Q, and U, and wind velocities at A with an eastnortheasterly wind

A short decrease in wind velocity at around 2:00 is apparently accompanied by a similar decrease in wind velocity at hub height, as the sound level varies much in the same way. However, the registrations show that the sound level increases from 0:30 until 6:00 while the 10-m wind velocity does not show a net increase in this period. In fact the sound level at location A at 3:00 implies a rotational speed of 21 rpm, which is just below maximum (22 rpm), even though the wind velocity at 10 m height is

only 4.5 m/s and at 2 m height is less than 1 m/s. Only occasionally there are other sounds until the dawn chorus of birds just after 4:00 and after that the near-ground wind picks up.
In figure IV.9 the 5-minute equivalent sound levels at P/Q and U relative to the sound level at A are plotted. The advantage of taking the sound level at A as a reference value is that it is not necessary to know the exact sound power level of the turbines themselves. The level differences are 3.5 and 6.5 dB, respectively, with a variation of ± 1 dB. The variations must be due to differences in sound propagation mostly, because other disturbances (such as one at 23:55 at P) are rare.

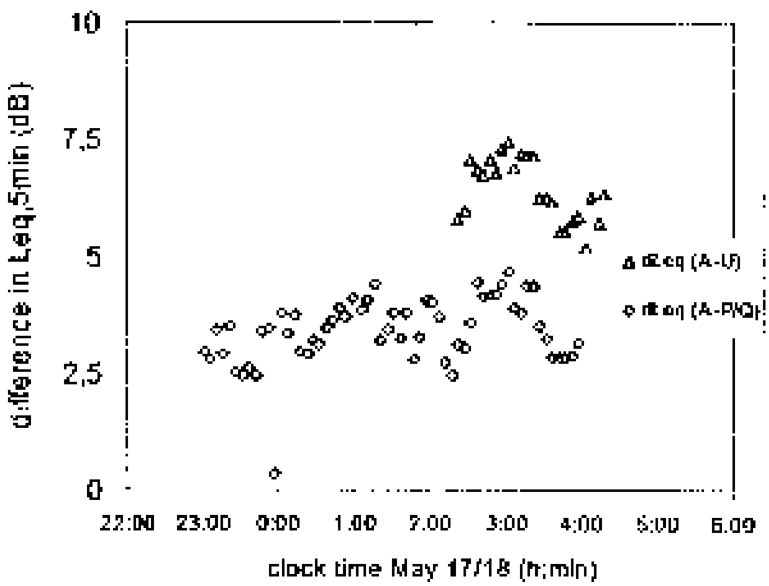


Figure IV.9: difference between simultaneously measured broad band A-weighted immission levels at locations U and P/Q and at location A

Comparable simultaneous measurements have been made in the night of June 2 - 3 and of June 17 - 18, 2002. In Appendix C the registrations are given, as well as the level differences between the distant locations P through T, V and X and the reference location A. The measured and calculated decrease in sound level with distance, relative to location A, as well as the discrepancy between both, are given in table IV.4 and figure IV.10. In all cases the wind was easterly (60° - 100°), that is: from the wind farm to the measurement location. Also there was little near-ground wind and low background sound levels from other sources.

The calculated differences have been determined with equation IV.1 and the Dutch national model [VROM 1999]. The measured differences in table IV.4 are the difference in the equivalent sound level at a location minus the same at location A over the given measurement time T; only very few of the $L_{eq,5min}$ values were omitted from this Leq,T because they were apparently disturbed by another sound. To minimize influence of possible disturbing sounds the median of all $L_{eq,5min}$ values can be used, as this value gives the prevailing difference and is thus less sensitive to the influence of disturbances; this, however, yields the same results within 0.5 dB.

The discrepancies between measured and calculated levels are small, especially considering the large distances involved: -0.2 to 1.5 dB. One may conclude that the calculation model is quite satisfactory in this relatively simple situation (a high sound source above flat ground).

Table IV.4: measured and calculated differences in sound level $L_{eq,T}$ at locations R - T and at location A, when wind blows from the wind farm

location	R	P/Q	U	V	S	X	T
distance to western row wind farm (m)	600	750	1000	1100	1250	1900	2250
date of measurement (in 2002)	June 2/3	May 17/18, June 2/3 + 18	May 17/18	June 18	June 2/3	June 18	June 2/3
measurement time T (min.)	200	295+200+115	120	140	190	85	195
measured difference	-3.5	-3.8 *	-6.4	-9.1	-8.5	-12.1	-1.3
calculated difference	-4.5	4.1	-6.6	-10.6	-8.3	13.1	14.2
discrepancy calculation - measurement	1.0	-0.3	-0.2	-1.5	0.2	-1.0	-12.9

*: measurement time weighted logarithmic average of resp. 3.5, 3.6 and 4.6 dB

In figure IV.10 a line is plotted corresponding to $-20 \cdot \log(R/R_0)$, where R_0 is the distance from A to the western turbine row. This decrease corresponds to spherical divergence from a point source only, with no attenuation due to absorption. It is clear that, with the exception of location T (see next section), the measured decrease is close to this spherical divergence: the measured values at the locations P/Q, U, S and X are 1.4 to 1.7 dB above the plotted line, at the more northern locations R and V they are 0 to 0.3 dB below the line. Approximately the same is true for the calculated levels: the calculated values at the locations P/Q, U, S and X are 0.4 to 1.6 dB above the plotted line, at the more northern locations R and V they are 1.0 to 1.8 dB below the line.

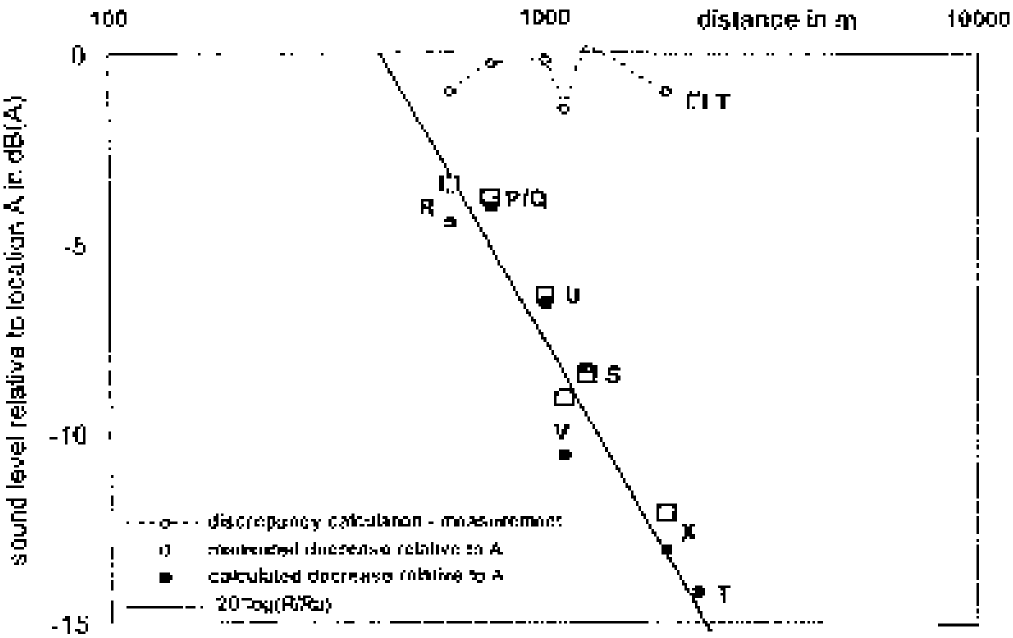


Figure IV.10: measured and calculated decrease in immission sound level due to the wind farm at locations P through X relative to location A, and the discrepancy between both; the straight line corresponds to $-20 \cdot \log(R/R_0)$

There are two counteracting causes explaining this apparently 'almost spherical' attenuation. The first is that the wind farm cannot be considered a point source. Due to its large dimension (3 km from south to north, see figure IV.2) normal to the shortest distance from location A and locations further west. the geometrical divergence should be between cylindrical and spherical divergence, that is: proportional to $-X \cdot \log(R/R_A)$, with $10 < X < 20$. Secondly one expects a decrease due to absorption ('excess attenuation') above the decrease due to geometrical divergence: for the Rhede turbines calculation shows that this excess attenuation is expected to be 1.7 dB per km.

IV.10.2 Immission level increase due to inversion layer?

In the night of June 2 to 3, 2002, high sound levels were measured at the most distant measurement location T, 2250 m from the wind farm. The immission sound level varied between approximately 40 and 45 dB(A) and was more variable than at the other locations (see Appendix C). The resident close to this measurement location could hear the wind farm well, at 22:30 hours describing it as: "The sound changes from 'an endless train' to a more pulsating sound; the sound grows louder en sharper. At the background is a kind of humming, comparable to the sound of a welding transformer". The sound was audible indoors.

In our research we have not met this phenomenon again. However, mr. Flight living near another wind farm south of the Rhede wind farm observed the same phenomenon: on a location appr. 750 m from the closest turbine, where at night he usually measured an immission level of 42 to 44 dB(A), he measured a level of 50 to 52 dB(A) in the night of September 24, 2002. It was clear that the sound came from the nearest wind farm, but also from a second, more distant wind farm that usually was not audible here. Again, the atmosphere was stable and there was a weak near-ground easterly wind, blowing from the wind farm to the observer.

This may be a result of strong refraction of sound below an inversion layer. This inversion layer must be at or above the rotor to have the highest effect, so at or above 130 m (= hub height + blade length).
Suppose the turbines in the Rhede wind farm each have a sound power level L_W at a certain wind velocity. If we substitute the entire farm by one single turbine at the site of the turbine closest to location T (nr. 12), it can be calculated that the sound level of that single turbine must be L_W + 9.4 to produce the same immission level at T as the entire wind farm.

Considering only spherical spreading, this immission level is $L_{imm} = L_W + 9.4 - 10 \cdot \log(4\pi \cdot 2250^2) = L_W - 68.6$. Now the sound waves will be refracted downwards at the inversion layer and we assume that all sound propagates below the inversion layer. At large distances (>> height inversion layer) this is equivalent to sound spreading cylindrically from a vertical line source. To simulate this we replace the substitute single turbine, which was modelled as a point source at hub height, by a vertical line source from the ground up to the inversion layer height (130 m). If the sound power levels of both point and line source are equal, the line source must have a sound power level of $L_W' = L_W + 9.4 - 10 \cdot \log(130) = L_W - 11.7$ dB/m. If again the sound level decreases by geometrical (now: cylindrical) spreading only, the sound immisson level at 2250 m from this line source is $L_{imm}' = L_W - 11.7 - 10 \cdot \log(2\pi \cdot 2250) = L_W - 54.6$ dB. Comparison of the immission level due to a point source ($L_W - 68.6$) and a line source ($L_W - 54.6$) shows that the line source causes a 14 dB higher immission level. This simple calculation shows that the rise in level caused by a simplified high inversion layer is close to the observed increase (13 dB): the higher level is a result of the sound being 'trapped' below the inversion layer. However, more observations and data are needed to verify this hypothesis.

IV.11 Conclusion

Sound immission measurements have been made at 400 m (location A) and 1500 m (location B) from the wind farm Rhede with 17 tall (98 m hub height), variable speed wind turbines. It is customary in wind turbine noise assessment to calculate immission sound levels assuming wind velocities based on wind velocities V_{10} at reference height (10 m) and a logarithmic wind profile. Our study shows that the immission sound level may, at the same wind velocity V_{10} at 10 m height, be significantly higher in night-time than in daytime. A 'stable' wind profile predicts a wind velocity V_h at hub height 1.8 times higher than expected and agrees excellently with the average measured night-time sound immission levels. Wind velocity at hub height may still be higher: at low wind velocities V_{10} up to 4 m/s, the wind velocity v_h is at night up to 2.6 times higher than expected.

Thus, the logarithmic wind profile, depending only on surface roughness and not on atmospheric stability, is not a good predictor for wind profiles at night. Especially for tall wind turbines, estimates of the wind regime at hub height based on the wind velocity distribution at 10 m, will lead to an underestimate of the immission sound level at night: at low wind velocities (V_{10} < 5 m/s) the actual sound level will be higher than expected for a significant proportion of time. This is not only the case for a stable atmosphere, but also -to a lesser degree- for a neutral atmosphere.

The change in wind profile at night also results in lower ambient background levels then expected: at night the wind velocity near the ground may be lower than expected from the velocity at 10 m and a logarithmic wind profile, resulting in low levels of wind induced sound from vegetation. The contrast between wind turbine and ambient sound levels is therefore at night more pronounced.

Measured immission sound levels at 400 m from the nearest wind turbine almost perfectly match (average difference: 0,1 dB) sound levels calculated from measured emission levels near the turbines. From this it may be concluded that both the emission and immission sound levels could be determined accurately, even though the emission measurements were not fully in agreement with the standard method. As both levels can be related through a propagation model, it may not be necessary to measure both: the immission measurements can be used to assess immission as well as emission sound levels.
At greater distances the calculated level may underestimate the measured level, but considering the distances involved (up to 2 km) the discrepancy is small: 1.5 dB or less.

In one night the sound level at a distant location (over 2 km from the wind farm) was much higher than expected, perhaps because of an inversion layer adding more downward refracted sound. It apparently is a rare occurrence at the Rhede wind farm, and could be more significant where high inversion layers occur more often.

V THE BEAT IS GETTING STRONGER: low frequency modulated wind turbine sound

V.1 Effects of atmospheric stability

Atmospheric stability is not only relevant for wind turbine sound *levels*, as we saw in the preceding chapter, but also for the *character* of the sound. In conditions where the atmosphere is stable, distant wind turbines can produce a beating or thumping sound that is not apparent in daytime.

The magnitude of the effects of increasing stability depends on wind turbine properties such as speed, diameter and height. We will use the dimensions of the wind turbines in the Rhede wind farm, that are typical for a modern variable speed 2 MW wind turbine: hub height 100 m, blade length 35 m and blade tip speed increasing with wind velocity up to a maximum value of $\Omega \cdot R = 81$ m/s (at 22 rpm). Here a speed of 20 rpm (70 m/s) will be used as this was typical for situations where at the Rhede wind farm a clear beating sound was heard.

We will assume the optimum angle of attack α is 4°. The change in trailing edge (TE) sound pressure level SPL_{TE} with the angle of attack from this optimum up to 10° can be approximated by $\Delta SPL_{TE}(\alpha) = 1.5 \cdot \alpha - 1.2$ dB or $d(\Delta SPL_{TE})/d\alpha = 1.5$ (see appendix B, equation B.8). When the pitch angle is constant, the change in angle of attack due to a variation dV in wind velocity is $d\alpha = 0.84 \cdot dV$ (see appendix B, equation B.9).

To calculate vertical wind velocity gradients the simple engineering formula (III.1) will be used: $V_h = V_{ref}(h/h_{ref})^m$ (see section III.2). In the text below we will use a value $m = 0.15$ for a daytime atmosphere (unstable – neutral), $m = 0.4$ for a stable, and $m = 0.65$ for a very stable atmosphere (see table III.1).[1] These values will be used for altitudes between 10 and 120 m.

[1] A value $m = 0.65$ is not obvious from table III.1, but is chosen as a relatively high value that is exceeded for a small part of the time (see figures VI.6 and VI.16, and section VI.6)

There are now three factors influencing blade swish level when the atmosphere becomes more stable: a) the higher wind velocity gradient, b) the higher wind direction gradient, and c) the relative absence of large scale turbulence.

a. Wind velocity gradient. Rotational speed is determined by a rotor averaged wind velocity, which here is assumed to be the induced wind velocity at hub height (equation III.5). The free, unobstructed wind at height h is denoted by V_h, the induced wind speed at the blade by $V_{h,b}$. With increasing atmospheric stability the difference in wind velocity between the upper and lower part of the rotor increases. As in a complete rotation the pitch angle is constant the change in angle of attack due to a change in induced wind velocity is $d\alpha = 0.82 \cdot dV_{h,b}$ which can be expressed in a change of the free wind velocity by $d\alpha = 0.82 \cdot (2/3) \cdot dV_h = 0.55 \cdot dV_h$ (see equation III.5).

Suppose that the free wind velocity at hub height is V_{100} = 14 m/s, corresponding to V_{10} = 9.8 m/s in a neutral atmosphere in flat open grass land (roughness length 5 cm). Then in daytime (m = 0.15) the free wind velocity at the height of the lowest point of the rotor would be V_{65} = 13.1 m/s, at the height of the highest point V_{135} = 14.6 m/s (corresponding to velocities at the blade of $V_{65,b}$ = 8.7 m/s and $V_{135,b}$ = 9.7 m/s, respectively). The difference of 1.0 m/s between the low tip and hub height wind velocities causes a change in angle of attack on the blade of $\Delta\alpha$ = 0.55°. Between the high tip and hub height the change is smaller and of opposite sign: -0.3°. In a stable atmosphere (m = 0.4), at the same wind velocity at hub height, V_{65} is 11.8 m/s causing a change in angle of attack at the lower tip relative to hub height of 1.2° (at the high tip: V_{135} = 15.8 m/s, $\Delta\alpha$ = -1.0°). When the atmosphere is very stable (m = 0.65), wind velocity V_{65} = 10.5 m/s and the angle of attack on the low altitude tip deviates 1.9° from the angle at hub height (at the high tip: V_{135} = 17.0 m/s, $\Delta\alpha$ = -1.7°).
In fact when the lower tip passes the tower there is a greater mismatch between optimum and actual angle of attack α because there was already a change in angle of attack related to the wind velocity deficit in front of the tower. For a daytime atmosphere and with respect to the situation at hub

height, the change in α associated to a blade swish level of 2 ± 1 dB is estimated as 1.8 ± 1.1° (see appendix B.3), part of which (0.55 °) is due to the wind profile and the rest to the tower. The increase in α due to the stability related wind profile change must be added to this daytime change in α. Thus, the change in angle of attack when the lower tip passes the mast is 1.8 ± 1.1° in daytime (unstable to neutral atmosphere), increasing to 2.5 ± 1.1° in a stable atmosphere and to 3.2 ± 1.1° in a very stable atmosphere. The associated change in TE sound level is 3.8 ± 1.7 dB for a stable and 4.8 ± 1.7 dB for a very stable atmosphere (compared to 2 ± 1 dB in daytime), which is the increase when the blade passes the tower. The corresponding total A-weighted sound level will be somewhat less as trailing edge sound is not the only sound source (but it is the dominant source; see section V.2.3).
At the high tip the change in angle of attack is smaller and of opposite sign with respect to the low tip, and also there is no (sudden) tower induced change to add to the wind gradient dependent change. The change in angle of attack at the high tip in a very stable atmosphere (-1.7°) is comparable to the change at the low tip in daytime, and this change is more gradual than for the low tip. This in fact lowers the sound emission from the high tip (with approximately 2 dB), most so when the high blade is vertical so just before and just after the low blade passes the tower, thereby in fact increasing the variation in swish sound level even more.

Thus we find that, for v_{100} · 14 m/s, the 1-2 dB daytime blade swish level increases to approximately 5 dB in a very stable atmosphere. The effect is stronger when wind velocity increases, up to the point where friction turbulence overrides stability and the atmosphere becomes neutral. The increase in trailing edge sound level will be accompanied by a lower peak frequency (see appendix B, equation B.2). For $\Delta\alpha$ = 5° the shift is one octave.

b. Wind direction gradient. In a stable atmosphere air masses at different altitudes are only coupled by small scale turbulence and are therefore relatively independent. Apart from a higher velocity gradient a higher wind direction gradient is also possible, and with increasing height the wind direction may change significantly. This wind direction shear will change the angle of attack with height. Assuming the wind at hub height to be normal to the rotor, the angle of attack will decrease below and increase above hub height (or vice versa). This effect, however, is small: if we suppose a change in wind direction of 20° over the rotor height at an induced wind velocity of 10 m/s, the change in angle of attack between extreme tip positions at 20 rpm is only 0.25°, which is negligible relative to the wind velocity shear.

c. Less turbulence. In a stable atmosphere turbines in a wind farm can run almost synchronously because the absence of large scale turbulence leads to less variation superimposed on the constant (average) wind velocity at each turbine. In unstable conditions the average wind velocity at the turbines will be equal, but instantaneous local wind velocities will differ because of the presence of large, turbulent eddies at the scale of the inter-turbine distance. In a stable atmosphere the turbulence scale decreases with a factor up to 10, relative to the neutral atmosphere and even more relative to an unstable atmosphere [Garratt 1992]. In stable conditions turbines in a wind farm therefore experience a more similar wind and as a consequence their instantaneous speeds are more nearly equal. This is confirmed by long term measurements by Nanahara *et al.* [2004] who analysed coherence of wind velocities between different locations in two coastal areas. At night wind velocities at different locations were found to change more coherently than they did at daytime [Nanahara 2004]. The difference between night and day was not very strong, probably because time of day on its own is not a sufficient indicator for stability.[1] The decay of coherence was strongly correlated with turbulence intensity, which in turn is closely correlated to stability.

Thus several turbines can be *nearly* synchronous: sometimes two or more turbines are in phase and the blade passing pulses coincide, then they go out of phase again. Synchronicity here refers to the sound pulses from the

[1] In a coastal location atmospheric stability also depends on wind direction as landwards stability is a diurnal, but seawards a seasonal phenomenon. Also, a fixed duration for all nights in a year does not coincide with the time that the surface cools (between sundown and sunrise), which is a prerequisite for stability.

different turbines as observed at the location of the observer: pulses synchronise when they arrive simultaneously. This is determined by differences in phase (rotor position) between turbines and in propagation distances of the sound from the turbines. Phase differences between turbine rotors occur because turbines are not connected and because of differences in actual performance. The place where synchronicity is observed will change when the phase difference between turbines changes. With exact synchronicity there would be a fixed interference pattern, with synchronicity at fixed spots. However, because of *near*-synchronicity, synchronous arrival of pulses will change over time and place and an observer will hear coinciding pulses for part of the time only.
Near a wind farm the variation in sound level will depend on the distances of the wind turbines relative to the observer: the level increase due to several turbines will reach higher levels when more turbines are at approximately equal distances and thus contribute equal immission levels. The increase in level variation, or beating, is thus at well-audible frequencies and has a repetition rate equal to the blade passing frequency.

A second effect of the decrease in turbulence strength is that in-flow turbulent sound level also decreases. The resulting decrease in sound level at frequencies below that of TE noise lowers the minimum in the temporal variations, thereby increasing modulation depth. The higher infrasound level due to extra blade loading is not perceptible because of the high hearing threshold at the very low blade passing frequency and its harmonics.
Thus, theoretically it can be concluded that in stable conditions (low ambient sound level, high turbine sound power and higher modulation or swish level) wind turbine sound can be heard at greater distances where it is of lower frequency due to absorption and the frequency shift of swish sound. It will thus be a louder and more low frequency 'thumping' sound and less the swishing sound that is observed close to a daytime wind turbine.

V.2 Measurement results

V.2.1 Locations

In the summer of 2002 and of 2004 wind turbine sound has been recorded in and near the Rhede wind farm (see section IV.1 for a specification of the turbines and a map of the area). In this chapter measurement results will be used from two locations: R and P (see figure IV.2). Location R is close to a dwelling west of the turbines, 625 m from the nearest turbine. The microphone position was at 4 m height and close to the house, but with no reflections except from the ground. Location P, 870 m south of R, was 1.5 m above a paved terrace in front of the façade of a dwelling at 750 m distance from the nearest turbine (in fact this is a short distance from the location P in chapter IV, which was not in front of the façade). The entire area is quiet, flat, agricultural land with some trees close to the dwellings. There is little traffic and there are no significant permanent human sound sources.

A third dwelling Z is in Boazum in the northern part of the Netherlands, 280 m west of a single, two-speed turbine (45 m hub height, 23 m blade length, 20/26 rpm). The area is again quiet, flat and agricultural, with some trees close to the dwelling. The immission measurement point is at 1.5 m height above gravel near dwelling Z. This measurement site is included here to show that the influence of stability on blade swish levels occurs also with smaller and single turbines. At all locations near dwellings the microphone was fitted in a 9 cm diameter foam wind screen.

Table V.1 gives an overview of measurement (start) time and date, of observed turbine speed and of wind velocity and direction, for situations of which results will be given below. The wind velocity at hub height V_{hub} has been determined from turbine rotation speed N or sound power level L_W (figure III.3, the relation V_{hub} N follows from [Kerkers 1999] and [Van den Berg 2002]). The wind velocity V_{10} was continuously measured at or near location A, except for location Z, where data from several meteorological stations were used showing that the wind was similar and nearly constant throughout the night of the measurement in the entire nothern part of the Netherlands. In all cases there were no significant variations in wind velocity at the time of measurement. Wind velocity at the microphone was lower than V_{10} because of the low microphone height and shelter provided by trees nearby. Wind direction is given in degrees relative to north and clockwise (90° is east).

The spectra near a turbine were measured with the microphone just above a hard surface at ground level 100 m downwind of a turbine in compliance with IEC 61400 [IEC 1998] as much as possible (non-compliance did not lead to differences in result; for reasons of non-compliance, see section II.4). The levels presented here are broad band immission levels: measured L_{eq} minus 6 dB correction for coherent reflection against the hard surface [IEC 1998]. The presented levels near the dwellings are also broad band immission levels: measured L_{eq} minus 3 dB correction for incoherent reflection at the façade for dwelling P, or measured L_{eq} without any correction for dwellings R and Z.

Table V.1: overview of measurement locations and times and of turbine speed and wind

Location	measurement date	measurement time	turbine speed (rpm)	wind velocity (m/s) V_{10}	wind velocity (m/s) V_{hub}	wind direction (° north)
Dwelling P	June 3, 2002	00:45	20	5	14	100
Turbine 7	June 3, 2002	06:30	19	5	15	100
Turbine 1	June 3, 2002	06:45	19	5	15	100
Dwelling R	Sep.9, 2004	23:07	18	4	14	80
Turbine 16						
Dwelling Z	Oct.18, 2003	01:43	26	3	6	60

At dwelling P at the time of measurement the beat in the turbine sound was very pronounced. In the other measurements (dwellings R and Z) the beating was not as loud. The measurements near turbine 16 and dwelling R at 23:07 on September 9 were performed simultaneously.

V.2.2 Frequency response of instruments

For the Rhede measurements in this chapter sound was recorded on a TASCAM DA-1 DAT-recorder with a precision 1" Sennheiser MKH 20

P48 microphone. The sound was then sampled in 1-second intervals on a Larson Davis 2800 frequency analyser. From 1 to 10 000 Hz the frequency response of the DAT-recorder and LD2800 analyser have been determined with a pure tone electrical signal as input. The LD2800 response is flat (±1 dB) for all frequencies. The DAT-recorder is a first order high pass filter with a corner frequency of 2 Hz. The frequency response of the microphone was of most influence and has been determined relative to a B&K ½" microphone type 4189 with a known frequency response [B&K 1995]. Equivalent spectral sound levels with both microphones in the same sound field (10 cm mutual distance) were compared. For frequencies of 2 Hz and above the entire measurement chain is within 3 dB equivalent to a series of two high pass filters with corner frequencies of f_1 = 4 Hz and f_2 = 9 Hz, or a transfer function equal to $-10\cdot\log[1+(f_1/f)^2]$ $-10\cdot\log[1+(f_2/f)^2]$. For frequencies below 2 Hz this leads to high signal reductions (< -40 dB) and consequentially low signal to (system) noise ratios. Therefore values at frequencies < 2 Hz are not presented.

For the Boazum measurements sound was recorded on a Sharp MD-MT99 minidisc recorder with a 1" Sennheiser ME62 microphone. The frequency response of this measurement chain is not known, but is assumed to be flat in the usual audio frequency range. Simultaneous measurement of the broad band A-weighted sound level were done with a precision (type 1) 01dB sound level meter. Absolute precision is not required here as the minidisc recorded spectra are only used to demonstrate relative spectral levels. Because of the ATRAC time coding of a signal, a minidisc recording does not accurately follow a level change in a time interval < 11.6 ms. This is insignificant in the present case as the 'fast' response time of a sound level meter is much slower (125 ms).

V.2.3 Measured emission and immission spectra

Recordings were made at evening, night or early morning. On June 3, 2002, sound was recorded at dwelling P at around midnight and early in the morning near two turbines (numbers 1 and 7 in figure IV.1). At P at these times a distinct beat was audible in the wind turbine sound. In figure V.1, 1/3 octave band spectra of the recorded sound at P and at both turbines have been plotted. In each figure A, B and C, 200 sound pressure spectra sampled in one-second intervals, as well as the energy averaged spectrum of the 200 samples have been plotted. The standard deviation of 1/3 octave band levels is typically 7 dB at very low frequencies, decreasing to approx. 1 dB at 1 kHz. The correlation coefficient ρ between all 200 unweighted 1/3 octave band levels and the overall A-weighted sound level has also been plotted for each 1/3 octave band frequency.

For frequencies below approximately 10 Hz the sound is dominated by the thickness sound associated with the blade passing frequency and harmonics. In the rest of the infrasound region and upwards, in-flow turbulence is the dominant sound producing mechanism. Gradually, at frequencies above 100 Hz, trailing edge sound becomes the most dominant source, declining at high frequencies of one to several kHz. Trailing edge sound is more pronounced at turbine 1 (T1) compared to turbine 7 (T7), causing a hump near 1000 Hz in the T1 spectra. At very high frequencies (> 2 kHz) sometimes spectral levels are influenced by birds'sounds.

It is clear from the spectra that most energy is found at lower frequencies. However, most of this sound is not perceptible. To assess the infrasound level relevant to human perception it can be expressed as a G-weighted level [ISO 1995], With G-weighting sound above the infrasound range is suppressed. The average infrasound perception threshold is 95 dB(G) [Jakobsen 2004]. The measured G-weighted levels are 15-20 dB below this threshold: 80.5 and 81.1 dB(G) near turbines 1 and 7 respectively, and 76.4 dB(G) at the façade.

The correlations show that variations in total A-weighted level near the turbines are correlated with the 1/3 octave band levels with frequencies from 400 through 3150 Hz (where ρ > 0.4), which is trailing edge sound. This is one octave lower (200 - 1600 Hz) for the sound at the façade; the higher frequencies were better absorbed during propagation through the atmosphere.

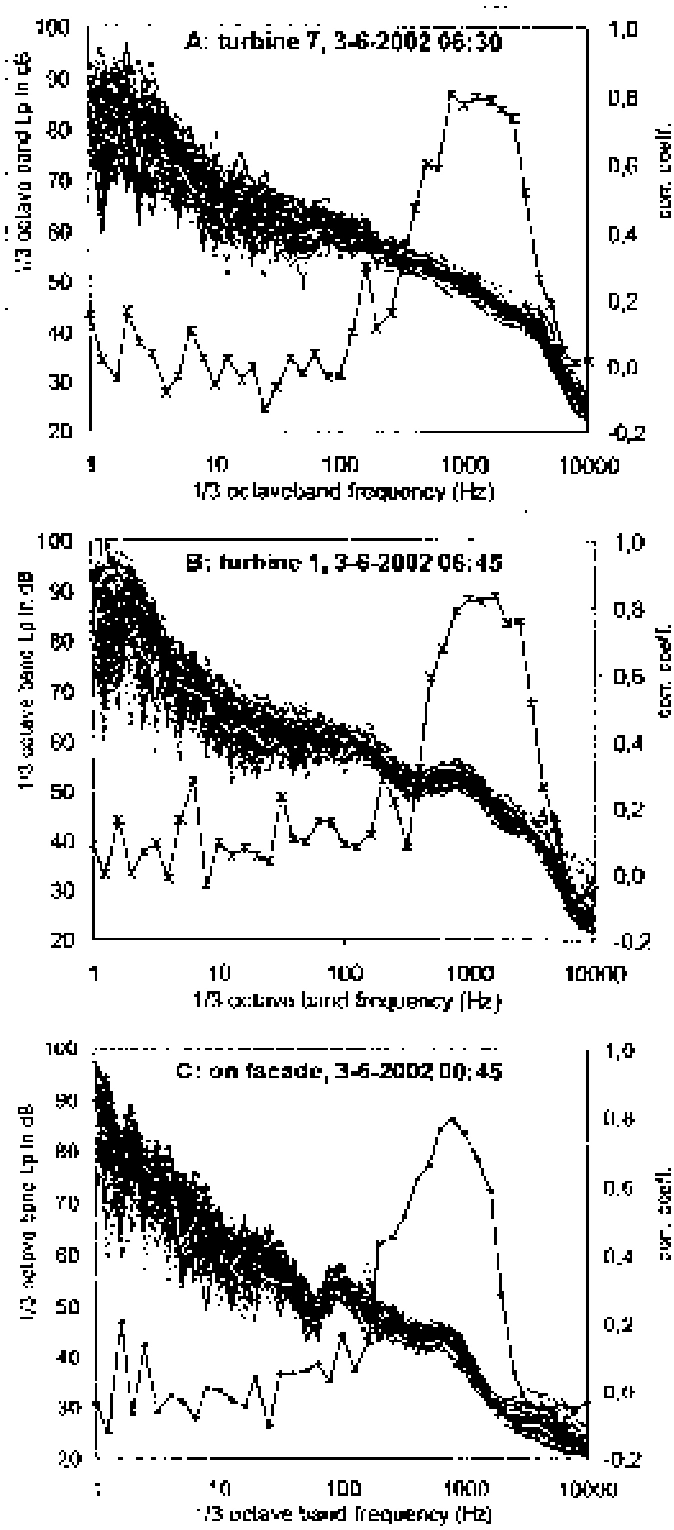


Figure V.1: left axis: 200 consecutive, unweighted and 1 second spaced 1/3 octave band spectra (thin lines), and averaged spectrum (thick line) of sound pressure level L_p near turbines 1 (A) and 7 (B) and near dwelling P (C);

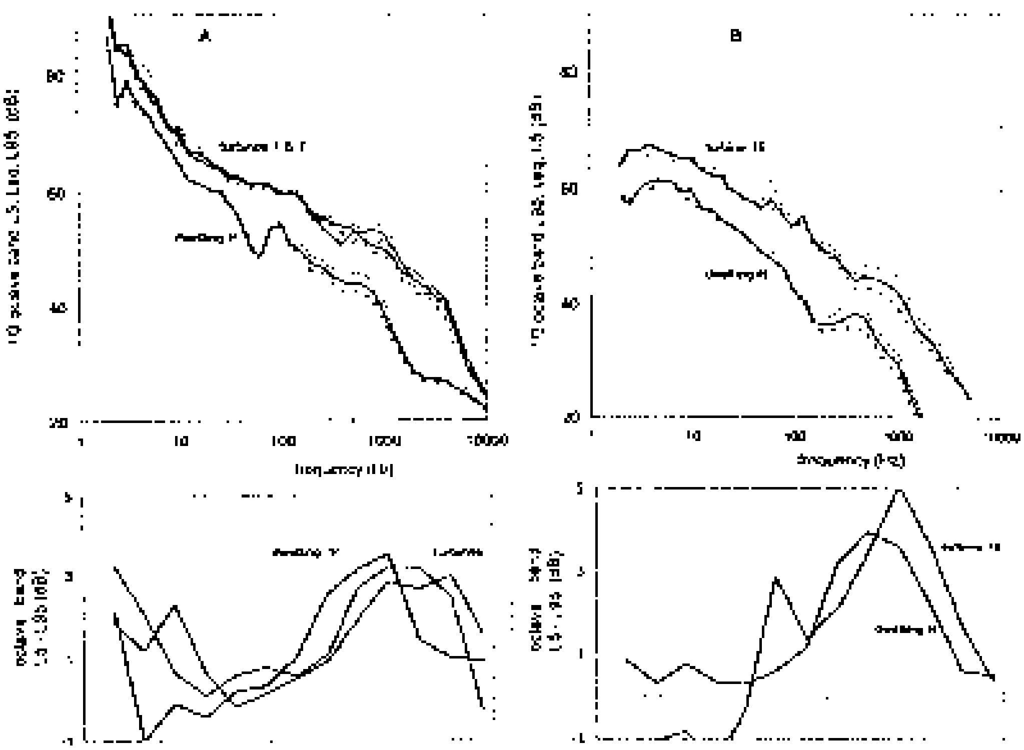
right axis: coefficient of correlation (line with markers) at each 1/3 octave band frequency between all 200 1/3 octave band levels and overall A-weighted level

The façade spectra in figure V.1C show a local minimum at 50-63 Hz, followed by a local maximum at 80-100 Hz.[1] This is caused by interference between the direct sound wave and the wave reflected by the façade at 1.5 m from the microphone: for wave lengths of approximately 6 m (55 Hz) this leads to destructive interference, for wave lengths of 3 m (110 Hz) to constructive interference.

In figure V.2A the three average spectra at the same locations as in figure V.1A-C have been plotted, but now for a total measurement time of 9.5 (façade), 5 (T7) and 6 (T1) minutes. For each of these measurement periods the average of the 5% of samples with the highest broad band A-weighted sound level (*i.e.* the equivalent spectral level of the L_{A5} percentile) has also been plotted, as well as the 5% of samples with the lowest broad band level (L_{A95}). The range in A-weighted broad band level can be defined as the difference between the highest and lowest value: $R_{bb} = L_{Amax} - L_{Amin}$. Similarly the range per 1/3 octave or octave band R_f can be defined by the difference in spectral levels corresponding to L_{Amax} and L_{Amin}. The difference between L_{A5} and L_{A95} is a more stable value, avoiding possibly incidental extreme values, especially when spectral data are used. $R_{bb,90}$ is defined as the difference in level between the 5% highest and the 5% lowest broad band sound levels: $R_{bb,90} = L_{A5} - L_{A95}$. For spectral data, $R_{f,90}$ is the difference between spectral levels associated with L_{A5} and L_{A95}. Values of $R_{f,90}$ are plotted in the lower part of figure V.2A (here octave bandlevels have been used to avoid the somewhat 'jumpy' behaviour of the 1/3 octave band levels). Close to turbines 1 and 7 R_{bb} is 4.8 and 4.1 dB, respectively. $R_{bb,90}$ is 3.2 and 2.6 dB, which is almost the same as $R_{f,90}$ (3.2 and 3.0 dB) at 1000-4000 Hz. Further away, at the façade, R_{bb} is comparable to the near turbine values: 4.9 dB. $R_{bb,90}$ at the façade is 3.3 dB and again almost the same as maximum $R_{f,90}$ (3.5 dB) at 1000 Hz.

Also, close to the turbine there is a low frequency maximum in $R_{f,90}$ at 2 (or 8) Hz that is also present at the façade, indicating that the modulation of trailing edge sound is correlated in time with the infrasound caused by the blade movement.

[1] In an FFT spectrum minima are at 57 and 170 Hz, maxima at 110 and 220 Hz



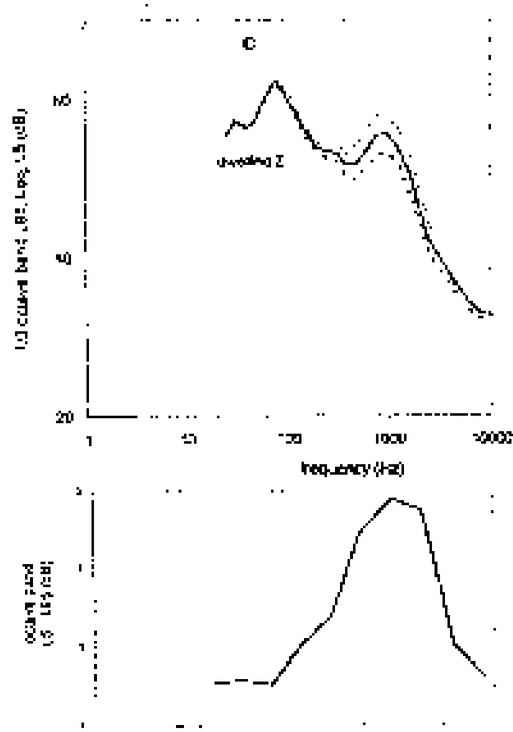


Figure V.2: upper panels of A, B, C: thick lines: 1/3 octave band L_{eq} near windturbines and dwellings; dotted lines: L_{eq} of all samples with resp. 5% highest (thin dotted lines) and 5% lowest (thick dotted lines) values of broad band L_A ;

lower panels A, B, C: difference between L_{eq} of 5- and 95-percentile octave band levels = dynamic range $R_{f,90}$

Figure V.2B presents similar plots for the average spectra and the L_{A5} and L_{A95} spectra at dwelling R and near turbine T16, simultaneously over a period of 16 minutes. Close to the turbine the broadband R_{bb} is 6.2 dB and $R_{bb,90}$ is 3.7 dB; octave band $R_{f,90}$ is highest (5.1 dB) at 1000 Hz. Near R broad band $R_{bb,90}$ is also 3.7 dB, and octave band $R_{f,90}$ is highest (4.0 dB) at 500 Hz. The R_{bb} ranges are 2.3 - 2.5 dB higher than the 90% ranges $R_{bb,90}$. In the measurements at this time and place (dwelling R) the infrasound level was lower than in the previous measurements at dwelling P where beating was more pronounced. G-weighted sound level during the 16 minutes at R was 70.4 dB(G), and at T16 77.1 dB(G).

Finally figure V.2C gives average spectra over a period of 16 minutes at dwelling Z. $R_{f,90}$ is now highest (4.8 dB) at 1 kHz, and broadband $R_{bb,90}$ is 4.3 dB (R_{bb} = 5.9 dB). The turbine near Z is smaller and lower, but rotates faster than the Rhede turbines; for a hub height wind velocity of 6 m/s the expected calculated increase in trailing edge sound for the lower tip relative to the day time situation is 2.0 ± 0.8 dB for a stable, and 2.9 ± 0.8 dB for a very stable atmosphere. For this turbine a peak trailing edge sound level is expected (according to equation B.2 in appendix B) at a frequency of 1550/h Hz = 400 – 800 Hz.

In all cases above the measured sound includes ambient background sound. Ambient background sound level could not be determined separately at the same locations because the wind turbine(s) could not be stopped (see section II.4). However, at audible frequencies it could be ascertained by ear that wind turbine sound was dominant. At infrasound frequencies this could not be ascertained. But if significant ambient sound were present, subtracting it from the measured levels would lead to lower (infrasound) sound levels, which would not change the conclusion, based on the G-weighted level, that measured infrasound must be considered inaudible.

A 25 second part of the 16 min period that corresponds with the spectra in figure V.2B is shown in figure V.3. The broad band level L_A changes with time at T16 and R, showing a more or less regular variation with a period of approximately 1 s (= $1/f_B$). Note that the level differences at R are of the same magnitude as close to the turbine, but the fluctuations at R consist of narrow peaks in comparison to the broader near-turbine fluctuations.

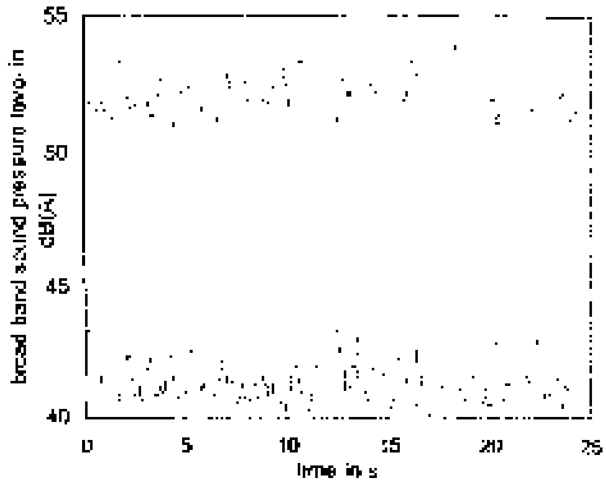


Figure V.3: broad band A-weighted immission sound level near turbine 16 (upper plot) and close to dwelling R (lower plot)

V.2.4 Beats caused by interaction of several wind turbines

In the previous section we saw that measured variations in broad band sound level (R_{66}) were 4 to 6 dB. In figure V.4 a registration is given of the sound pressure level every 50 msec over a 180 seconds period, taken from a DAT-recording on a summer night (June 3rd, 0:40 h) on a terrace of dwelling P at 750 m west of the westernmost row of wind turbines (this sound includes the reflection on the façade). In this night stable conditions prevailed (m = 0.45 from the wind velocities in table V.1). Turbines 12 and 11 are closest at 710 and 750 m, followed by turbines 9 and 14 at 880 and 910 m. Other turbines are more than 1 km distant and have an at least 4 dB lower immission level than the closest turbine has.

In figure V.4 there is a slow variation of the 'base line' (minimum levels) probably caused by variations in wind velocity and atmospheric sound transmission. There is furthermore a variation in dynamic range: a small difference between subsequent maximum and minimum levels of less than 2 dB is alternated by larger differences.

The expanded part of the sequence in figure V.4 (lower panel) begins when the turbine sound is noisy and constant within 2 dB. After some time (at t = 155 s) regular pulses[1] appear with a maximum height of 3 dB, followed by a short period with louder (5 dB) and steeper (rise time up to 23 dB/s)

[1] the term 'pulse' is used to indicate a short, upward variation in sound level

pulses. The pulse frequency is equal to the blade passing frequency. Then (t > 175 s) the pulses become weaker and there is a light increase in wind velocity.

This was one of the nights where a distinct beat was audible: a period with a distinct beat alternating with a period with a weaker or no beat, repeated more or less during the entire night. This pattern is compatible with a complex of three pulse trains with slightly different repetition frequencies of ca. 1 Hz. When the pulses are out of phase (around 150 s in figure V.4), the variations are 1 dB or less. When 2 of them are in phase (around 160 s) pulse height is doubled (+3 dB), and tripled (+5 dB, 170 s) when all three are in phase. The rotational speed of the turbines at the time was 20 rpm, so the repetition rate of blades passing a mast was 1 Hz.

The low number of pulse trains, compared to 17 turbines, is compatible with the fact that only a few turbines dominate the sound immission at this location. The calculated immission level is predominantly caused by two wind turbines (numbers 11 and 12: see figure IV.2, contributing 35% of the A-weighted sound energy), less by two others (9 and 14; 21%), so only 4 turbines contribute more than half of the sound immission energy.

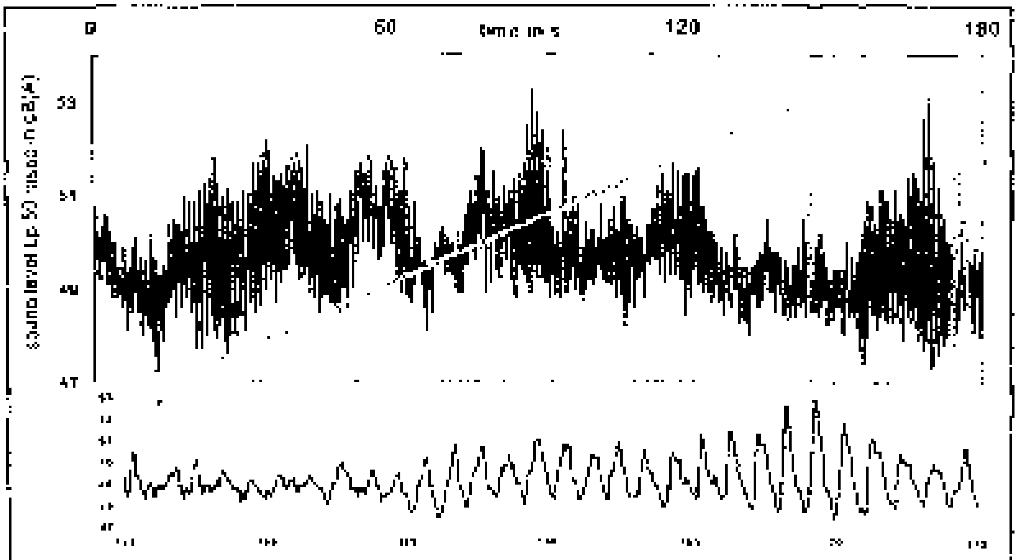


Figure V.4: fluctuations in broad band A-weighted sound immission level at façade of dwelling P; the lower panel is an expansion of the part within the grey rectangle

In figure V.5 the equivalent 1/3 octave band spectrum at the façade of P has been plotted for the period of the beat (165 < t < 175 s in figure 6, spectra sampled at a rate of 20 s^{-1}), as well as the equivalent spectrum associated with the 5% highest (L_{A5} = 52.3 dB(A)) and the 5% lowest (L_{A95} = 47.7 dB(A)) broad band levels within this 10 s period, and the difference between both. As in the similar spectra in figure 4 we see that the beat corresponds to an increase at frequencies where trailing edge sound dominates: the sound pulses correspond to variations in 1/3 octave band levels at frequencies between 200 and 1250 Hz and are highest at 800 Hz. In figure V.5 also the equivalent 1/3 octave band levels are plotted for the period after beating where the wind was picking up slightly (t > 175 s in figure 6). Here spectral levels above 400 Hz are the same or slightly lower as on average at the time of beating, but at lower frequencies down to 80 Hz (related to in-flow turbulence) levels now are 1 to 2 dB higher. The increase in the 'more wind' spectrum at high frequencies (> 2000 Hz) is probably from rustling tree leaves.

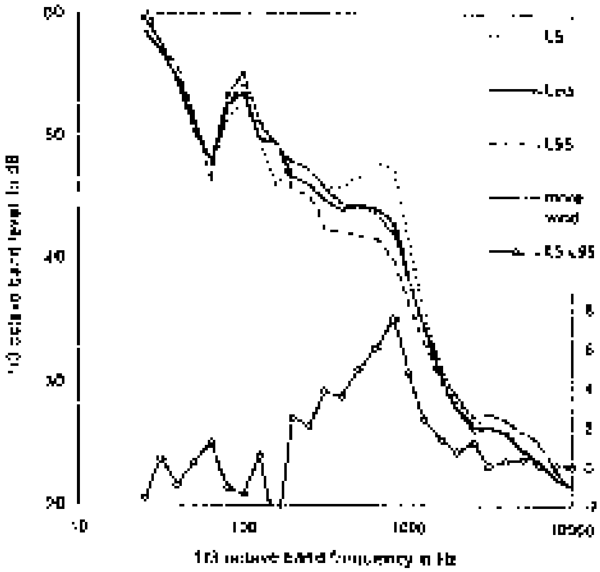


Figure V.5: 1/3 octave band levels at façade of dwelling P during beating (L_{eq}, L_5 and L_{95}) and when wind speed is picking up (L_{eq}); lower line: dynamic range ($R_{(xx)}$) of 1/3 octave band

Figure V.6 shows sound power spectra for a period with a distinct beat (150 < t < 175 s in figure 6), and a period with a weak or no beat (130 < t < 150 s). Each spectrum is an FFT of 0.2 Hz line width from broad band A-weighted immission sound pressure level values. The frequencies are therefore *modulation*, not sound frequencies. The spectra show that distinct beating is associated with higher total A-weighted levels at the blade passing frequency and its harmonics ($k \cdot f_B$ with k = 1, 2, 3, …). As has been shown above, the higher level is related to the frequency range of trailing edge sound. Infrasound frequencies linked to thickness sound are negligible in total A-weighted sound levels. When beating is weaker but there is more wind (t > 175 s), the level of the odd harmonics (base frequency k = 1, and k = 3) is lower than during 'beat', whereas the first two even harmonics (k = 2, 4) are equally loud, indicating more distorted (less sinusoidal) and lower level pulses. It is important to realize that the periodic variation as represented in figure V.6 is the result from a wind farm, not from a single turbine.

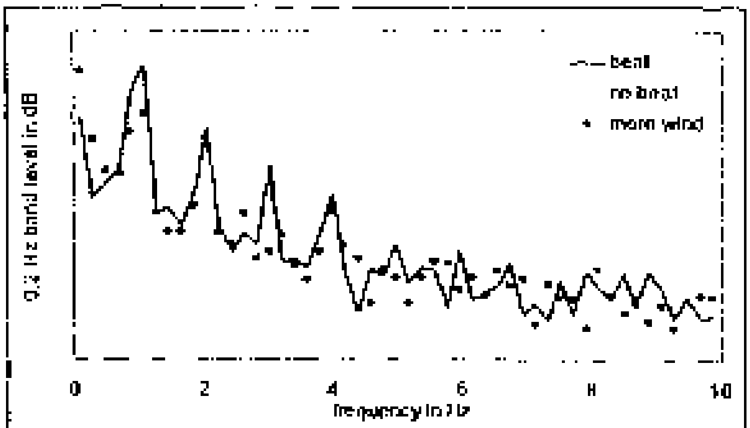


Figure V.6: sound power spectrum of A-weighted broad band immission sound level at façade of dwelling P when beating is distinctly or not audible and with slightly increased wind speed. The ordinate spans 20 dB.

In the long term measurements near the Rhede wind farm (see Chapter IV) average and percentile sound levels were determined over 5 minute periods. Periods where wind turbine sound was dominant could be selected with a criterion ($R_{bb,90} \leq 4$ dB) implying a fairly constant source with less than 4 dB variation for 90% of the time. The statistical distribution of the values of $R_{bb,90} = L_{A5} - L_{A95}$ (≤ 4 dB) has been plotted in 1 dB intervals in figure V.7 for the two long term measurement locations A and B (see map in figure IV.1). Relative to dwellings P and R, location A (400 m from nearest turbine) is closer to the turbines, while location B (1500 m) is further away. Total measurement times –with levels in compliance with the criterion– were 110 and 135 hours, respectively. Figure V.7 shows that the criterion value $R_{bb,90}$ (cut off at 4 dB) at both locations peaks at 2.5 dB.

Also plotted in figure V.7 is the value of L_{Amax} - L_{Aeq} within 5 minute periods (while $R_{bb,90} \leq 4$ dB), peaking at 3.5 dB at both locations. Finally, the difference between maximum and minimum level within 5 minute periods, $R_{bb} = L_{Amax} - L_{Amin}$, peaks at 4.5 dB (location A) and 5.5 dB (B).

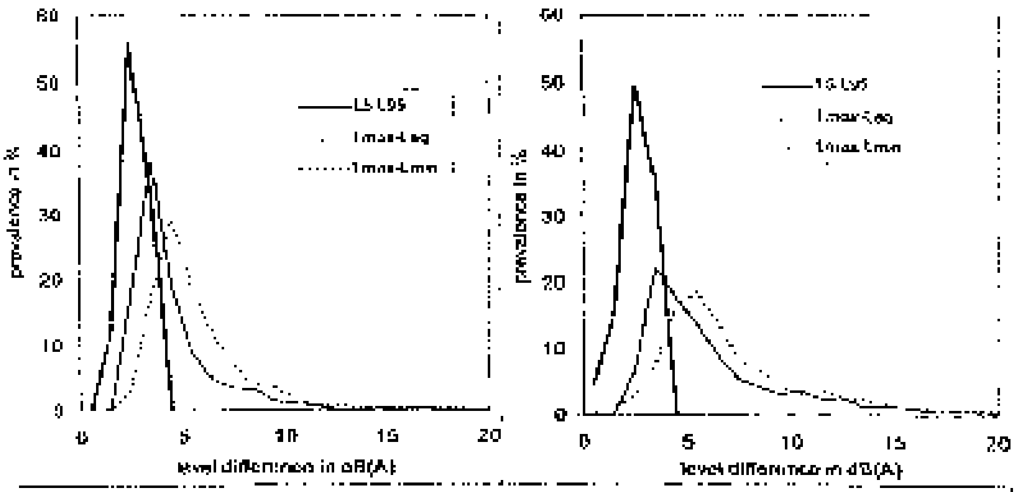


Figure V.7: statistical distribution of level differences (in 1 dB-classes) between high and low sound levels within 5 minute periods at 400 m (left) and 1500 m (right) from the nearest wind turbine

Where $R_{bb} > 7$ dB, the distributions are influenced by louder (non-turbine) sounds, such as from birds, causing a tail in the distributions at high levels. If we assume approximately symmetrical distributions without high level tails, the maximum range $L_{Amax} - L_{Amin} = R_{bb}$ due to the wind farm is 8.5 dB (location A) to 9.5 dB (B). This is 4 dB more than the prevailing difference at both locations.

V.2.5 Summary of results

In table V.2 the level variations due to blade swish as determined in the previous sections have been summarised. Some values not presented in the text have been added.[1] The ranges are presented as R_{bb} and $R_{bb,90}$. The

[1] in table in [Van den Berg 2005a] level variations close to the turbines were also given (as shown in figures V.2A-B); these values (R_{bb} = 4.8 dB close to turbine T1, 4.1 dB at T7 and 6.0 dB at T16) are not presented here as in fact these variations are not caused by the mechanism given in section V.1, but by other phenomena (see section II.2)

latter is of course a lower value as it leaves out high and low excursions occurring less than 10% of the time. The time interval over which these level differences occur differ: from several up to 16 minutes for the short term measurements, where wind conditions can be presumed constant, up to over 100 hours at locations A and B.

Table V.2: level variation in wind turbine [1] sound due to blade swish, in dB

	location	Reference	atmospheric condition	R_{66} $L_{Amax}-L_{Amin}$	$R_{66,90}$ $L_{A1}-L_{A95}$
Calculated results					
Single turbine		Section V.1a	neutral	2 ± 1	
		Section V.1a	stable	3.8 ± 1.7	
		Section V.1a	very stable	4.8 ± 1.7	
N equidistant turbines			(very) stable	single + 10·logN	
Measured results					
Single turbine		[ETSU 1996]	unspecified [4]	< 3	
	dwelling Z	Fig. V.2C	stable	5.9 [5]	4.3
Multiple turbines	dwelling R	Fig. V.2B	stable	6.2	3.7
	façade dwelling P	Fig. V.2A	stable	4.9	3.3
	façade P + beat	Fig. V.5	stable	5.4	
	location A	fig. V.7left	long term, stable	4.5 (most frequent) 8.5 (maximum)	
	location B	fig. V.7right	long term, stable	5.5 (most frequent) 9.5 (maximum)	

notes: 1) hub height 100 m, rotor diameter 70 m, 20 rpm; 2) probably neutral; 3) for this turbine (H = 45 m, D = 46 m, 26 rpm, V_5 = 12 m/s) R_{66} < 3.3 dB was calculated

V.3 Perception of wind turbine sound

In a review of literature on wind turbine sound Pedersen concluded that wind turbine noise was not studied in sufficient detail to be able to draw general conclusions, but that the available studies indicated that at relatively low levels wind turbine sound was more annoying than other sources of community noise such as traffic [Pedersen 2003]. In a field study by Pedersen and Persson Waye [2004] 8 of 40 respondents living in dwellings with (calculated) maximum outdoor immission levels of 37.5 - 40.0 dB(A) were very annoyed by the sound, and at levels above 40 dB(A) 9 of 25 respondents were very annoyed. The correlation between sound level (in 2.5 dB classes) and annoyance was significant ($p < 0.001$). In this field study annoyance was correlated to descriptions of the sound characteristics, most strongly to swishing with a correlation coefficient of 0.72 [Pedersen *et al* 2004]. A high degree of annoyance is not expected at levels below 40 dB(A), unless the sound has special features such as a low-frequency components or an intermittent character [WHO 2000]. Psychoacoustic characteristics of wind turbine sound have been investigated by Persson-Waye and Öhrström in a laboratory setting with naive listeners (students not used to wind turbine sound): the most annoying sound recorded from five different turbines were described as 'swishing', 'lapping' and 'whistling', the least annoying as 'grinding' and 'low frequency' [Persson Waye *et al* 2002]. People living close to wind turbines, interviewed by Pedersen *et al.* [2004], felt irritated because of the intrusion of the wind turbines in their homes and gardens, especially the swishing sound, the blinking shadows and constant rotation.

Our experience at distances of approx. 700 to 1500 m from the Rhede wind farm, with the turbines rotating at high speed in a clear night and pronounced beating audible, is that the sound resembles distant pile driving. When asked to describe the sound of the turbines in this wind farm, a resident compares it to the surf on a rocky coast. A resident living further away from the wind farm (1200 m) likens the sound to an 'endless train'. Another resident near a set of smaller wind turbines, described the sound as that of a racing rowing boat (where rowers simultaneously draw, also creating a periodic swish). On the website of MAIWAG, a group of

citizens from villages near four wind farms in the south of Cumbria (UK), the sound is described as 'an old boot in a tumble dryer', and also as 'Whumph! Whumph! Whumph!' (see text box in section III.4). Several residents near single wind turbines remarked that the sound often changed to clapping, thumping or beating when night falls: 'like a washing machine'. It is common in all descriptions that there is noise ('like a nearby motorway', 'a B747 constantly taking of') with a periodic fluctuation superimposed. In all cases the sound acquires this more striking character late in the afternoon or at night, especially in clear nights and downwind from a turbine.
Part of the relatively high annoyance level and the characterisation of wind turbine sound as lapping, swishing, clapping or beating may be explained by the increased fluctuation of the sound. Our results in table V.2 show that in a stable atmosphere measured fluctuation levels are 4 to 6 dB for single turbines, and in long term measurements (over many 5 minute periods) near the Rhede wind farm fluctuation levels of approx. 5 dB are common but may reach values up to 9 dB.

The level difference associated with an amplitude modulation (AM) factor mf is:

$$\Delta L = 20 \cdot \log((1+mf)/(1-mf)) \qquad (V.2a)$$

The modulation factor mf is the change in sound pressure amplitude due to modulation, relative to the average amplitude. For $\Delta L < 9$ dB a good approximation (±5%) is:

$$mf = 0.055 \cdot \Delta L \qquad (V.2b)$$

Now when ΔL rises from 3 dB, presumably a maximum value for a daytime (unstable or neutral) atmosphere, to 6 dB, mf rises from 17% to 33%. For a maximum value of $\Delta L = 9$ dB, mf is 50%.

Fluctuations are perceived as such when the modulation frequencies are less than 20 Hz. Human sensitivity for fluctuations is highest at $f_{mod} = 4$ Hz, which is the frequency typical for rhythm in music and speech [Zwicker *et al* 1999], and for frequencies of the modulated sound close to 1 kHz. For wind turbines we found that a typical modulation frequency is 1 Hz, modulating the trailing edge sound that itself is at frequencies of 500 – 1000 Hz. So human sensitivity for wind turbine sound fluctuations is relatively high.

Fluctuation strength can be expressed in a percentage relative to the highest perceptible fluctuation strength (100%) or as an absolute value in the unit vacil [Zwicker *et al* 1999]. The reference value for the absolute fluctuation strength is 1 vacil, equalling a 60 dB, 1 kHz tone, 100% amplitude-modulated at 4 Hz [Zwicker *et al* 1999].

For an AM pure tone as well as AM broad band noise, absolute fluctuations strength is zero until $\Delta L \approx 3$ dB, then increases approximately linearly with modulation depth up to a value of 1 vacil. For a broad band noise level L_A the fluctuation strength F_{bb} can be written as [Zwicker *et al* 1999]:

$$F_{bb} = \frac{5.8 \cdot (1.25 \cdot mf - 0.25) \cdot (0.05 \cdot L_A - 1)}{(f_{mod}/5\ \text{Hz})^2 + (4\ \text{Hz}/f_{mod}) + 1.5}\ \text{vacil} \qquad \text{(V.3a)}$$

With typical values for wind turbine noise of $f_{mod} = 1$ Hz and $L_A = 40$ dB(A), this can be written as $F_{bb} = 1.31 \cdot (mf - 0.2)$ vacil or, when $\Delta L < 9$ dB:

$$F_{bb} = 0.072 \cdot (\Delta L - 3.6) \qquad \text{vacil} \qquad \text{(V.3b)}$$

When ΔL increases from 3 to 5 dB, F_{bb} increases from negligible to 0.1 vacil. For the high fluctuation levels found at locations A and B ($\Delta L = 8$ to 9 dB), F_{bb} is 0.3 to 0.4 vacil.

It can be concluded that, in a stable atmosphere, the fluctuations in modern wind turbine sound can be readily perceived. As yet it is not clear how this relates to possible annoyance. However, the sound can be likened to the rhythmic beat of music: pleasant when the music is appreciated, but distinctly intrusive when the music is unwanted.

The hypothesis that these fluctuations are important, is supported by descriptions of the character of wind turbine sound as 'lapping', 'swishing', 'clapping', 'beating' or 'like the surf'. Those who visit a wind turbine in daytime will usually not hear this and probably not realise that the sound can be rather different in conditions that do not occur in daytime. This may add to the frustration of residents: "Being highly affected by the wind turbines was hard to explain to people who have not had the experiences themselves and the informants felt that they were *not being believed*" [Pedersen *et al* 2004]. Persson-Waye *et al* [2002] observed that, from five recorded different turbine sounds "the more annoying noises were also paid attention to for a longer time". This supported the hypothesis that awareness of the noise and possibly the degree of annoyance depended on the content (or intrusive character) of the sound.

Fluctuations with peak levels of 3 – 9 dB above a constant level may have effects on sleep quality. The Dutch Health Council [2004] states that "at a given L_{night} value, the most unfavourable situation in terms of a particular direct biological effect of night-time noise is not, as might be supposed, one characterised by a few loud noise events per night. Rather, the worst scenario involves a number of noise events all of which are roughly 5 dB(A) above the threshold for the effect in question." For transportation noise (road, rail, air traffic) the threshold for motility (movement), a direct biological effect having a negative impact on sleep quality, is a sound exposure level per sound event of SEL = 40 dB(A) in the bedroom [Health Council 2004]. The pulses in figure V.4 have SEL-values up to 50 dB(A), but were measured on the façade. With an open window facing the wind turbines indoor SEL-values may exceed the threshold level. In other situations this of course depends on distance to and sound power of the turbines and on the attenuation between façade and bedroom. It is not clear whether the constant and relatively rapid repetition of wind turbine sound beats will have more or less effect on sleep quality, compared to vehicle or airplane passages. Pedersen and Persson Waye [2004] found that at dwellings where the (outdoor) sound level due to wind turbines exceeded 35 dB(A), 16% of 128 respondents reported sleep disturbance by this sound, of whom all but two slept with a window open in summer.

V.4 Conclusion

Atmospheric stability has a significant effect on the character of wind turbine sound. The change in wind profile causes a change in angle of attack on the turbine blades. This increases the thickness (infra)sound level as well as the level of trailing edge (TE) sound, especially when a blade passes the tower. TE sound is modulated at the blade passing frequency, but it is a high frequency sound, well audible and indeed the most dominant component of wind turbine noise. The periodic increase in sound level dubbed blade swish, is a well known phenomenon. Less well known is the fact that increasing atmospheric stability creates greater changes in the angle of attack over the rotor plane that add up with the change near the tower. This results in a thicker turbulent TE boundary layer, in turn causing a higher swish level and a shift to somewhat lower frequencies. It can be shown theoretically that for a modern, tall wind turbine in flat, open land the angle of attack at the blade tip passing the tower changes with approx. 2° in daytime, but this value increases with 2° when the atmosphere becomes very stable. The calculated rise in sound level during swish then increases from 2 dB to 5 dB. This value is confirmed by measurements at single turbines in the Rhede wind farm where maximum sound levels rise 4 to 6 dB above minimum sound levels within short periods of time.

Added to this, atmospheric stability involves a decrease in large scale turbulence. Large fluctuations in wind velocity (at the scale of a turbine) vanish, and the coherence in wind velocity over distances as great as or larger than the size of an entire wind farm increases. As a result turbines in the farm are exposed to a more constant wind and rotate at a more similar speed with less fluctuations. Because of the near synchronicity, blade swishes may arrive simultaneously for a period of time and increase swish level. The phase difference between turbines determines where this amplification occurs: whether the swish pulses will coincide at a location depends on this phase difference and the propagation time of the sound. In an area where two or more turbines are comparably loud the place where this amplification occurs will sweep over the area with a velocity determined by the difference in rotational frequency. The magnitude of this effect thus depends on stability, but also on the number of wind turbines and the distances to the observer. This effect is in contrast to what was expected, as it seemed reasonable to suppose that turbines would behave independently and thus the blade swish pulses from several turbines would arrive at random, resulting in an even more constant level than from one turbine. Also, *within* a wind farm the effect may not be noticed, since comparable positions in relation to two or more turbines are less easily realised at close distances and the position relative to a turbine rotor is quite different.

Sound level differences L_{Amax}-L_{Amin} (corresponding to swish pulse heights) within 5 minute periods over long measurement periods near the Rhede wind farm show that level changes of approximately 5 dB occur for an appreciable amount of time and may less often be as high as 8 or 9 dB. This level difference did not decrease with distance (from 400 m to 1500 m). The added 3-5 dB, relative to a single turbine, is in agreement with simultaneously arriving pulses from two or three approximately equally loud turbines.

The increase in blade swish level creates a new percept, fluctuating sound, that is absent or weak in neutral or unstable atmospheric conditions. Blade passing frequency is now an important parameter as a modulation frequency (not as an infrasound frequency). Human perception is most sensitive to modulation frequencies close to 4 Hz of sound with a frequency of approximately 1 kHz. The hypothesis that fluctuations are important is supported by descriptions given by naïve listeners as well as residents: turbines sound like 'lapping', 'swishing', 'clapping', 'beating' or 'like the surf'. It is not clear to what degree this fluctuating character determines the relatively high annoyance caused by wind turbine sound and to a deterioration of sleep quality. Further research is necessary into the perception and annoyance of wind turbine sound, with correct assumptions on the level and character of the sound. Also the sound exposure level of fluctuations in the sound in the bedroom must be investigated to be able to assess the effects on sleep quality.

VI STRONG WINDS BLOW UPON TALL TURBINES: wind statistics below 200 m altitude

VI.1 Atmospheric stability in wind energy research

In the European Wind Atlas model ('Wind Atlas Analysis and Application Program' or WAsP) [Troen *et al* 1989] wind energy available at hub height is calculated from wind velocities at lower heights. The Atlas states that "modifications of the logarithmic wind profile are often neglected in connection with wind energy, the justification being the relative unimportance of the low wind velocity range. The present model treats stability modifications as small perturbations to a basic neutral state." With the increase of wind turbine heights this quote is now an understatement. In recent years atmospheric stability is receiving gradually more attention as a determinant in wind *energy* potential, as demonstrated by a growing number of articles on stability related wind profiles in different types of environments such as Danish offshore sites [Motta *et al* 2005], the Baltic Sea [Smedman *et al* 1996], a Spanish plateau [Pérez *et al* 2005] or the American Midwest [Smith *et al* 2002]. Recently Archer and Jakobsen [2003] showed that wind energy potential at 80 m altitude in the contiguous US 'may be substantially greater than previously estimated' because atmospheric stability was not taken into account: on average 80-m wind velocities appear to be 1.3 – 1.7 m/s higher than assumed from 10-m extrapolated wind velocities in a neutral atmosphere.

VI.2 The Cabauw site and available data

To investigate the effect of atmospheric stability on wind, and thence on energy and sound production, data from the meteorological research station of the KNMI (Royal Netherlands Meteorological Institute) at Cabauw in the western part of the Netherlands were kindly provided by dr Bosveld of the KNMI. The site is in open pasture for at least 400 m in all directions. Farther to the west the landscape is open, to the distant east are trees and low houses. More site information is given in [KNMI 2005, Van Ulden *et al* 1996]. The site is considered representative for the flat western and northern parts of the Netherlands. These in turn are part of the low-lying plain stretching from France to Sweden.

Meteorological data are available as half hour averages over several years. Here data of the year 1987 are used. Wind velocity and direction are measured at 10, 20, 40, 80, 140 and 200 m altitude. Cabauw data are related to Greenwich Mean Time (GMT); in the Netherlands the highest elevation of the sun is at approximately 12:40 Dutch winter time, which is 20 minutes before 12:00 GMT.

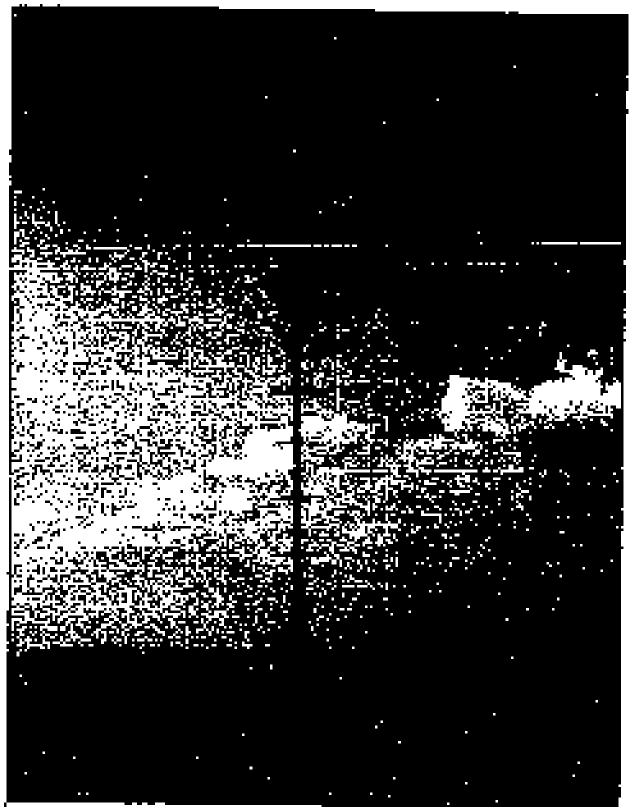


Figure VI.1 the Cabauw site with 200 m mast for meteorological research (photo: Marcel Schmeier)

An indirect measure for stability is Pasquill class, derived from cloud cover, wind velocity and position of sun (above or below horizon). Classes range from A (very unstable: less than 50% clouding, weak or moderate wind, sun up) to F (moderately to very stable: less than 75% clouding, weak or moderate wind, sun down). Pasquill class values have been estimated routinely at Dutch meteorological stations [KNMI 1972].

VI.3 Reference conditions

To relate the meteorological situation to wind turbine performance, an 80 m hub height wind turbine with three 40 m long blades will be used as reference for a modern 2 to 3 MW, variable speed wind turbine. To calculate electrical power and sound power level, specifications of the 78 m tall Vestas V80 – 2MW wind turbine will be used. For this turbine cut-in (hub height) wind velocity is 4 m/s, and highest operational wind velocity 25 m/s.

Most data presented here will refer to wind velocity at the usual observation height of 10 m and at 80 m hub height. Wind shear will be presented for this height range as well as the range 40 to 140 m where the rotor is. The meteorological situation is as measured in Cabauw in 1987, with a roughness height of 2 cm. The year will be divided in meteorological seasons, with spring, summer, autumn and winter beginning on the first day or April, July, October and January, respectively.

We will consider four classes of wind velocity derived from Pasquill classes A to F and shown in table I: unstable, neutral, stable and very stable. In table VI.1 (the same as table III.1, but written slighly different to show boundaries between stability classes in terms of m) this is also given in terms of the shear exponent, but this is tentative as there is no fixed relation between Pasquill classification and shear exponent or stability function Ψ. This classification is in agreement with that in chapter III, though there typical mid-class values of m were given, not values at the boundaries between classes. In our reference situation 'very stable' (m > 0.4) corresponds to a Monin-Obukhov length 0 < L < 100 m, 'stable' (0.25 < m < 0.4) refers to 100 m < L < 400 m, near neutral to |L| > 400 m.

This is somewhat different from the Monin-Obukhov length based classification used by Motta *et al* [2005] for a coastal/marine environment. Motta *et al* qualified 0 < L < 200 m as very stable, 200 m < L < 1000 m as stable and |L| > 1000 m as near-neutral, so they considered a wider range of conditions as (very) stable when compared to table 1.

Table VI. 1: stability classes and shear exponent m

Pasquill class	name	shear exponent
A – B	(very – moderately) unstable	m ≤ 0.21
C	near neutral	0.21 < m ≤ 0.25
D – E	(slightly – moderately) stable	0.25 < m ≤ 0.4
F	very stable	0.4 < m

VI.4 Results: wind shear and stability

VI.4.1 Wind velocity shear

In figure VI.2 the average wind velocities at altitudes of 10 m to 200 m are plotted versus time of day. Plotted are averages per half hour of all appropriate half hours in 1987. As figure VI.2 shows, the wind velocity at 10 m follows the popular notion that wind picks up after sunrise and abates after sundown. This is obviously a 'near-ground' notion as the reverse is true at altitudes above 80 m. Figure VI.2 helps to explain why this is so: after sunrise low altitude winds are coupled to high altitude winds due to the vertical air movements caused by the developing thermal turbulence. As a result low altitude winds are accelerated by high altitude winds that in turn are slowed down. At sunset this process is reversed. In figure VI.2 also the wind velocity V_{80} is plotted as calculated from the measured wind velocity V_{10} with equation III.3 (z_0 = 2 cm, equivalent to equation III.1 with m = 0.14), as well as the shear exponent m calculated with equation III.4. The logarithmically extrapolated V_{80} approximates actual V_{80} in daytime when the shear exponent has values close to 0.14. However, the prediction is very poor at night time, when m rises to a value of 0.3, indicating a stable atmosphere.

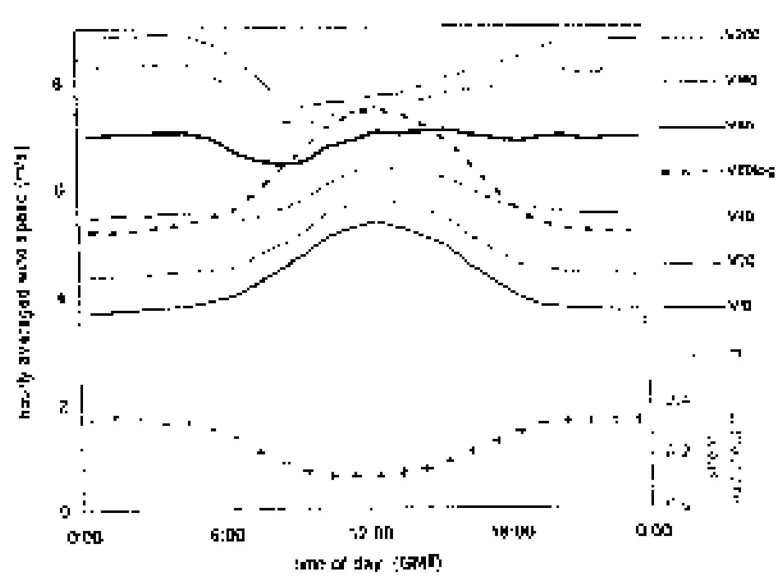


Figure VI.2: solid lines, bottom to top: 1987 wind velocity per clock hour at heights 10 to 200 m; dotted line: logaritmically extrapolated V_{80}; + : shear exponent $m_{10,80}$

For the hourly progress of wind velocities large deviations from the average wind profile occur. This is illustrated in figure VI.3 for a week in winter and a week in summer with measured V_{10} values and measured as well as logarithmically extrapolated V_{80} values. In the winter week in January 1987 ground and air were cold for a long time (below freezing point) with very little insolation. Temperature varied from night to day (diurnal minimum to maximum) with 7 °C on the first day and 5 °C or less on the next days, and the atmosphere was close to neutral with measured V_{80} more or less equal to the extrapolated V_{80}. In the summer week in July 1987 there was little clouding after the first two days; insolation was strong in daytime, and nights were 10 to 14 °C cooler than days, resulting in a stable to very stable night time atmosphere. Here, night time wind velocity was rather higher than predicted with the logarithmic wind profile.

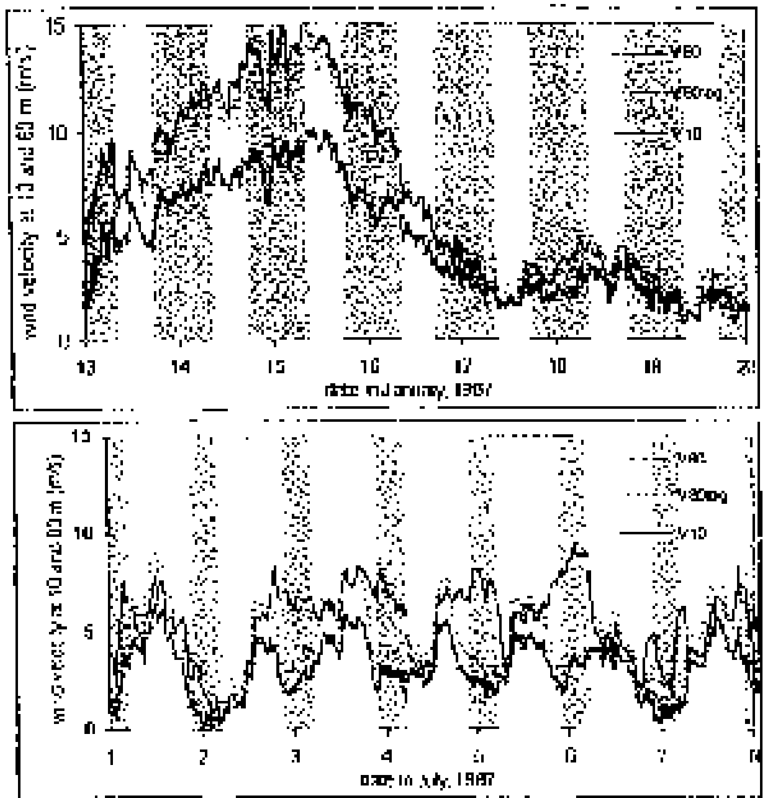


Figure VI.3: wind velocity at 10 and 80 m (solid lines), and logarithmically extrapolated $V_{80_{log}}$ (dotted line) over 7 days in January (top) and July (bottom); grey background: time when sun is down

In figure VI.4 wind velocities per half hour are again plotted for different heights, as in figure VI.2, but now averaged per clock half hour and per meteorological season. In spring and summer differences between night and day seem more pronounced than in autumn or winter. In fall and winter wind velocities are on average higher.

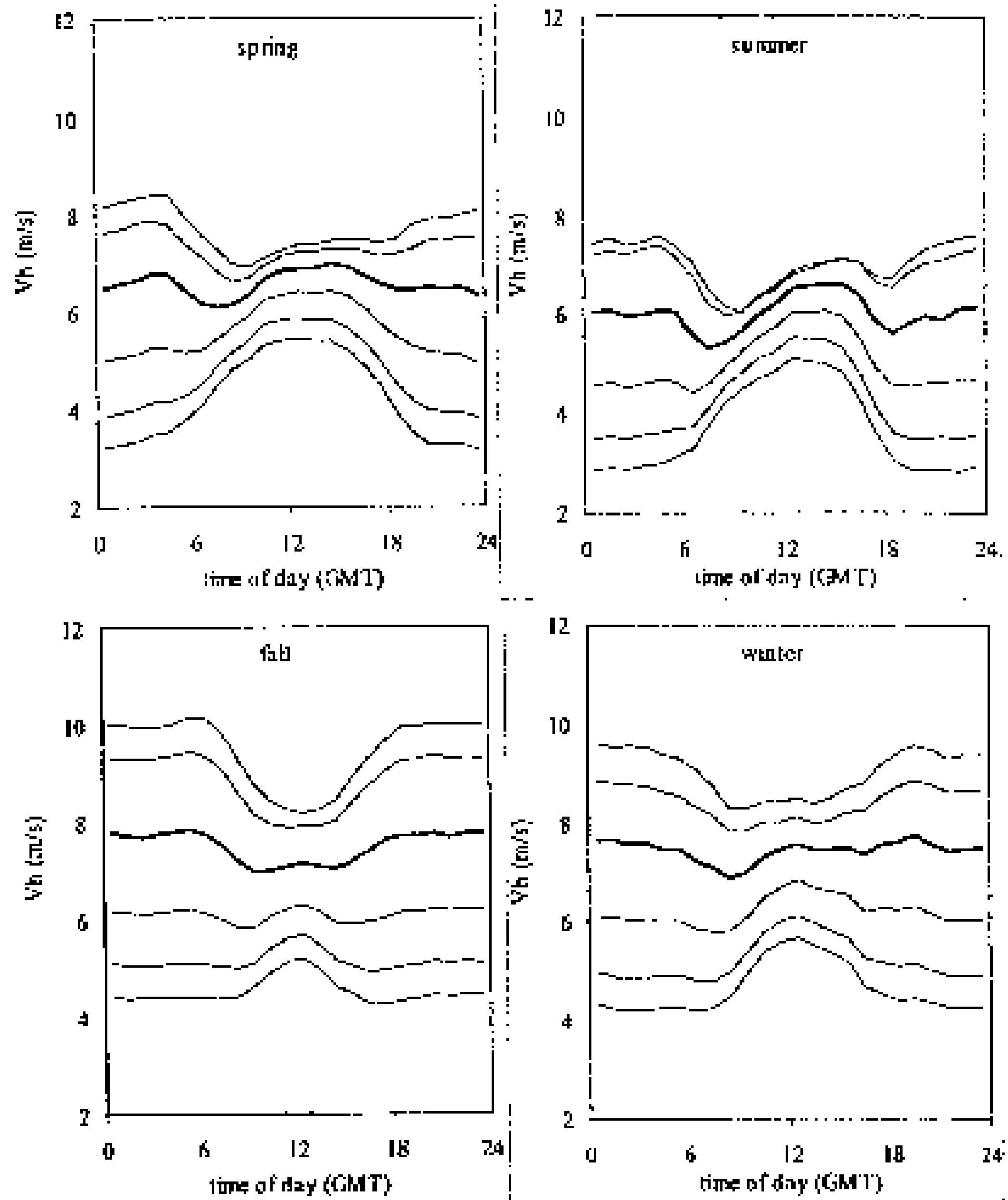


Figure VI.4: wind velocity per hour GMT at heights of 10, 20, 40, 80, 140 and 200 m (bottom to top; 80 m is bold) in the meteorological seasons in 1987

In figure VI.5 the frequency distribution is plotted of the half-hourly wind velocities at five different heights. Also plotted is the distribution of wind velocity at 80 m as calculated from the 10-m wind velocity with the logarithmic wind profile (equation III.3, $m = 0.14$). Wind velocity at 80 m has a value of 7 ± 2 m/s for 50% of the time. For the logarithmically extrapolated wind velocity at 80 m this is 4.5 ± 2 m/s.

In figure VI.6 the prevalence of the shear exponent in the four meteorological seasons is plotted, determined from the half-hourly 10-m and 80-m wind velocities. It shows that, relative to autumn and winter, a neutral or mildly stable atmosphere occurs less often in spring and summer, whereas an unstable as well as –in summer- a very stable atmosphere occurs more often . As summer nights are short this means that a relatively high percentage of summer night hours has a stable atmosphere.

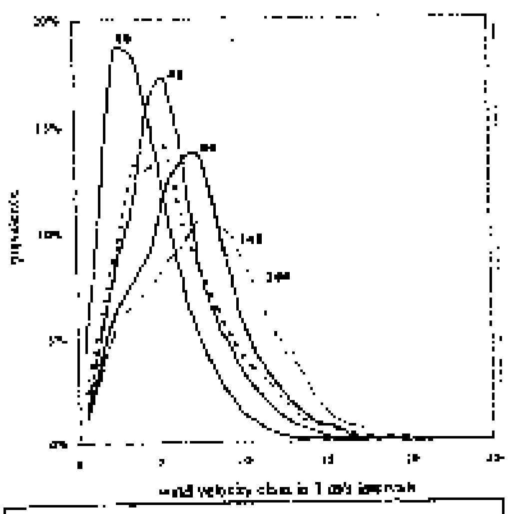


Figure VI.5: distribution of measured wind velocities at 10, 40, 80, 140 and 200 m;dashed line: V_{80} extrapolated from V_{10}

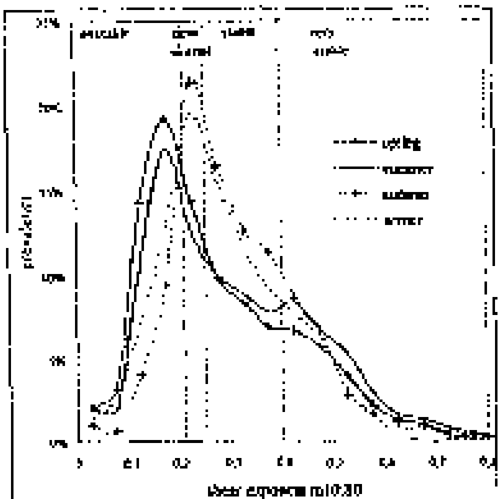


Figure VI.6: distribution of shear exponent per meteorological season, determined from V_{80}/V_{10}

VI.4.2 Shear and ground heat flux

Figure VI.7 shows how the shear exponent depends on the total heat flow to the ground for two different height ranges: 10 – 80 m in the left panel, 40 – 140 m in the right panel. The shear exponent is calculated from the wind velocity ratio with equation III.1. The heat flow at Cabauw is determined from temperature measurements at different heights, independent of wind velocity. Total heat flow is the sum of net radiation, latent and sensible heat flow, and positive when incoming flow dominates. For heat flows above approximately 200 W/m² the shear exponent m is between 0 and 0.21, corresponding to an unstable atmosphere, as expected. For low or negative (ground cooling) heat flows the range for m increases, extending from -1 up to +1.7. These values include conditions with very low wind velocities. If low wind velocities at 80 m height (V_{80} < 4 m/s, occurring for 19.7% of the time) are excluded, $m_{10,80}$ varies (with very few exceptions) between 0 and 0.6, and $m_{40,140}$ varies between -0.1 and +0.8. A negative exponent means wind velocity decreases with height. The data show that below 80 m this occurs in situations with little wind (V_{80} < 4 m/s), but at greater heights also at higher wind velocities. In fact, V_{140} was lower than V_{80} for 7.5% of all hours in 1987, of which almost half (3.1%)

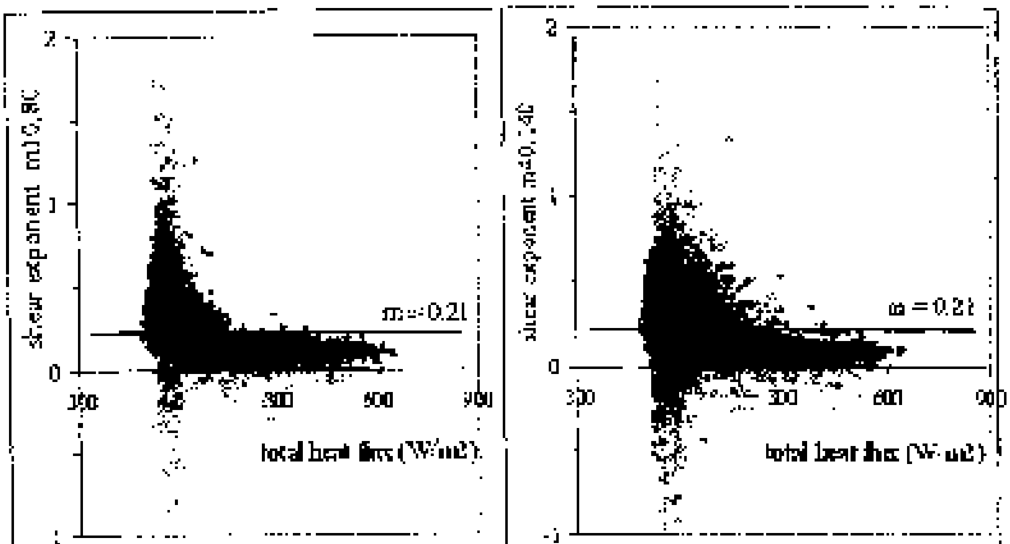


Figure VI.7: shear exponent m from wind velocity gradient between 10 and 80 m (left), and 40 and 140 m (right) vs. total ground heat flow: grey circles: all data, black dots: V_{80} > 4 m/s when V_{80} was over 4 m/s. Such a decrease of wind velocity with height occurs at the top of a 'low level jet' or nocturnal maximum; it occurs at night when kinetic energy of low altitude air is transferred to higher altitudes.

For V_{80} > 4 m/s both shear exponents ($m_{10,80}$ and $m_{40,140}$) are fairly strongly correlated (correlation coefficient 0.85), showing that generally there is no appreciable change between both altitude ranges. For low wind velocities (V_{80} < 4 m/s) both shear exponents are less highly correlated (correlation coefficient 0.62).

VI.4.3 Wind direction shear

When stability sets in the decoupling of layers of air also affects wind direction. The higher altitude wind more readily follows geostrophic wind and therefore can change direction when stability sets in, while lower altitude winds are still influenced by the surface following the earth's rotation. In the left panel of figure VI.8 the change in wind direction at 80 m relative to 10 m is plotted as a function of the shear exponent as a measure of stability. A positive change means a clockwise change (veering wind) at increasing altitude. The right panel shows the wind direction change from 40 to 140 m as a function of the shear exponent determined from the wind velocities at these heights. In both cases the prevailing change from m = 0 to m = 0.5 is 30°, but with considerable variation.

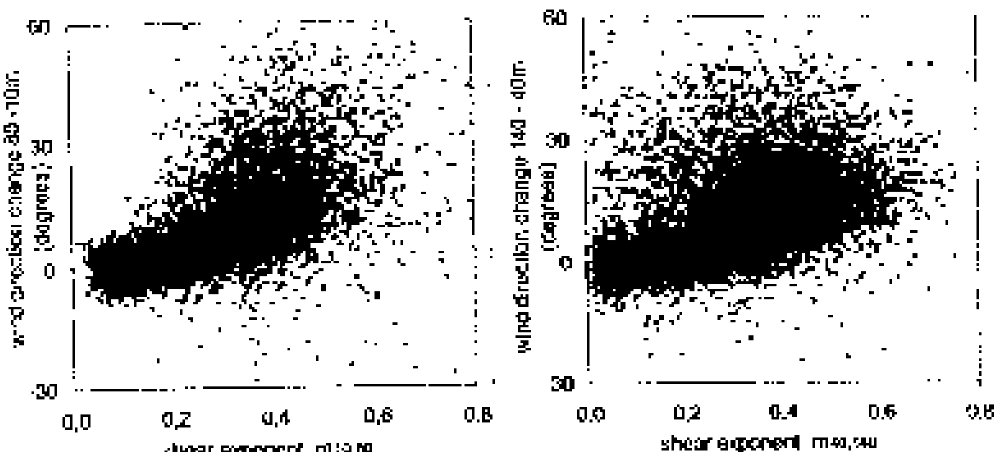


Figure VI.8: wind direction change between 10 and 80 m (left) and 40 and 140 m (right) vs. shear exponent m between same heights for V_{80} > 4 m/s

VI.4.4 Prevalence of stability

In figure VI.9 the percentages are given that the atmosphere is very stable, stable, neutral and unstable respectively (as defined in table VI.1) for 1987 as a whole and per meteorological season. Prevalence is given for heights from 10 and 80 m (upper panel figure VI.9) and for heights from 40 to 140 m (lower panel). The upper panel is in fact a summation over the four ranges of the shear exponent indicated in figure VI.6. It appears that in autumn the atmosphere is most often stable, and least often unstable. In spring the opposite is true: instability occurs more often than stability. Overall the atmosphere up to 80 m is unstable (m < 0.21) for 47% of the time and stable (m > 0.25) for 43% of the time. At higher altitudes (40 to 140 m) percentages are almost the same: 44% and 47%, respectively. This means that for most of the daytime hours the atmosphere is unstable, and for most of the night time hours stable. For the rest (9 to 10%) of the time the atmosphere is near neutral.

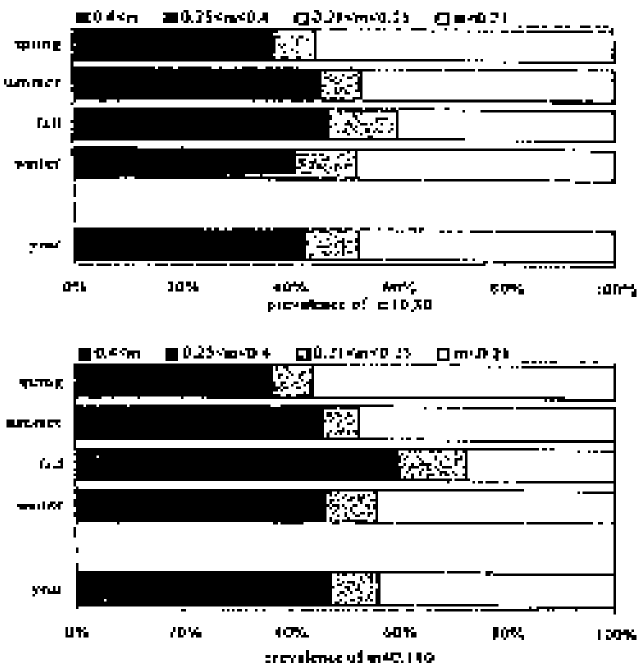


Figure VI.9: prevalence of shear exponent m between 10 and 80 m (top) and 40 and 140 m (bottom) in four seasons and year of 1987

Climatological observations can put the Cabauw data in national perspective. In figure VI.10 the prevalence of Pasquill classes E and F (corresponding to approximately m > 0.33) are given as observed at 12 meteorological stations all over the Netherlands over the period 1940 - 1970 [KNMI 1972], ordered according to yearly prevalence. Three of the dunes on the North Sea coast, Vlissingen is at the Westerschelde estuary and Den Helder is on a peninsula between the North Sea and the Wadden Sea. At Den Helder a stable atmosphere occurs for only 8% of the time per year, whereas at both other coastal stations this is 13% to 16% and at the other landward stations 15% to 20% of the time. At Cabauw a value of $m > 0.33$ occurs for 27% of the time.

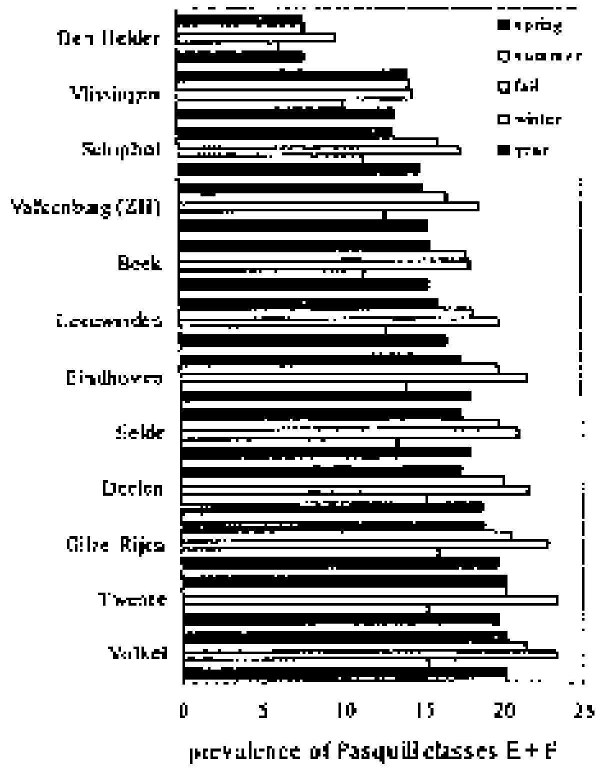


Figure VI.10: prevalence of observed stability (Pasquill classes E and F) per season and per year at 12 different Dutch stations over 30 years (data from [KNMI

VI.5. Results: effects on wind turbine performance

VI.5.1 Effect on power production

The effect of atmospheric stability can be investigated by applying the Cabauw data to a reference wind turbine, the Vestas V80-2MW [Vestas 2003, Jorgensen 2002]. This turbine has an 'Optispeed' sound reduction possibility to reduce sound power level (by adapting the speed of the rotor and generator). We will present data for the highest ('105.1dB(A)') and lowest ('101.0dB(A)') sound power curve. To calculate the electric power P80 as a function of wind velocity V_h at hub height the factory '105.1dB(A)' highest power ('hp') curve is approximated with a fourth power polynome:

$$P_{h,bp} = 0.0885 \cdot V_h^4 - 8.35 \cdot V_h^3 + 186 \cdot V_h^2 - 1273 \cdot V_h + 2897 \quad \text{kW} \qquad \text{(VI.1a)}$$

which is valid for $4 < V_h < 14.3$ m/s. In figure VI.11 this fitted curve is plotted as diamonds on top of the manufacturer's specification [Vestas 2003]. For higher wind velocities (>14.3 m/s; 2% of time at Cabauw) electric power is constant at 2000 kW, for lower wind velocities (< 4 m/s; 20% of time) electric power is set to zero.

A fourth power relation is used as this is convenient to fit the power curve at 12 m/s where maximum power is approached. For lower wind velocities (V_h < 11 m/s) the power curve can be fitted with a third power ($P_h = 1.3 \cdot V_h^3$) in agreement with the physical relation between wind power and wind velocity.

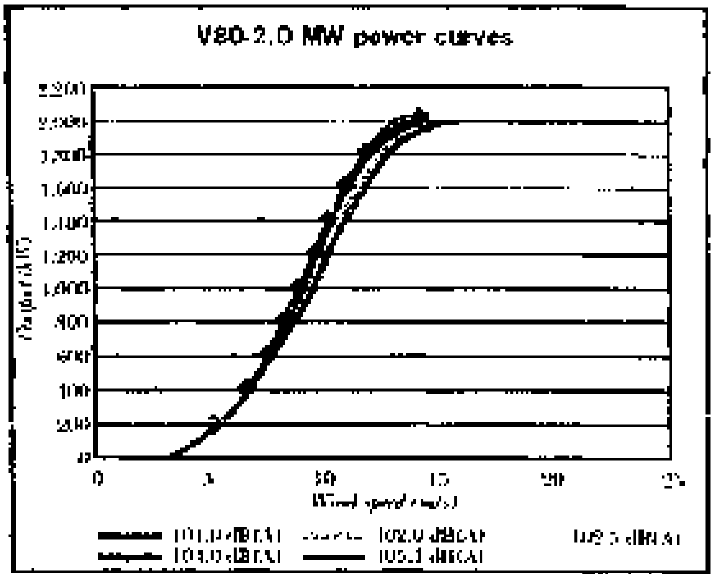


Figure VI.11: lines: Vestas V80 power curves vs. hub height wind speed; diamonds: best fit to 105.1dB(A) curve (figure adapted from [Vestas 2003])

Electric power can thus be calculated from real wind velocities as measured each half hour at 80 m height, or from 80-m wind velocities logarithmically extrapolated from wind velocity at 10 m height. The result is plotted in figure VI.12 as an average power versus time of day $P_{80,hp}$ (the power averages are over all hours in 1987 at each clock hour). Actual power production appears to be more constant than estimated with extrapolations from 10-m wind velocities. When using a logarithmic extrapolation, daytime power production is overestimated, while night time power production is underestimated. The all year average is plotted with large symbols at the right side of the graph in figure VI.12: 598 kW when based on measured wind velocity or a 30% annual load factor, 495 kW when based on extrapolated wind velocity or a 25% load factor. In figure VI.12 also the wind power is plotted when the turbine operates in the lowest '101.0dB(A)' power curve ('lp') where the best fit is:

$$P_{h,lp} = 0.089 \cdot V_h^4 + 0.265 \cdot V_h^3 + 43 \cdot V_h^2 - 326 \cdot V_h + 749 \text{ kW} \qquad \text{(VI.1b)}$$

The year average is now 569 kW, corresponding to a 28% annual load factor. The 4 dB lower sound level setting thus means that yearly power production has decreased to a factor 0.94

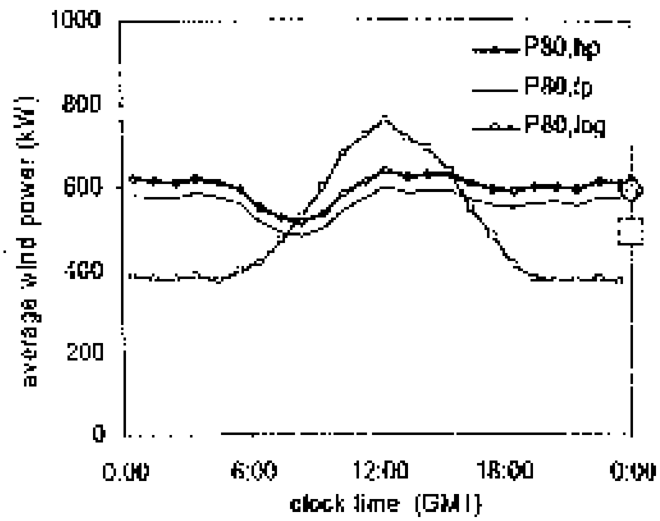


Figure VI.12: hourly averaged estimated (log) and real wind power at 80 m height per clock hour in 1987

In the calculations it was implicitly assumed that the wind velocity gradient over the rotor was the same as at the time the power production was determined as a function of hub height wind velocity. In stable conditions however, the higher wind gradient causes a non-optimal angle of attack at the blade tips when the tips travel far below and above the hub. This will involve some loss, which is not determined here.

VI.5.2 Effect on sound production

Figure VI.13 shows 'theoretical' sound power levels for the Vestas turbine [Vestas 2003, Jorgensen 2002]; in fact for $V_h < 8$ m/s measured levels are somewhat lower, for $V_h > 8$ m/s somewhat higher [Jorgensen 2002]. To calculate the sound power level L_W as a function of hub height wind velocity V_h the factory '105.1dB(A)' high power curve is approximated with a fourth power polynome:

$$L_{W,hp} = -0.0023 \cdot V_h^4 + 0.146 \cdot V_h^3 - 2.82 \cdot V_h^2 + 22.6 \cdot V_h + 39.5 \quad \text{dB(A)} \qquad \text{(VI.2a)}$$

for $4 < V_h < 12$ m/s and $L_{W,hp} = 107$ dB(A) for $V_h > 12$ m/s. In figure VI.14 the result per clock hour is plotted when using actual and extrapolated (from 10 m) wind velocities. Averaged over all 1987 the sound power level in daytime is overestimated by 0.5 dB, but at night underestimated by 2 dB. In the '101.0dB(A)' low power curve setting the best fourth power polynomal fit is (in figure VI.13 plotted as diamonds over the Vestas curve):

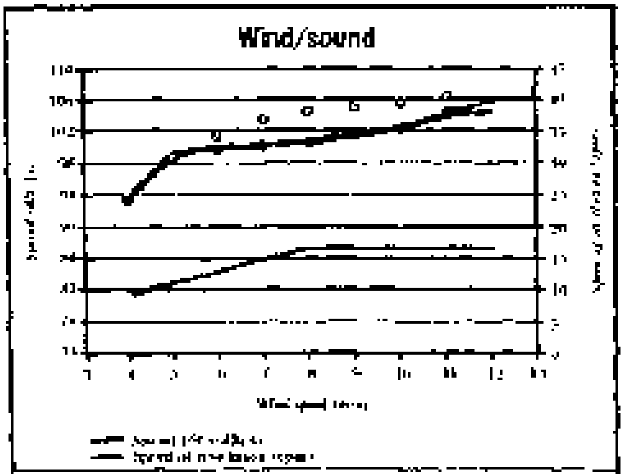


Figure VI.13: Vestas V80 sound power level at '101.0dB(A)' (diamonds and upper line) and '105.1dB(A)' power curve (circles); lower line: speed of rotation vs. hub height

$$L_{W,lo} = -0.022 \cdot V_S^4 + 0.78 \cdot V_h^3 - 10 \cdot V_h^2 + 55.3 \cdot V_h - 12.3 \quad \text{dB(A)} \qquad \text{(VI.2b)}$$

for $4 < V_h < 12$ m/s and $L_{W,hp} = 105$ dB(A) for $V_h > 12$ m/s. The sound power levels in this setting are, for $6 < V_h < 12$ m/s, on average 3 dB lower than in the high power setting.

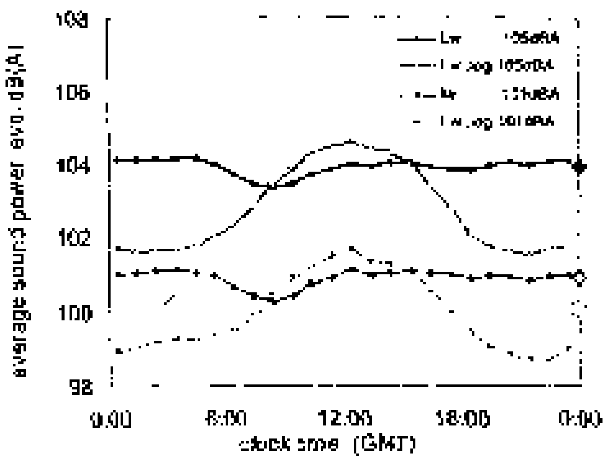


Figure VI.14: hourly averaged real and estimated (log) sound power level at '105.1dB(A)' and '101.0dB(A)' power curves

The differences between actual and logarithmically predicted sound power levels can be bigger than the over one year hourly averaged values in figure VI.14 show. This is illustrated in figure VI.15 for two days each in January and July 1987 (also shown in figure VI.3) where actual and predicted half-hour sound power levels are plotted as a function of 10-m wind velocity. On both winter days actual sound power agrees within 1 dB with the predicted sound power for wind velocities $V_{10} > 5.5$ m/s; at lower 10-m wind velocities actual levels are rather higher for most of the time. On both summer days the 10-m wind velocities are lower than in winter, and sound power level now is more often higher than predicted and can reach near maximum levels even at very low (2.5 m/s) 10-m wind velocities (when at ground level people will probably feel no wind at all). In these conditions residents in a quiet area will perceive the highest contrast: hardly or no wind induced sound in vegetation, while the turbine(s) are rotating at almost top speed. In these conditions also an increased fluctuation strength of the turbine sound will occur (see chapter V), making the sound more conspicuous.

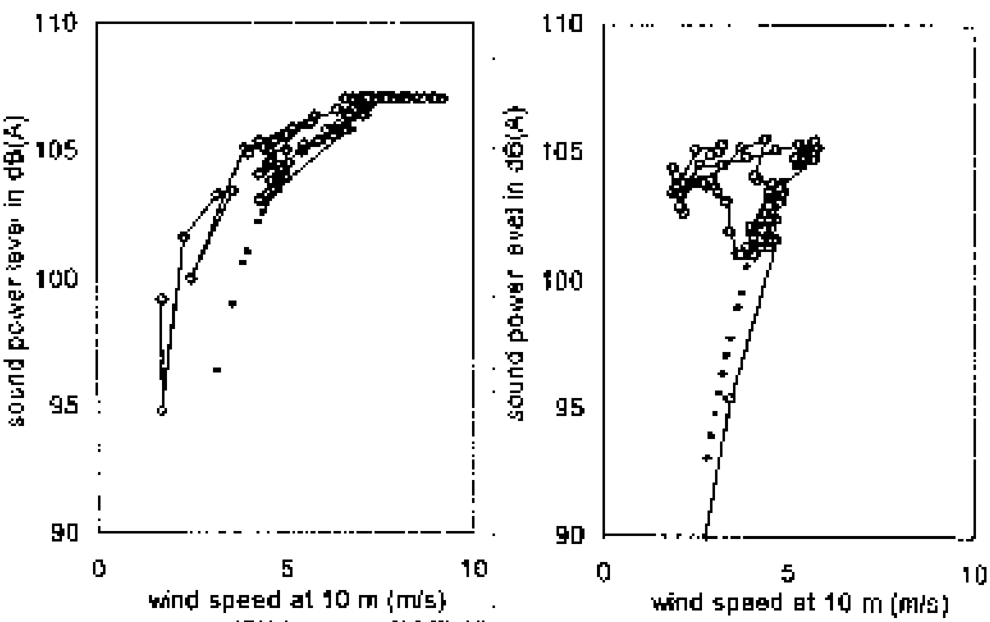


Figure VI.15: half-hourly progress of actual (grey diamonds) and logaritmically predicted (black dots) sound power level plotted vs. 10-m wind speed over 48 hours; left: January 13-14; right: July 2-3

VI.6 Other onshore results

Values of wind shear have been reported by various authors, showing similar results. Pérez *et al* [2005] measured wind velocities up to 500 m above an 840 m altitude plateau north of Valladolid, Spain, for every hour over sixteen months. The shear exponent, calculated from the wind velocity at 40 m and 220 m, varied from 0.05 to 0.95, but was more usual between 0.1 and 0.7. High shear exponents occurred more often than in Cabauw: $m > 0.48$ for 50% of the time. This is likely the result of the more southern position: insolation is higher, causing bigger temperature differences between day and night, and the atmosphere above the plateau is probably drier causing less reflection of outward infrared radiation at night. There was a distinct seasonal pattern, with little day-night differences in January, and very pronounced differences in July.

Smith *et al* [2002] used data from wind turbine sites in the US Midwest over periods of 1.5 to 2.5 years and calculated shear exponents for wind velocities between a low altitude of 25 - 40 m and a high altitude of 40 – 123 m. At four sites the hourly averaged night time (22:00 – 6:00) shear exponent ranged from 0.26 to 0.44, in daytime from 0.09 to 0.19. The fifth station (Ft. Davis, Texas) was exceptional with a day and night time wind shear below 0.17 and a very low day time wind shear ($m = 0.05$).

Archer *et al* [2003] investigated wind velocities at 10 m and 80 m from over 1300 meteorological stations in the continental USA. No shear statistics are given, but for 10 stations the ratio V_{80}/V_{10} is plotted versus time of day. At all these stations the ratio is 1.4 ± 0.2 in most of the daytime and 2.1 ± 0.3 in most of the night time. Using equation III.4, it follows that the shear exponent has a value of 0.15 ± 0.07 and 0.35 ± 0.07, respectively.

At the 2005 Berlin Conference on Wind Turbine Noise two presentations added to these wind shear data, now (also) from a noise perspective. Harders *et al* [2005] showed hourly wind velocity averaged over the year 2000 at altitudes between 10 and 98 m from the Lindenberg Observatory near Berlin. The results are very much like those in figure VI.2, with a wind velocity ratio $V_{80}/V_{10} = 1.3$ at noon, increasing to 1.9 in night time hours. This corresponds to an avarage shear exponent of 0.13 and 0.3, respectively.

Botha [2005] presented results from 8 to 12 months measurements at sites in two flat Australian areas and two sites in more complex (non flat) New Zealand terrain. On the Australian sites the average day time wind velocity ratio V_{80}/V_{10} was 1.5, in night time 1.7 and 1.8. This corresponds to shear exponents of to 0.19 and 0.26 to 0.28, respectively. In the hilly New Zealand areas the average wind velocity ratio was between 1.2 and 1.25 in day as well as night time, from which the shear exponent can be calculated as 0.1.

From the measurements at the Rhede wind farm the shear exponent could be calculated from the 10-m and 100-m wind velocity, the latter determined from the sound level and the relation between sound power level and hub height (100 m) wind velocity. This was done for all (892) five minute periods when wind turbine sound was dominant between 23:00 and 04:00 hours within the measurement period (May and June; location A in figure IV.2). From the Cabauw data the same period and time was selected and all values of the half-hour shear exponent $m_{10,80}$ were determined. For both locations the resulting frequency distributions of the shear exponent are plotted in figure VI.16. The distributions are rather similar and show that a stable atmosphere ($m > 0.25$) occurred for over 95% of the time in night time hours (23 - 4 o'clock) in spring (May – June) at Cabauw as well as at Rhede.

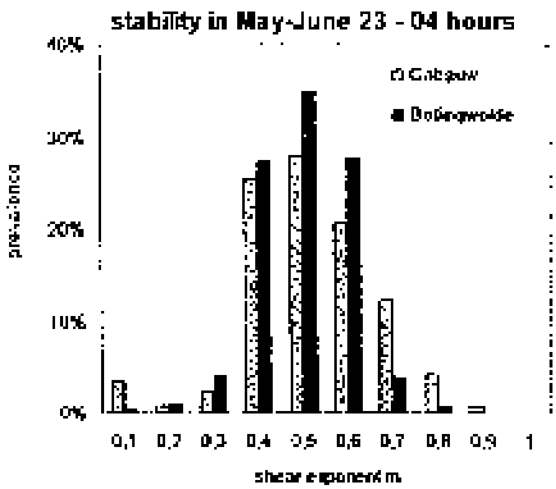


Figure VI.16: frequency distribution of the shear exponent at Cabauw and in the measurement period near the Rhede wind farm in the same period of time

VI.7 Conclusion

Results from various landward areas show that the shear exponent in the lower atmospheric boundary layer (< 200 m) in daytime is 0.1 to 0.2, corresponding to a wind velocity ratio V_{80}/V_{10} of 1.25 to 1.5. The associated wind profile is comparable to the profile predicted by the well-known logarithmic wind profile for low roughness lengths (low vegetation).

At night the situation is quite different and in various landward areas the shear exponent has a much wider range with values up to 1, but more usually between 0.25 and 0.7. Near the Rhede wind farm the same range of wind shear occurred, showing that the site indeed was suitable to study the effect of atmospheric stability on wind turbine performance and representative for many other locations.

A shear exponent $0.25 < m < 0.7$ means that the ratio V_{80}/V_{10} varies between 1.7 and 4.3. High altitude wind velocities are thus (much) higher than expected from logarithmic extrapolation of 10-m wind velocities.

A high wind shear at night is very common and must be regarded a standard feature of the night time atmosphere in the temperate zone and over land. In fact the atmosphere is neutral for only a small part (approximately 10%) of the time. For the rest it is either stable (sun down) or unstable (sun up).

As far as wind power concerns, the underestimate of high altitude night time wind velocity has been compensated somewhat by the overestimate of high altitude daytime wind velocity. This may partly explain why, until recently, atmospheric stability was not recognized as an important determinant for wind power.

To assess wind turbine electrical and sound power production the use of a neutral wind profile should be abandoned as it yields data that are not consistent with reality.

VII THINKING OF SOLUTIONS: measures to mitigate night time wind turbine noise

VII.1 Meeting noise limits

Sound from modern wind turbines is predominantly the result of turbulence on the blades; reduction of this source is the topic of dedicated research, such as the SIROCCO (*Si*lent *ro*tors by a*c*oustic optimisation) program which seeks to improve the design of the wind turbine blade; in the near future a reduction of approximately 2 dB might be achieved [Schepers *et al* 2005]. Sound reduction by reducing blade speed is an option already available in modern turbines.
In this chapter we will deal with the ('added') sound produced by a wind turbine due to increased atmospheric stability. To address this problem two types of mitigation measures can be explored:

1. reduce the sound level down to to the pertinent (legal) limit for environmental noise;
2. reduce the level variations due to blade swish/beating.

The first measure of course must be pursued as it is a legal obligation. The need for reduction depends on the type of limit. *E.g.*, in Germany the limit applies to the maximum sound immission level (the level produced at nominal maximum power), regardless of wind velocity as such. In many countries the limit is based on the wind velocity related background ambient sound level (L_{95} or L_{90}). In the UK and elsewhere the limit is a constant at low 10-m wind velocities and 5 dB above ambient background level (L_{90} + 5 dB) at higher 10-m wind velocities. In the Netherlands the standard limit is a reference curve constructed from a constant value at low 10-m wind velocities and a wind velocity dependent part at higher 10-m wind velocities (see figure VII.1). For wind farms over 15 MW other limit values may apply, and local authorities may enforce other limits in 'non-standard' local conditions.

In assessments of wind turbine noise immission the effect of atmospheric stability has usually been disregarded and the 10-m wind velocity was erroneously used for all atmospheric conditions. In that case high sound levels only occur at high wind velocities and this can be accommodated by limit values as in figure VII.1. In reality however these limits are not always met as high immission sound levels already occur at a lower 10-m wind velocity. This implies that an extra effort to reduce the immission level may be necessary.

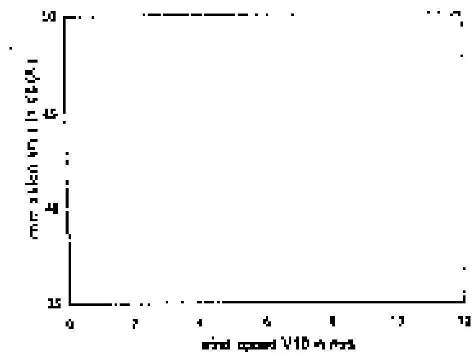


Figure VII.1: standard Dutch limit for night time wind turbine immission sound level

In hilly and certainly in mountainous terrain this change in wind profile may be influenced or even overridden by relief related changes. For example: in a valley a down flowing (decelerating) wind may enhance the effect of stability, whereas an up flowing (accelerating) wind may compensate the effect of stability. Furthermore the wind profile as well as the temperature profile will simultaneously influence the propagation paths of sound. Combined effects are therefore complex and, though readily understood qualitatively, not easily predicted quantitatively.

The second measure is worth considering when the noise limit incorporates a penalty for a sound having a distinctive (impulsive or fluctuating) character. In that case either the sound immission level should be reduced by a value equal to the penalty (usually 5 dB) or the sound character must change.

VII.2 Reduction of sound level

When the sound immission level is limited to a value depending on the 10-m wind velocity or the (supposedly 10-m wind velocity dependent) ambient sound level, the problem is that hub height wind velocity is not uniquely related to 10-m wind velocity and the sound emission as well as immission level can have a range of levels depending on atmospheric stability. The turbine thus operates at hub height wind velocity, but must be controlled by a 10-m based wind velocity. To decrease the sound level from a given turbine the speed of rotation can be decreased, either by directly changing blade pitch or indirectly by changing the mechanical load (torque) on the rotor. This implies a lower efficiency at the turbine as the tip speed ratio $\Omega \cdot R/V_0$ will decrease and deviate from its value optimized for produced power. It is necessary to find a new optimum that also takes noise production into account.

VII.2.1 Wind velocity controlled sound emission

As a result of opposition to wind farm proposals in the relatively densely populated central province of Utrecht in the Netherlands all proposals were cancelled but one. The exception is in Houten (incidentally 8 km east of Cabauw; see previous chapter), where the local authorities want to stimulate wind energy by allowing the constructing of several 3 MW turbines, at the same time ensuring that residents will not be seriously annoyed. Atmospheric stability is taken into account by not accepting the usual logarithmic relation between 10-m and hub height wind velocity. The official permission will require that the immission sound level at specified locations must not exceed the background level of all existing ambient sound. Of course ambient sound level depends on wind velocity if the wind is sufficiently strong, but in this area it also depends on wind direction as that determines audibility of distant sources: a motorway to the west, the town to the north-east and relatively quiet agricultural land to the south-east. So the ambient background level, measured as L_{95}, must be measured in a number of conditions: as a function of wind velocity (1 m/s classes), wind direction (4 quadrants) and time of day (day, evening, night). These values equal the limit values for the immission level L_{imm} and from this it can be calculated what the maximum allowable sound power level L_{Wmax} per turbine is at every condition, presuming all (or perhaps a selection of) turbines produce. It is advisable to determine wind characteristics and turbine performance over a period of at least five minutes, as wind velocity variations are relatively strong at frequencies above approximately 3 mHz (inverse of 5 min) and weak at lower frequencies down to the order of 0.1 mHz (inverse of several hours) [Wagner *et al* 1996]. On the other hand it is desirable to adapt to changing conditions, so averaging over 5 minutes seems a good choice.

Control will thus be achieved in a number of steps:

1. measure wind direction D_{10} and wind velocity V_{10} in open land over a 5-minute period; from this determine the ambient back ground level from the previously established relation $L_{95}(D_{10},V_{10})$.
2. determine the limit value for the sound power level L_{Wmax} from the previously established relation $L_{imm}(L_W)$; the limit value is determined by $L_{imm} = L_{95}$.
3. determine the actual sound power level $L_{W,5min}$ from wind turbine performance (electric power or speed);
4. if $L_{W,5min} > L_{Wmax}$ (equivalent to $L_{imm} > L_{95}$) the control system must decrease sound power level for the next period; if $L_{W,5min} < L_{Wmax}$ the reverse applies (until maximum speed is attained).

The pro's of this control system are that it is straightforward, simple, easy to implement and directly related to existing Dutch noise limits. However, it is based on the assumption that L_{95} depends on three parameters only: wind velocity, wind direction and diurnal period (day, evening, night). In reality background level will also vary within a diurnal period (*e.g.* traffic: nights are very quiet at around 4 AM and most busy just before 7 AM), and it will depend on the day of the week (*e.g.* Sunday mornings are quieter than weekday mornings), the season (vegetation, holidays), the degree of atmospheric stability (no wind in low vegetation in stable conditions, even when 10 m wind velocity is several m/s) and other weather conditions such as rain. Also sound immission from distant sources will differ with weather conditions.

Measurements show that indeed 10-m wind velocity is not a precise predictor of ambient sound level. These measurements were performed from June 9 through June 20, 2005 at two locations: wind velocity was measured at 10-m height in open terrain, at least 250 m from any obstacles over 1 m height (trees lining the busy and broad Amsterdam-Rhine Canal to the northeast) and over 1000 m from obstacles in any other direction; the sound level was measured close to a farm next to the canal (see figure VII.2). Total measurement time was 220 hours.

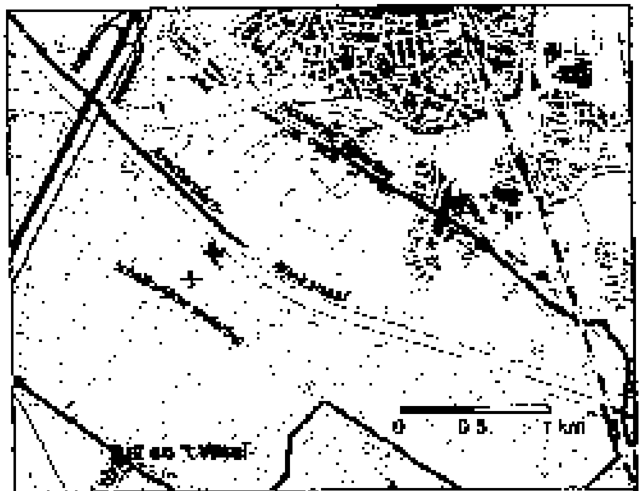


Figure VII.2: measurement locations for wind speed and direction (light cross) and ambient sound level (heavy cross) close to Houten (in upper part of map); top is north

Some results are plotted in figure VII.3: L_{95} per 5-minute period as a function of wind velocity, separately for two opposite wind directions (left and right panel) and two periods (black and blue markers). The periods are night (23 PM – 7 AM) and day (7 AM – 7 PM), the wind directions southeast (90° - 180° relative to north) and northwest (270° - 360°), where respectively the lowest and highest ambient levels were expected. The northwest data total 675 5-minute periods or 26% of all measurement time, the southeast data cover 511 periods or 19% of the measurement time.

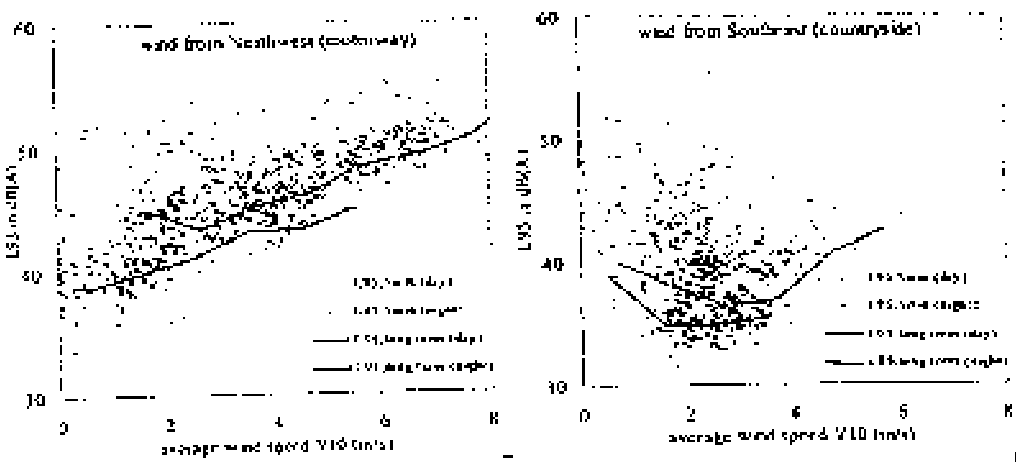


Figure VII.3: 5-minute $L_{95,5min}$ in day (open, grey diamonds) and night time (solid, black dots) and long-term L_{95} (lines) as a function of 10-m wind velocity in open terrain for two different wind directions

The values of $L_{95,5min}$ are calculated from all (300) 1-second samples of the sound pressure level within each 5-minute period, wind velocity is the average value of all 1-second samples of the wind velocity. To determine a long-term background level an appropriate selection (wind direction, period) of all measured 1-second sound levels can be aggregated in 1 m/s wind velocity classes (0-1 m/s, 1-2 m/s, etc.). In figure VII.3 these aggregated values (connected by lines to assist visibility) are plotted for day and night separately. It is clear that in many cases the 5-minute period values of L_{95} are higher, in less cases lower than the long-term value. This means that if the immission limit is based on the measured long-term background sound level, then in a significant amount of time the actual background level will not be equal to the previously established long-term background level. In many instances the actual value of L_{95} is higher than the long-term background level $L_{95,lt}$, which would allow for more wind turbine sound at that time.[1]

VII.3.2 Ambient sound level controlled sound emission

An alternative to a wind velocity controlled emission level is to measure the ambient sound level itself and thus determine the actual limit value directly. If the limit is L_{95}, then the immission level must be $L_{imm} \leq L_{95}$. To achieve this the background ambient sound level can be determined by measurement (e.g. in 5-minute intervals) and compared to the immission level calculated from the actual turbine performance. If the immission level L_{imm} would exactly equal the ambient background level L_{95} without turbine sound, it would attain its maximum value $L_{imm,max}$ = L_{95}. Then background sound level including turbine sound would be L_{95+wt} = log.sum($L_{imm,max}$ + L_{95}) = $L_{imm,max}$ + 3 dB or $L_{imm,max}$ = L_{95+wt} - 3 dB. If the calculated immission level exceeds the measured ambient level L_{95+wt} - 3, turbine sound apparently dominates the background level and the turbine should slow down.

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[1] perhaps for this reason the approach in the British ETSU-R-97 guideline [ETSU 1996] is to not use the long-term $L_{A90,lt}$ but an average of 10 minute $L_{A90,10min}$ values; this odd statistical construction can be viewed as an inefficient compromise that effectively allows excess of an appropriate limit in half of the time and a too severe limit in the other half

This type of control can also be achieved in several steps. Again assuming 5-minute measurement periods, these are:

1. determine the actual sound power level $L_{W,5min}$ (integrated over 5 minutes) from turbine power production or speed.
2. determine L_{imm} from the previously established relation $L_{imm}(L_W)$.
3. measure actual background level $L_{95+wt,5min}$ at a location where the limit applies;
4. if $L_{imm} > L_{95+wt,5min} - 3$ dB, then $L_{W,5min} > L_{Wmax}$ and the control system must decrease sound power level for the next 5-minute period, if $L_{W,5min} < L_{Wmax}$ the reverse must happen (until maximum speed is attained).

Here it is assumed that the microphone is on a location where immission level must not exceed the ambient background level. If a measurement location is chosen further away from the turbine(s), the immission sound level will decrease with a factor ΔL_{imm} at constant L_W, whereas L_{95} will not change (assuming that 5-minute ambient background sound does not depend on location). In this case a correction must be applied to the measured L_{95+wt} ($L_{imm,max} = L_{95+wt} - 10 \cdot \log(1+10^{-0.1 \cdot \Delta L_{imm}})$) to determine what sound power level is acceptable. An advantage of a more distant measurement location is that it is less influenced by the turbine sound. A similar approach may be used if the limit is not L_{95} itself, but L_{95} + 5 dB. In that case, is it not possible to determine L_{95} from measurements at a location where this limit applies, as the turbine sound is allowed to be twice as intense as background sound itself. In that case a measurement location may be chosen where, e.g., ΔL_{imm} = 5 dB.

An apparent drawback of this sound based control is that measured ambient sound may be contaminated by local sounds, that is: from a source close to the microphone, increasing only the local ambient sound level. Also, figure VII.3 suggests that there are significant variations in $L_{95,5min}$, which could imply large control imposed power excursions if these variations occur in short time.

The first drawback can be solved by using two or more microphones far enough apart not to be *both* influenced by a local source. The limit value is then either $L_{95,5min}$ determined from all measured sound levels within the previous 5-minute period, or the lowest value of $L_{95,5min}$ from each microphone location. It must be borne in mind that the value of $L_{95,5min}$ is not sensitive to sounds of short duration. Sounds from birds or passing vehicles or airplanes do not influence a measured $L_{95,5min}$ significantly, except when they are present for most of the time within the 5 minute period.

With regard to the second point: large variations in either wind velocity or background sound level are rare, as is shown in figure VII.4 where the difference is plotted between consecutive 5-minute values of L_{95} and average free 10-m wind velocity. The change in wind velocity averaged over consecutive periods of 5 is less than 0.5 m/s in 72% of the time, and less than 1.5 m/s in 99% of the time. The change in background sound level over consecutive periods of 5 minutes is less than 2.5 dB in 88% of the time and less than 3.5 dB in 94% of the time. So, if the adjustment of sound power level is in steps no larger than 3 dB, most changes can be dealt with in a single step. This also holds when a longer averaging period of 15 minutes is chosen: the change in background sound level over

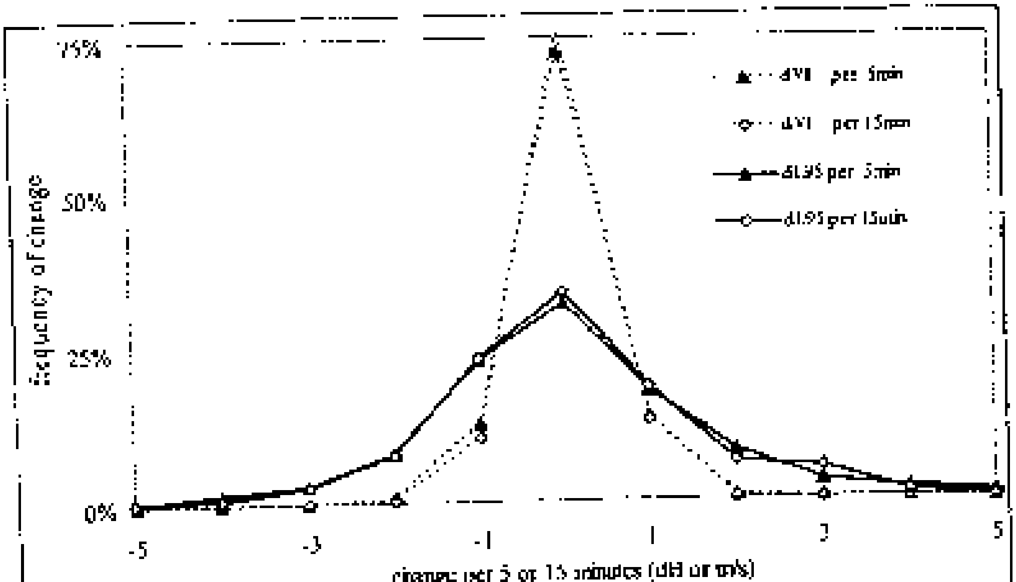


Figure VII.4: frequency distributions of changes per 5 and per 15 minutes of average wind velocity and background ambient sound level in classes of one unit (dB or m/s)

consecutive periods of 15 minutes is less than 2.5 dB in 89% of the time and less than 3.5 dB in 96% of the time.
The frequency of changes between 5-minute periods that are 10 minutes apart (that is: with two 5-minute periods in between) is very similar to the distributions in figure VII.4. This means that when there is a change of 3 dB for two consecutive periods, it is unlikely a similar change occurs within the next one or two periods.

VII.4 Reduction of fluctuations in sound level

The level variation due to blade swish increases when the atmosphere becomes more stable because the angle of attack on the blade changes. As a result the turbulent layer at the trailing edge of the blade becomes thicker and produces more sound. In a wind farm the increased level variations from two or more turbines turbines may coincide to produce still higher fluctuations. The increase of blade swish, or rather: blade beating, may be lessened by adapting the blade pitch angle, the increase due to coincidence (also) by desynchronizing turbines.

VII.4.1 Pitch angle

When a blade rotates in a vertical plane the optimum blade pitch angle α is determined by the ratio of the wind velocity and the rotational speed of the blade. As the rotational speed is a function of radial distance (from the hub), blade pitch changes over the blade length and is lowest at the tip. As the wind velocity closer to the ground is usually lower, the wind velocity at the low tip (where the tip passes the tower) is lower than at the high tip. As a result the angle of attack changes within a rotation if blade pitch is kept constant. For a 100 m hub height and 70 m diameter turbine at 20 rpm this change (relative to hub height) is about 0.5° at the lower tip in an unstable atmosphere, increasing to almost 2° in a very stable atmosphere (see section V 1). Added to this is a further change (of the order of 2°) in the angle of attack in front of the tower due to the fact that the tower is an obstacle slowing down air passing the tower. At the high tip the change in angle of attack is -0.3° (unstable) to -1.7° (very stable).

The optimum angle of attack of the incoming air at every position of the rotating blade can be realized by adapting the blade pitch angle to the local wind velocity. Pitch must then increase for a blade going upward and decrease on the downward flight. Such a continuous change in blade pitch is common in helicopter technology. If the effect of stability on the wind profile would be compensated by pitch control, blade swish due to the presence of the tower would still be left. This residual blade swish can be eliminated by an extra decrease in blade pitch close to the tower. If the variations in angle of attack can be reduced to 1° or less, blade swish will cause variations less than 2 dB which are not perceived as fluctuating sound.

VII.4.2 Rotor tilt

If the rotor is tilted backwards, a blade element will move forward on the downward stroke and backward on the upward stroke, thus having a varying velocity component in the direction of the wind. As a result the angle of attack will change while the blade rotates because the flow angle will depend on blade position. If the tilt angle changes from zero to θ, the flow angle at the low tip increases from φ to φ' (see figure III.2). From geometrical considerations (see figure VII.5) of a blade segment tilted around a horizontal axis, it follows that $C\cdot\sin\varphi + r\cdot\tan\theta = r\cdot\tan(\theta + \gamma)$, where $\gamma = \arctan(C\sin\varphi/r)$. This leads to:

$$\sin\varphi' = S\cdot(\tan[\theta + \arctan(\sin\varphi/S)] - \tan\theta) \quad \text{(VII.1)}$$

where $S = r/C$ is the ratio of radius r and blade width (or chord length) C at radius r. For small blade pitch angles and blade slenderness S between 10 and 40 the

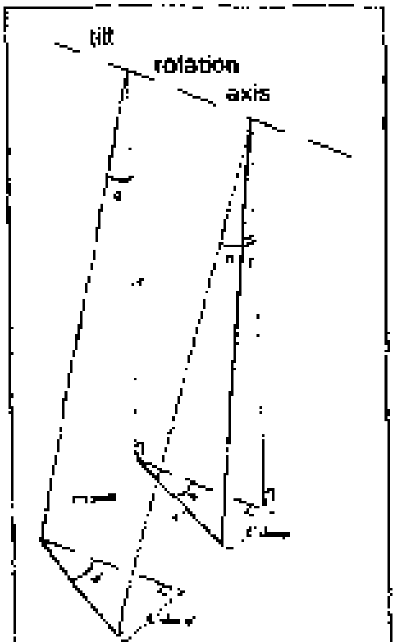


Figure VII.5: change of flow angle $\varphi \rightarrow \varphi'$ when blade is tilted over an angle θ around a horizontal axis increase of blade pitch with tilt (from 0 to θ) can be approximated with:

$$\Delta\varphi = \varphi' - \varphi = 1.1 \cdot \varphi \cdot \theta^2 \qquad \text{(angles in radians)} \qquad \text{(VII.2a)}$$

For values of φ, S and θ in the range φ ≤ 10°, 30 ≤ S ≤ 50 and θ ≤ 20°, the standard deviation of the constant 1.1 is 0.01. With angles expressed in degrees, equation VII.2a reads:

$$\Delta\varphi = 33 \cdot 10^{-5} \cdot \varphi \cdot \theta^2 \qquad \text{(angles in degrees)} \qquad \text{VII.2b)}$$

This means that for a tilt angle of 2° and a 6° blade pitch (tip rotational speed 70 m/s, induced wind velocity 10 m/s, angle of attack 2°), the change in angle of attack (relative to a vertical rotor with zero tilt) is negligible (0.008°). Rotor tilt could now compensate a 1° change in angle of attack at the low tip when the tilt angle is 22°. In this case the horizontal distance between the low tip and the turbine tower increases with approximately 15 m. This will in turn lead to a smaller change in angle of attack as at this distance the velocity deficit due to the presence of the tower is lower. For higher values of the blade pitch angle (*ceteris paribus* implying lower values of the angle of attack) increasing the tilt angle has a bigger effect. A substantial tilt however has major disadvantages as it decreases the rotor surface normal to the wind and induces a flow component parallel to the rotor surface which again changes the inflow angle. It therefore does not seem an efficient way to reduce the fluctuation level

VII.4.3 Desynchronization of turbines

When the atmosphere becomes stable, large scale turbulence becomes weaker and wind velocity is more coherent over larger distances. The result is that different turbines in a wind farm are exposed to a wind with less variations, and near-synchronization of the turbines may lead to coincidence of blade beats from two or more turbines for an observer near the wind farm, and thus higher pulse levels (see section V.2.4). To desynchronize the turbines in this situation, the random variation induced by atmospheric turbulence (such as occurs in an unstable and neutral atmosphere) can be simulated by small and random fluctuations of the blade pitch angle or the electric load of each turbine separately.

In an unstable atmosphere turbulence strength peaks at a non-dimensional frequency n = $fz/V \approx 0.01$, where V is the mean wind velocity and z is height (this is according to custom in acoustics; in atmospheric physics traditionally f is non-dimensional and n physical frequency). At z = 100 m and V = 10 m/s this corresponds to a physical frequency $f = nV/z = 1$ mHz. At higher frequencies the turbulence spectral power density decreases with $f^{-5/3}$. When atmospheric instability decreases, the maximum shifts to a higher frequency and wind velocity fluctuations in the non-dimensional frequency range of 0.01 to 1 tend to vanish. So, to simulate atmospheric turbulence the blade pitch setting of each turbine (or the load imposed by the generator) must be fed independently with a signal corresponding to noise such as pink (f^{-1}) or brown (f^{-2}) noise, in the range of appr. 1 to 100 mHz. The (total) amplitude of this signal must be determined from local conditions, but is of the order of 1°.

VII.5 Conclusion

Wind turbine noise has shown to be a complex phenomenon. In the future quieter blades will be available, reducing sound emission by some 2 dB. The only presently available effective measures to decrease the sound impact of modern turbines are to create more distance or to slow down the rotor.

In existing turbines the sound immission level can be decreased by controlling the sound emission, which in turn is decreased by slowing down the rotor speed. When the limit is a single maximum sound immission level, this in fact dictates minimum distance for a given turbine and there is no further legal obligation to control.

In other cases the control strategy will depend on whether the legally enforced limit is a 10-m wind velocity or an ambient background sound level dependent limit. The 10-m wind velocity or the background sound level act as the control system input, blade pitch and/or load on the rotor is the controlled parameter. In both cases a suitable place must be chosen to measure the input parameter. For background sound level as input it is probably necessary to use two or more inputs to minimize the influence of local (near-microphone) sounds. It may however be the best strategy in

relatively quiet areas as it controls an important impact parameter: the level above background or intrusiveness of the wind turbine sound.
Controlling sound emission requires a new strategy in wind turbine control: in the present situation there is usually more room for sound in daytime and in very windy nights, but less in quiet nights.

A clear characteristic of night time wind turbine noise is its beating character. Even if the sound emission level does not change, annoyance may decrease by eliminating the rhythm due to the blades passing the tower. Again, a lower rotational speed will help as this reduces the overall level including the pulse level. A better solution is to continuously change the blade pitch, adapting the angle of attack to local conditions in each rotation. This will also be an advantage from an energetic point of view as it optimizes lift at every rotor angle, and it will decrease the extra mechanical load on the blades accompanying the sound pulses.
When the impulsive character of the sound is heightened because of the interaction of several turbines in a wind farm, this may be eliminated by adding small random variations to the blade pitch, mimicking the random variations imposed by atmospheric turbulence in daytime when this effect does not occur.

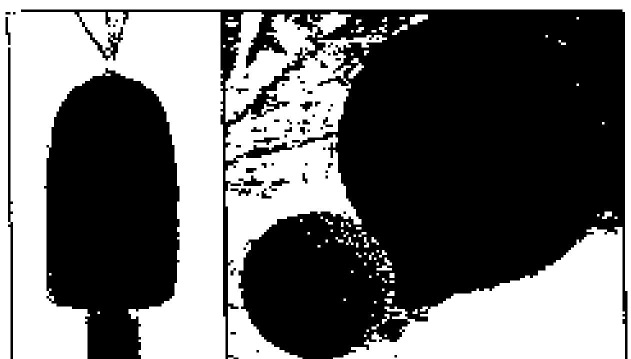


Figure VIII.0: foam wind screens

VIII RUMBLING WIND: wind induced sound in a screened microphone

VIII.1 Overview of microphone noise research

It is commonly known that a wind screen over a microphone reduces 'wind noise' that apparently results from the air flow around the microphone. An explanation for this phenomenon has been addressed by several authors. According to a dimensional analysis by Strasberg [1988] the pressure within a spherical or cylindrical wind screen with diameter D in a flow with velocity V, depends on Strouhal number $Sr = fD/V$, Reynolds number $Re = DV/\nu$ and Mach number $M = V/c$ (where ν is the kinematic viscosity of air and c the velocity of sound). Writing the rms pressure in a relatively narrow frequency band centered at frequency f as p_f and in dimensionless form by division with ρV^2, Strasberg found: $p_f/\rho V^2 = function(Sr, Re, M)$. Comparison with measured 1/3 octave band levels from four authors on 2.5 - 25 cm diameter wind screens, in air velocities ranging from 6 to 23 m/s yielded a definite expression for 1/3 octave frequency band:

$$20\cdot\log_{10}(p_{1/3}/\rho V^2) = -23\cdot\log_{10}(f_m D/V) - 81 \qquad \text{(VIII.1)}$$

where f_m is the middle frequency of the 1/3 octave band. The data points agreed within appr. 3 dB with equation VIII.1 for $0.1 < fD/V < 5$, except for one of the fourteen data series where measured values diverged at $fD/V > 2$. Equation VIII.1 can also be written in acoustical terms by expressing the rms pressure as a sound pressure level relative to 20 μPa:

$$L_{1/3} = 40\cdot\log_{10}(V/V_o) - 23\cdot\log_{10}(f_m D/V) + 15 \qquad \text{(VIII.2)}$$

Here V_o is a reference velocity of 1 m/s and $\rho = 1.23$ kg/m^3 is used (air density at 1 bar and 10 °C). Equation VIII.2 is slightly different from the expression given by Strasberg because SI-units are used and terms in logarithms have been non-dimensionalized.

Morgan and Raspet pointed out that all measurements reported by Strasberg were made in low turbulence flows, such as wind tunnel flow [Morgan *et al* 1992]. Strasberg's result thus referred to the wake created by a wind screen and excluded atmospheric turbulence (as Strasberg had noted himself in his concluding remarks [Strasberg 1988]). Outdoors, however, the flow is turbulent, and induced pressure variations are expected to depend on meteorological parameters also. Morgan & Raspet applied Bernoulli's principle by decomposing the wind velocity U in a constant time-averaged velocity V and a fluctuation velocity u with a time average u = 0, to obtain the rms pressure fluctuation $p = \rho V u$ [Morgan *et al* 1992] (in this chapter italics are used to denote the rms value x of a variable x: $x = \sqrt{x^2}$). This method can be compared to Strasberg's model for a microphone in turbulent water flow [Strasberg 1979]. Measurements in wind velocities of 3 – 13 m/s at 30.5 m and 1.5 m height for different screen diameters (90 and 180 mm) and screen pore sizes (10, 20, 40 and 80 ppi) yielded:

$$p = \alpha \cdot \rho (V u)^k \qquad \text{(VIII.3)}$$

with α ranging from 0.16 to 0.26 and k from 1.0 to 1.3 [Morgan *et al* 1992]. For some measurements Morgan *et al* showed spectra over almost the same frequency range where equation VIII.1 is valid ($0.1 < fD/V < 5$). The spectra have a positive slope up to 3 Hz, possibly due to a non-linear instrumental frequency response. At higher values the slope is roughly comparable to what Strasberg found, but values of $20 \cdot \log_{10}(p_{1/3}/\rho V^2)$ are generally 8 – 20 dB higher as predicted by equation VIII.1, implying that atmospheric turbulence dominated expected wake turbulence.

Zheng and Tan tried to solve this problem analytically [Zheng *et al* 2003]. Their analysis applies to low frequency variations, so the velocity variation u is uniform over the wind screen. Zheng & Tan state that this assumption seems to be valid for a low screen number D/λ (< 0.3), the ratio between screen diameter and wavelength. Ignoring viscous effects (*i.e.* infinite Reynolds number), and calculating the pressure variation p(0) at the center of a spherical wind screen caused by pressure variations at the surface induced by a wind velocity U = V + u, they found $p(0) = -\frac{1}{2} \cdot \rho V u$ or:

$$p(0) = \tfrac{1}{2} \rho V u \qquad \text{(VIII.4)}$$

Comparison with equation VIII.3 shows that now $\alpha = 0.5$ and k = 1.

Finally, in this overview, Boersma [1997] found that sound spectra due to wind measured at 1.5 m above flat, open grassland were in good agreement with Strasberg's results. However, Boersma used 95 percentile levels (L_{95}) which he estimated to be 6 to 13 dB lower than equivalent sound levels in the range considered ($30 < L_{95} < 70$ dB) [Boersma 1997], but he did not apply a level correction. So, in fact he found that his wind related spectra had slopes comparable to Strasberg's, but with a 6 – 13 dB higher value, not unlike the Morgan & Raspet spectra.

So, from literature we conclude that air turbulence creates pressure fluctuations especially at low frequencies, but the origin -wake or atmospheric turbulence- has not been definitely resolved.

In this chapter we will try to estimate the level of pressure variations due to atmospheric turbulence, *i.e.* the 'sound' pressure level taken from a sound level meter caused by turbulence on the microphone wind screen. First we will describe the spectral distribution of atmospheric turbulence and the effect this turbulence has on a screened microphone. Then we will turn to measured spectra related to wind, obtained by the author as well as by others. Finally the results will be discussed.

VIII.2 Atmospheric turbulence

A wind borne eddy that is large relative to the microphone wind screen (hence the change of wind velocity is nearly the same all over the wind screen) can be regarded as a change in magnitude and/or direction of the wind velocity [Zheng *et al* 2003]. The change in the magnitude of the velocity causes a change in pressure; the change in direction is irrelevant for a spherical wind screen as nothing changes relative to the sphere. As we saw in the previous section, when the velocity U is written as a constant (average) wind velocity V and a fluctuating part u, and similarly $P = P_{average} + p$, the relation between the rms microphone pressure fluctuation p and the rms wind velocity fluctuation u is $p = \alpha\rho V u$. For inviscid flow $\alpha = 0.5$. For finite Reynolds numbers ($Re/10^4 = 0.5 – 15$ for wind screens of 4 – 20 cm and wind velocities of 2 – 12 m/s), screening is better [Zheng *et al* 2003], and $\alpha \leq 0.5$; Morgan & Raspet [1992] found $\alpha = 0.16 – 0.26$. The pressure level due to atmospheric turbulence can be expressed as a sound pressure level L_{at} (with reference pressure p_{ref} = 20 μPa):

$$L_{at}(u) = 20 \cdot \log_{10}(\alpha\rho V u / p_{ref}) \qquad \text{(VIII.5)}$$

which is frequency dependent because of u.

VIII.2.1 Turbulence spectra

Turbulent velocity fluctuations v and w also exist perpendicular to the average wind velocity, in the vertical (w) as well as horizontal (v) direction, and are of the same order of magnitude as in the longitudinal direction [Jensen *et al* 1982]. Zheng & Tan [2003] showed that the effect of these fluctuations on the pressure at the microphone can be neglected in a first order approximation, as it scales with v^2 and w^2 and is therefore second order compared to the effect of the component u in line with the average wind velocity V that scales as Vu.

Atmospheric turbulence is treated in many papers and textbooks (such as [Jensen *et al* 1982, Zhang *et al* 2001]), also in reference to acoustics (see, *e.g.*, [Wilson *et al* 1994]). Here a short elucidation will be presented, leading to our topic of interest: turbulence spectra.

Atmospheric turbulence is created by friction and by thermal convection. Turbulence due to friction is a result of wind shear: at the surface the wind velocity is zero whereas at high altitudes the geostrophic wind is not influenced by the surface but a result of large scale pressure differences as well as Coriolis forces resulting from earth's rotation. In between, in the atmospheric boundary layer wind velocity increases with height z, equation III.2 is valid and for convenience repeated here :

$$V = (u_*/\kappa) \cdot [\ln(z/z_0) - \Psi] \qquad \text{(VIII.6)}$$

For $-1 < \zeta < 1$, $\Psi(\zeta)$ is of the same order of magnitude as the logarithmic term in equation VIII.6 ($2 < \ln(z/z_0) < 6$ for $1 < z < 5$ m, $1 < z_0 < 10$ cm). Hence, at the same height and roughness length, V may still change appreciably due to (in)stability.

The friction created by wind shear produces eddies over a range of frequencies and lengths, their size determined by z and V. These eddies break up in ever smaller eddies and kinetic turbulent energy is cascaded to smaller sizes at higher frequencies, until the eddies reach the Kolmogorov size η_s (≈ 1 mm) and dissipate into heat by viscous friction. It has been shown by Kolmogorov that for this energy cascade, in the so-called inertial subrange of the turbulent spectrum, the frequency dependency follows the well known 'law of 5/3': the spectrum falls with $f^{-5/3}$.

It is customary in atmospheric physics to express turbulence frequency in dimensionless form n, with n = fz/V (in fact n and f are usually interchanged, but we will use f for dimensional frequency, as is usual in acoustics). The seminal Kansas measurements showed that the squared longitudinal velocity fluctuation u_f^2 per unit frequency in a neutral atmosphere depends on frequency as [Kaimal *et al* 1972]:

$$f\cdot u_f^2/u_*^2 = 105n\cdot(1+33n)^{-5/3} \qquad \text{(VIII.7)}$$

The experimentally determined constants in this equation, the non-dimensional turbulent energy spectrum, are not exact, but are close to values determined by others [Garrat 1992, Zhang *et al* 2001]. For n << 1, the right-hand side approximates 105n, which, with n = fz/V and equation VIII.6, leads to $u_f^2 \approx 105\cdot u_*^2\cdot z/V \approx 105\kappa^2 zV\cdot[\ln(z/z_o) - \Psi]^{-2}$. Applying this to VIII.5, the induced pressure level per unit of frequency appears to be independent of frequency, but increases with wind velocity (≈ 30·logV).

For n >> 1 the right-hand side of equation VIII.7 reduces to $3.2\cdot(33n)^{-2/3}$, leading to $u_f^2 = 0.3\cdot u_*^2\cdot(V/z)^{2/3}\cdot f^{-5/3}$, which describes the inertial subrange. The frequency where the wind velocity spectrum VIII.7 has a maximum is $n_{max} \approx 0.05$ or $f_{max} = 0.05V/z$. As sound measurement are usually at heights $1 < z < 5$ m, f_{max} is less than 1 Hz for wind velocities V < 20 m/s,

When insolation increases the surface temperature, the atmosphere changes from neutral to unstable and eddies are created by thermal differences with sizes up to the boundary layer height with an order of magnitude of 1 km. Turbulent kinetic energy production then shifts to lower frequencies. In contrast in a stable atmosphere, where surface temperature decreases because of surface cooling, eddy production at low frequencies (corresponding to large eddy diameters) is damped and the spectral maximum shifts to a higher frequency up to appr. n = 0.5 for a very stable atmosphere. As low-altitude wind velocities ($z < 5$ m) in a stable atmosphere are restricted to relatively low values (for higher wind velocities, stability is disrupted and the atmosphere becomes neutral), the spectral maximum may shift up to $0.5V/z \approx 3$ Hz. The inertial subrange thus expands or shrinks at its lower boundary, but its frequency dependency follows the 'law of 5/3'.

VIII.2.2 Effect on microphone in wind screen

The spectrum of longitudinal atmospheric turbulence in the inertial subrange was described in the previous section with the (squared) rms value of velocity variation per unit frequency $u_f^2 = 0.3 \cdot u_*^2 \cdot (V/z)^{2/3} \cdot f^{-5/3}$. It is convenient to integrate this over a frequency range $f_1 - f_2$ to obtain a 1/3-octave band level ($f_m = 2^{-1/6} \cdot f_2 = 2^{1/6} \cdot f_1$) with centre frequency f_m: $u_{1/3}^2 = 0.046 \cdot u_*^2 \cdot (f_m \cdot z/V)^{-2/3} = [0.215 \cdot u_* \cdot (f_m \cdot z/V)^{-1/3}]^2$. Substituting u_* from equation VIII.6 and applying the result to equation VIII.5 for 1/3 octave band levels $L_{at,1/3}(f_m) = 20 \cdot \log(\alpha\rho V u_{1/3}/p_{ref})$, yields:

$$L_{at,1/3}(f) = 40 \cdot \log(V/V_o) - 6.67 \cdot \log(zf/V) - 20 \cdot \log[\ln(z/z_o) - \Psi] + C \quad \text{(VIII.8)}$$

Here the frequency index m as well as the logarithm index 10 have been dropped, as will be done in the rest of the text. In equation VIII.8 $C = 20 \cdot \log(0.215\kappa\alpha\rho V_o^2/p_{ref}) = 62.4$ dB for $\kappa = 0.4$, $\alpha = 0{,}25$, $\rho = 1{,}23$ kg/m^3 and pressure level is taken re $p_{ref} = 20$ µPa. For octave band levels $L_{at,1/1}(f)$ the constant C in the right hand side of VIII.8 is 67.2 dB.

Equation VIII.7 does not apply to frequencies where eddies are smaller then the wind screen. The contribution of small eddies will decrease proportional to the ratio of eddy size (ℓ^2, where ℓ is the eddy length scale and $f = V/\ell$) and wind screen surface πD^2. When this ratio decreases more eddies will simultaneously be present at the screen surface and resulting pressure fluctuations at the surface will more effectively cancel one another in the interior of the wind screen. The pressure variation in the wind screen centre resulting from one eddy is proportional to the size of the eddy relative to the screen surface, *i.e.* ℓ^2/D^2, but also the screen centre pressure resulting from the random contributions of all N eddies on the screen surface is proportional to $\sqrt{N}$, where $N = D^2/\ell^2$. The resulting screen centre pressure is thus proportional to individual eddy pressure p_f and $(\ell^2/D^2)\cdot\sqrt{(D^2/\ell^2)} = \ell/D = V/fD$. Consequently a factor $-20\cdot\log(fD/V)$ must be added to the resulting rms pressure level.

In wind noise reduction measured by Morgan there is a change in frequency dependency at screen number $D/\ell \approx 1/3$ ([Morgan 1993], see also [Zheng *et al* 2003]). We therefore expect at sufficiently high frequencies the pressure level at the microphone to decrease proportional to $20\cdot\log(D/\ell)$, relative to the level in equation (VIII.8), and this decrease must vanish when $D/\ell = Df/V < 1/3$, *i.e.* below the cut-off frequency $f_c = V/(3D)$. As the change will be gradual, a smooth transition can be added to equation VIII.8:

$$L_{a,1/3}(f) = 40\cdot\log(V/V_0) - 6.67\cdot\log(zf/V) + 20\cdot\log[\ln(z/z_0)-\Psi] +$$

$$- 10\cdot\log(1+(f/f_c)^2) + C \qquad \text{(VIII.9a)}$$

With usual screen diameters 5 – 25 cm and wind velocities 1 – 20 m/s, the cut-off frequency is in the range of 1 to 100 Hz. With the common 10 cm diameter wind screen f_c will usually be in the infrasound region. Equation VIII.9a can be rewritten with Strouhal number $Sr = fD/V$ as independent variable of a 'meteorologically reduced' 1/3 octave band level L_{red}:

$$L_{red,1/3} = L_{a,1/3} - 40\cdot\log(V/V_0) + 20\cdot\log[(z/D)^{1/3}\cdot(\ln(z/z_0)-\Psi)] =$$

$$- 6.67\cdot\log(Sr) - 10\cdot\log[1 + (3Sr)^2] + C \qquad \text{(VIII.9b)}$$

The levels according to equation VIII.9 have been plotted in figure VIII.1 for different wind velocities and with $z = 20\cdot D = 40\cdot z_0 = 2$ m, $\Psi = 0$. For $f < 0.5\cdot f_c$ the term before C is less then 1 dB and equation VIII.9a reduces to equation VIII.8. For frequencies $f >> f_c$ the term before C in equation VIII.9b reduces to $-20\cdot\log(3Sr)$ and equation VIII.9b can be written as:

$$L_{red,1/3} = - 26.67\cdot\log(Sr) + C - 9.5 \qquad \text{(VIII.10a)}$$

This can be rewritten in a aerodynamic terms as:

$$L_{p,1/3} = 20 \cdot \log(p_{1/3}/\rho V^2) = -26.67 \cdot \log(Sr) + F(z) + C_p \qquad \text{(VIII.10b)}$$

where and $F(z) = -20 \cdot \log[(z/D)^{1/3} \cdot (\ln(z/z_o) - \Psi)]$ and $C_p = 20 \cdot \log(0.215\kappa\alpha) - 9.5 = -43$ dB. For $F(z) = -20$ dB (*e.g.* a 10 cm diameter wind screen at a z = 2 m, z_o = 5 cm and Ψ = 0) the right hand side of equation VIII.10b is $-26.67 \cdot \log(Sr) - 63$. Comparing this with Strasberg's result (equation VIII.1 and gray lines in figure VIII.1) we see that the frequency dependency is slightly different, and levels are 13 - 19 dB higher ($0.5 < Sr < 20$), which is of the order of what we found in the measurements by Boersma and Raspet *et al* (see section VIII.1). The change in slope, visible at Strouhal number $Df_c/V = 1/3$ in figure VIII.1, is a feature not explained by the earlier authors.

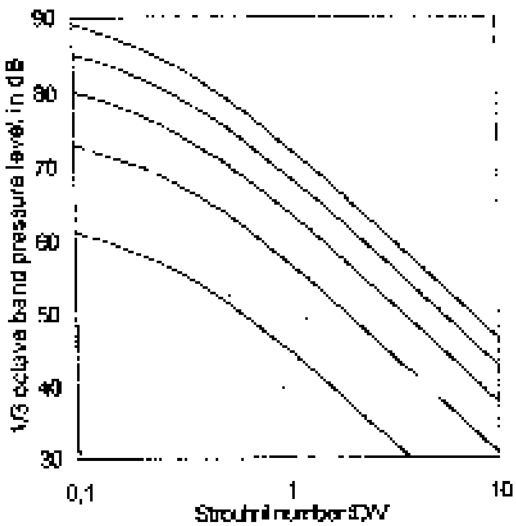


Figure VIII.1: black lines: calculated 1/3 octave band levels $L_{at,1/3}$ due to atmospheric turbulence at wind velocities of (bottom to top) 2, 4, 6, 8 and 10 m/s. F(z) = -18 dB; gray lines: levels at some wind velocities according to Strasberg

VIII.2.3 Frequency regions

From the theory above it can now be concluded that the wind induced pressure level on a (screened) microphone stretches over four successive frequency regions:

i. at very low frequencies (less than a few Hz) the turbulence spectrum is in the energy-producing subrange; 1/3 octave band pressure level $L_{at,1/3}$ is independent of frequency (white noise), but increases with wind velocity;

ii. at frequencies up to $f_c = 0.3V/D$, which is usually in the infrasound region, the turbulence spectrum is in the inertial subrange, $L_{at,1/3} \sim 46.7 \cdot \log V$ and $\sim -6.7 \cdot \log f$;

iii. at higher frequencies, but still in the inertial subrange, eddies average out over the wind screen more effectively at increasing frequency

($L_{at,1/3} \sim -26.7 \cdot \log f$), but pressure level increases faster with wind velocity ($L_{at,1/3} \sim 66.7 \cdot \log V$) ;

iv. at frequencies beyond $0.1 V/\eta_s$ (see [Plate 2000, p. 585]) atmospheric turbulence enters the dissipation range and turbulence vanishes. This is in the range $Sr = fD/V > 0.1 D/\eta_s \approx 100 \cdot [D/\text{m}] = D/\text{cm}$.

The inertial subrange (ii and iii) is of most interest here, as it is within the commonly used range of acoustic frequency and level.

VIII.2.4 Wind induced broad band A-weighted pressure level

In figure VIII.2 1/3-octave band levels according to equation VIII.9 are plotted for different wind velocities for $z = 50 \cdot z_0 = 20 \cdot D = 2$ m (or $F(z) = -20.5$ dB with $\Psi = 0$). Also levels are plotted after A-weighting to show the relevance to most acoustic measurements, where wind induced noise may be a disturbance added to an A-weighted sound level. At the frequency where turbulent eddies enter the dissipation subrange ($f = 0.1 V/\eta_s$), no data are plotted as the turbulent velocity spectrum falls very steeply and induced pressure levels are considered negligible. A-weighted pressure levels $L_{at,A}$ can be calculated by summing over all 1/3-octave bands. The wind velocity dependency can then be determined from the best fit of $L_{at,A}$ vs. V:

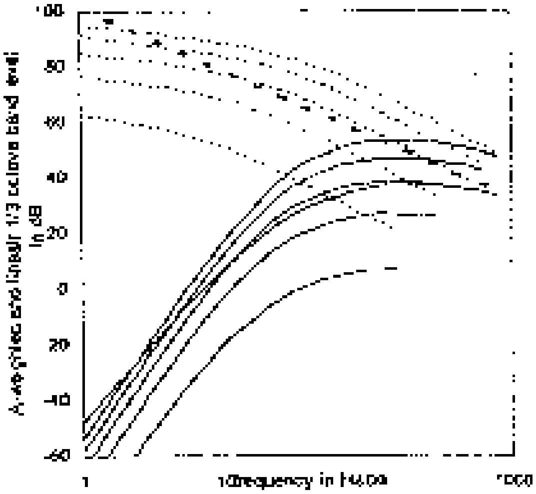


Figure VIII.2: calculated lineair (dashed) and A-weighted (solid lines) 1/3-octave pressure levels due to atmospheric turbulence on a screened microphone with F(z)+C=42 dB, D = 0.1 m and wind speeds 2, 4, 6, 8, 10 m/s (black, bottom to top); bold grey lines: 1/3 octave band levels according to Strasberg for 10 m/s

$$L_{at,A} = 69.4 \cdot \log(V/V_0) - 26.7 \cdot \log(D/\ell_0) + F(z) + C - 74.8 \qquad \text{(VIII.11a)}$$

where $\ell_o = 1$ m is a reference length. Equation VIII.11a has the same structure as VIII.10a, but a rather higher slope with logV because higher frequencies (with lower A-weighting) are progressively important, and a much smaller constant term as a result of A-weighting. The slope decreases with wind screen diameter and is 65.5 dB when D = 1.25 cm (unscreened ½" microphone), but is constant within 1 dB for 5 < D/cm < 50. Equation VIII.11a is not very sensitive for the cut-off at $f = 0.1V/\eta$: if spectral levels are integrated over all frequencies, total level does not increase significantly at high wind velocities, and with less than 3 dB at low wind velocities. It will be noted that the slope with wind velocity is slightly higher than for individual spectral levels for $f > fc$ (66.7 dB, see equation VIII.10a, due to lower A-weighting at the increasingly higher frequencies.
If we put $G(z) = F(z) - 6.7\cdot\log(D/\ell_o) + 14 = -20\cdot\log[0.2\cdot(z/\ell_o)^{1/3}\cdot(\ln(z/z_o - \Psi)]$, and use 10D for convenience, equation VIII.11a becomes:

$$L_{at,A} = 69.4\cdot\log(V/V_o) - 20\cdot\log(10D/\ell_o) + G(z) + C - 68.8 \qquad \text{(VIII.11b)}$$

Now for z_o = 2,5 - 6 cm and $\Psi = 0$, G(2 m) = 0 ± 1 dB. This means that for a 10 cm wind screen and measurement over a flat area with a low vegetation cover in neutral conditions $L_{at,A} = 69.4\cdot\log(V/V_o) - 6.4$ dB(A).
Figure VIII.3 is a plot of equation VIII.11 with G(z) = 0, C = 62 dB. Also plotted in figure VIII.3 is the relation according to Strasberg, obtained by A-weighting and integrating equation VIII.2 over f.

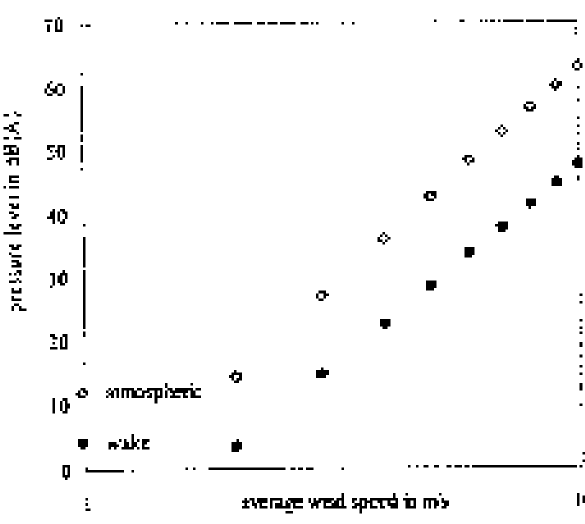


Figure VIII.3. calculated A-weighted broad band pressure level caused by atmospheric or wake turbulence with G(z) + C = 62.4 dB and D = 0.1 m

VIII.3 Comparison with experimental results

VIII.3.1 Measured spectral pressure levels

Several authors have performed measurements to determine spectral levels due to wind, including wind induced sound pressure fluctuations. We will use data from Larsson and Israelsson [1982], Jakobsen and Andersen [1983] and Boersma [1997] from screened as well as unscreened microphones. Table VIII.1 gives an overview of measurement parameters. None of the authors give the degree of stability, but in Jakobsen's data $\Psi \leq 0$ (night), in Boersma's $\Psi \geq 0$ (summer's day). Jakobsen mentions roughness height of the location (a golf course), Boersma grass height (≈ 10 cm), Larsson only mentions measurement height over grass at either 1.25 or 4 m, without specifying which height applies to a measurement result. To prevent using spectra at large values of $|\Psi|$ no data at low wind velocities (< 2 m/s at microphone) are used. This is also recommendable as at low wind velocity sound not related to wind is more likely to dominate. We preferably use L_{eq} data. However, these are not available from Boersma. Boersma used 95 percentile levels (L_{95}), but we have L_{50} values from the original data. Though Boersma quotes $L_{Aeq} = L_{A50}$, we will use $L_{Aeq} = L_{A50} + 3$, in agreement with long term data on wind noise [Van den Berg 2004b] and assume this to be valid for every frequency band. If measurements yielded octave band levels, 4.8 dB was subtracted to obtain the 1/3 octave band level at the same frequency.

Also L_{eq} values are presented from measurements made by the author at several locations; at one location (Zernike) for the purpose of wind noise measurements, and otherwise (Horsterwold, Kwelder) selected for having little other noise. Here also the degree of atmospheric stability is unknown, as at the time of measurement it was not known to be a relevant factor. The 'Zernike' measurements were done at the university grounds (latitude 53°14'43", longitude 6°31'48") with both the microphone (in a spherical foam screen of 2.5, 3.8 or 9.5 cm diameter) and the wind meter at 1.2 or 2.5 m over grass at least several hundred meters from trees, and an estimated roughness height of 5 cm. They were performed in daytime in December 2003 and august 2004 with a fair wind under heavy clouding.

The 'Kwelder' measurements were made in daytime or evening in July and August of 1996 at an open area at the Dutch coast (latitude 53°25'46", longitude 6°32'40"), consisting of level land overgrown with grass and low weeds and close to tidal water. Sound measurements were taken at a height of 1.5 m at times when no sound could be heard but wind-related sound and distant birds. The microphone was fitted with a spherical 9.5 cm diameter foam wind screen. Wind velocity at microphone height at 1.5 m was estimated from measured wind velocity at 5 m height with equation VIII.6, z_0 estimated as 2 cm. Finally the 'Horsterwold' measurements were made in December 2001 in an open space with grass and reeds (latitude 52°18'3", longitude 5°29'38") between 5 to 10 m high trees at a distance of approximately 30 m but farther in the windward direction, in a mostly clouded night. Wind velocity and sound were measured at 2 m height, the wind screen was a 9 cm diameter foam cylinder. Due to the differences in vegetation, roughness length here was difficult to estimate, and was determined by fitting measurement results to the expected level (resulting in 60 cm and a more limited range of values of Ψ to fit).

At very low frequencies in our Zernike measurements the 1/3 octave band levels were corrected for non-linear response. The frequency response of the B&K ½" microphone type 4189 is specified by Brüel & Kjaer [B&K 1995] and is effectively a high pass filter with a corner frequency of 2.6 Hz. The response of the Larson Davis type 2800 frequency analyser is flat (±1 dB) for all frequencies.
To plot spectra we calculate the reduced pressure level $L_{red,1/3}$, leaving only the screen diameter based Strouhal number Sr = fD/V as the independent variable. Octave band pressure levels $L_{red,1/1}$ are substituted by $L_{red,1/3}$ + 4.8. As atmospheric stability is as yet unknown, the stability function is set to zero. If wind velocity was not measured at microphone height, the logarithmic wind profile (equation (VIII.6 with Ψ = 0, or III.3) is used to determine V_{mic} from the wind velocity at height h.

Linear spectra of 1/3-octave levels are plotted in the left part of figure VIII.4 for the unscreened microphones. Also plotted is the spectrum according to Larsson *et al* [1982], valid for the inertial subrange. Due to the small size of the unscreened microphone (1.25 cm) part of the spectrum lies in the dissipation range at frequencies $f > 0.1V/\eta \approx 100V/m$, corresponding to $Sr > 100D/m = 1.25$.

In figure VIII.4B spectra are plotted from screened microphones, from the data from Larsson, Jakobsen and Boersma. As these spectra were determined with a range of screen diameters, the change from the inertial to the dissipation subrange extends over a range of non-dimensional frequencies (Strouhal numbers). Finally figure VIII.4C shows spectra from the Horsterwold, Zernike and Kwelder measurements. In all figures spectra deviate from the predicted spectrum at high Strouhal numbers because either the lower measurement range of the sound level meter is reached or

Table VIII.1: wind induced noise measurement characteristics

author	period	location	zo (cm)	H_{wind} (m)	H_{mic} (m)	V_{min} (m/s)	D (cm)	T (min.)	N [1]	F (Hz)	band width [6]
Larsson *et al*	late summer - early autumn	grass lawn	5 [3]	mic	1.25 or 4	2 - 7	no [4] / 9.5	6 obs. [5]	9 / 9	63-8k	1/1
Jakobsen *et al*	summer – dec, night	golf course	2	10	1.5	3 – 7	9.5 / 25	? [5]	5 / 5	63-8k	1/1
Boersma	summer, day	grass land	3 [3]	2	1.5	3 - 7	no [4]	160	9	6-16k	1/3
						2 - 9	9	430	7	6-16k	
this study:											
Horsterwold	night, clouded	grass, reeds	60 [3]	10	2	4 - 6	9.5	230	4	31-8k	1/1
Kwelder	summer, day	grass, herbs	2 [2]	5	1.5	3 - 5	9.5	40	6	6-16k	1/3
Zernike	summer, clouded day	grass land	5 [2]	1.5	2.5	5	2.5/3.8/9.5	30	3	6-1k	1/3
	winter, clouded day				1.2	4	3.8/9.5	20	2	1-1k	

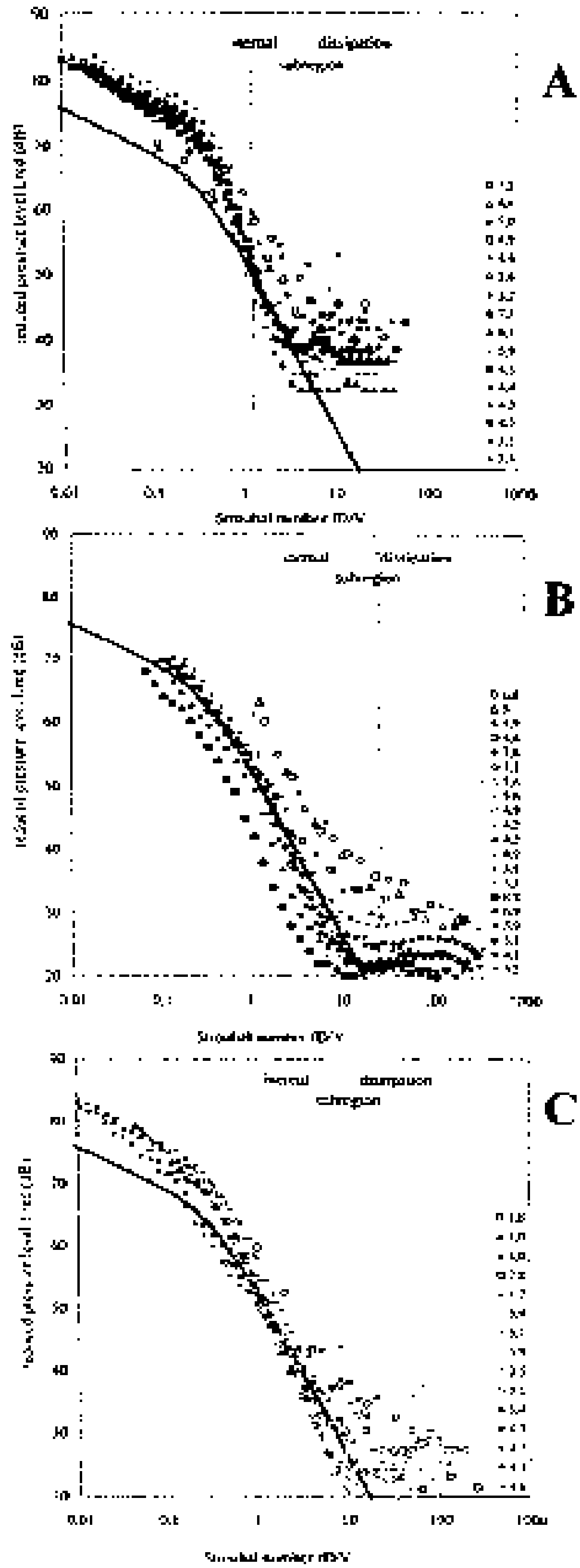
notes: 1: # of measurements 2: estimated; 3: fitted; 4: no = unscreened;
5: observations of unknown length; 6: 1/1 or 1/3 octave band

Figure VIII.4:
reduced 1/3 octave band pressure levels at different wind velocities (in legend: V in m/s), bold line is predicted spectrum;

A: unscreened microphone, from Larsson (open symbols) and Boersma (black symbols);

B: screened microphone, from Larsson (open symbols), Jakobsen (grey) and Boersma (black symbols);

C. screened microphone, measurements in Horsterwold (open symbols), Kwelder (grey) and Zernike (black symbols).



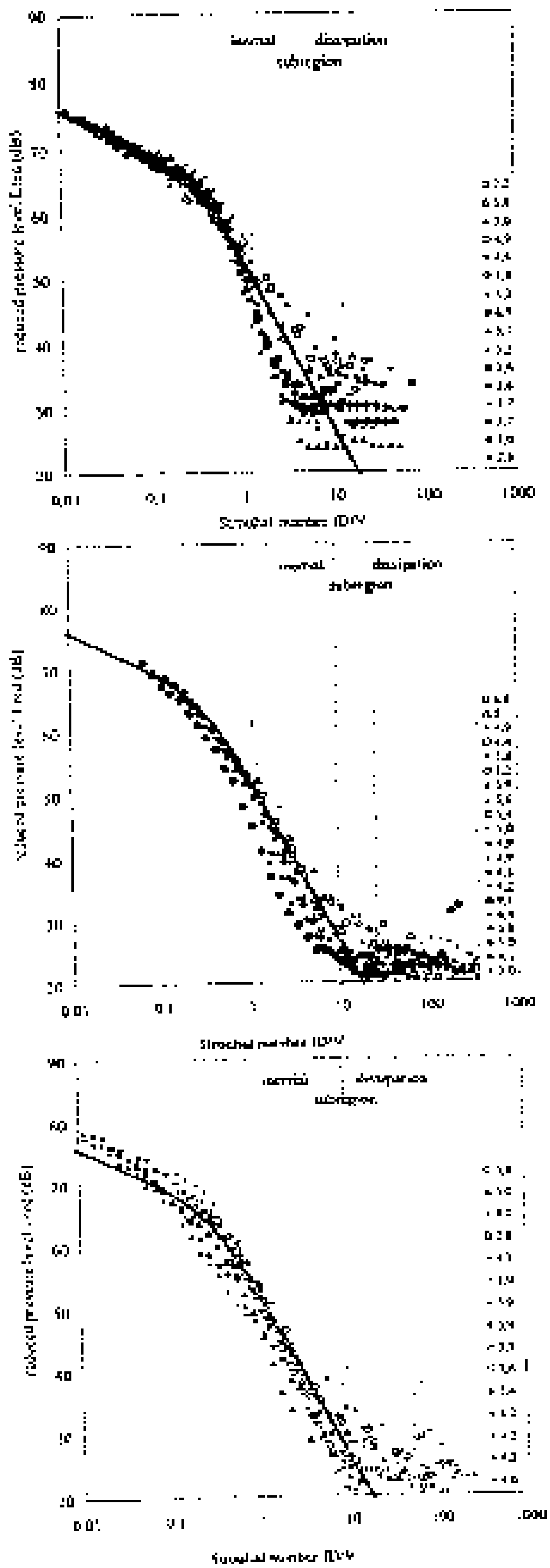


Figure VIII.5:
same as figure VIII.4, but after fitting with stability function

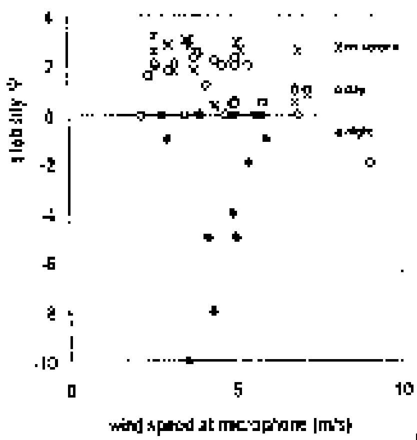


Figure VIII.6: values of the stability function Ψ found by fitting reduced spectral levels L_{red} with theoretical spectrum, for measurements in day or night time, and for unscreened microphones in daytime ambient sound dominates the wind-induced pressure level. Also, at these high Strouhal numbers most values are in the dissipation range where the present model is not valid.

In figure VIII.4 atmospheric stability has not been taken into account yet (in fact $\Psi = 0$ was used), due to lack of data to determine Ψ. In stable conditions ($\Psi < 0$) L_{red} will be higher, in unstable conditions ($\Psi > 0$) lower, causing the plotted spectra to shift vertically if the proper value $\Psi \neq 0$ is applied.
If wind velocity at microphone height is deduced from wind velocity at another height, the shift is more complex, as stability then also affects the term $40 \cdot \log(V/V_0)$ as well as the ordinate value $Sr = fD/V$. The approach taken here is to vary Ψ to obtain a best fit to the theoretical value of the L_{red} levels at non-dimensional frequencies in the inertial subrange. The fitted spectra are plotted in figure VIII.5. The values of Ψ that gave the best fits are plotted in figure VIII.6, categorized in daytime and night time measurements (where one would expect $\Psi \geq 0$ and $\Psi \leq 0$, respectively). Measurements with unscreened microphones are indicated separately, and are in daytime for Boersma's measurements and probably also for Larsson's, so one would expect $\Psi \geq 0$.

VIII.3.2 Measured broad band pressure levels

Several authors give a relation between broad band A-weighted sound pressure level L_A and wind velocity [Boersma 1997, Larsson *et al* 1982, Jakobsen *et al* 1983]. According to Boersma $L_A \sim 22.6 \cdot \log(v)$ (with v measured at 2 m height, L_A at 1.5 m), to Larsson $L_A = 4.4 \cdot v + 27.5$ (v and L_A measured at the same height), to Jakobsen $L_A = 6.8 \cdot v - 2.6$ (v measured at 10 m, L_A at 1.5 m). However, as Boersma clearly shows, most of the A-weighted sound is due to ambient wind induced sound, especially at low wind velocities. So we cannot use these relations for just sound induced by wind on the microphone.

A practical situation where the influence of wind on the microphone + wind screen could be investigated directly offered itself when on May 28, 2000 a storm occurred during our 'Wieringerwaard' measurements. The microphone, in a 9 cm foam cylinder, and a wind meter were both placed at a height of 4.6 m, 2 m apart, in front of a big farmer's shed 5 m to the west of the microphone (latitude 52°48'41", longitude 4°52'23"). A second, 'free wind' windmeter at 10 m height was placed further away to measure undisturbed wind. Around the measurement location were fields with potato plants of 20 - 30 cm height. As it was May, an unstable atmosphere is expected in daytime, leaning to neutral when the wind velocity increases.

Some measurement results are given in figure VIII.7 (all values are 10 minute averages of samples measured at a rate of 1 s^{-1}). In the left part of the figure the 'free' wind velocity v_{10} is seen to increase to 20 m/s (72 km/h) in the course of the day after a relatively quiet night. The wind velocity v_{mic} near the microphone increased at practically the same rate between 6 and 12 o'clock, but then abruptly falls from 13 m/s to 2 m/s and thereafter remains at a low value even while the 'free' wind velocity is still increasing. Up to 12 o'clock the sound level (equivalent A-weighted level per 10 minutes) increases in proportion to the wind velocity reaching a maximum of 84 dB(A), but then falls abruptly to 50 dB(A) at the same time the local wind velocity collapses. In this morning the unobstructed wind began in the east and gradually turns south. When at 12 o'clock the wind passes behind the shed, the microphone is suddenly taken out of the wind. There is no reason that the *sound* reaching the microphone changes significantly during this change, but due to the sudden wind velocity reduction the measure sound pressure level drops to 50 dB(A). After that the sound pressure level increases again as long as the storm is gaining strength. The measured pressure level above 60 dB(A) is pure wind-induced 'pseudo' sound, that is: sound resulting from moving air, not from airborne sound.

In the right part of figure VIII.7 the A-weighted equivalent (pseudo-) sound pressure level per 10 minutes over the same period as in the left part of figure 7, is plotted as a function of wind velocity at the microphone. There is an obvious direct correlation between pressure level and wind velocity at higher wind velocities (V > 6 m/s) in contrast to the levels at

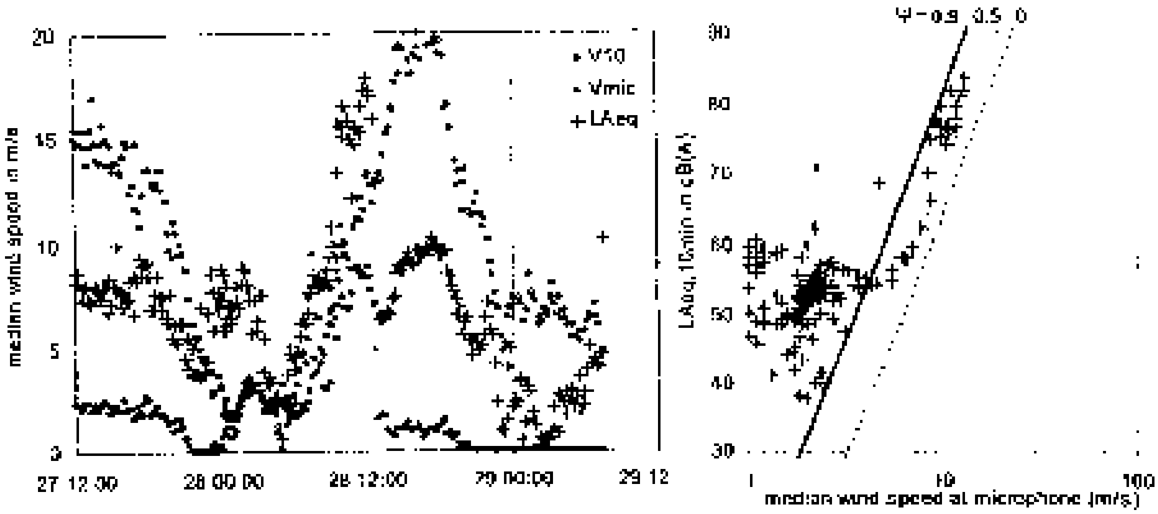


Figure VIII.7: measurements during a storm in front of a big shed; left: 10 minute averages of wind speed at microphone and at 10 m height and sound pressure level Leq; right: Leq as a function of microphone wind speed and predicted sound pressure level (G(4.6) 8.2 dB)

lower wind velocities. Again, the stability factor Ψ is not known, but in daytime and in strong winds it must be small and positive. The lines in figure VIII.7 show the calculated pressure levels for plausible values 0 < Ψ < 1 (with z_0 = 20 cm), encompassing the measured values.

VIII.3.3 Screen reduction

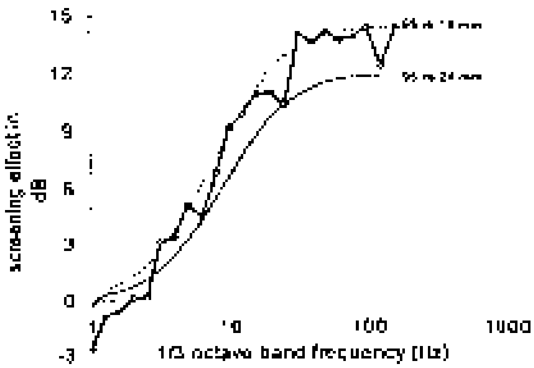


Figure VIII.8: measured (line with markers) and calculated screening effect of a 9.5 cm relative to a 2.4 or 1.8 cm wind screen

For two of our Zernike summer measurements (see table VIII.1) with place and atmospheric conditions unchanged within the measurement period, the difference between 1/3 octave band pressure levels measured with an approximately spherical 2.4 cm wind screen and a spherical 9.5 cm wind screen are plotted in figure VIII.8. Also plotted is the calculated screening effect based on equation VIII.9a, with only both term before C differing between both measurements. It appears that the measured screening effect is on average approximately 1 dB higher than the calculated level. It is not clear why the difference in screening is negative at frequencies below 2 Hz. For a somewhat smaller wind screen (18 mm < D < 24 mm) the average screening effect would agree better with the calculated effect.

VIII.4 Discussion

The model developed in this paper starts with the assumption that wind induced 'sound' pressure levels on a microphone are caused by atmospheric turbulence. Then, at low non-dimensional frequencies (Sr << 0.3) spectral levels are determined entirely by atmospheric turbulence. In this frequency range a wind screen has no effect. At higher frequencies, where pressure fluctuations tend to cancel one another more effectively as their scale decreases relative to the wind screen diameter, a wind screen acts as a first order low pass filter for turbulent fluctuations. In this frequency range (Sr > 0.3) a wind screen diminishes the effect of turbulence, and better so if it is bigger.

Wind induced pressure levels are determined not just by wind velocity and screen diameter, but also by two factors that are relevant for the production of turbulence: atmospheric instability and surface roughness. The stability factor Ψ and roughness height z_0 are determinants for thermal and frictional turbulence, respectively. These determinants are usually not taken into account with respect to wind induced noise and are consequently not reported. Atmospheric stability therefore had to be estimated by varying the value of Ψ until a best fit was obtained of measured spectra to the calculated spectrum. Roughness length, when unknown, was assumed to be comparable to vegetation height.

The values of Ψ that resulted in the best fits are shown in figure VIII.6. They can also be compared to values obtained from long term measurements at the Cabauw measurement site of the Royal Netherlands Meteorological Institute (KNMI). The Cabauw site is in open, flat land west of the central part of the Netherlands (see Chapter VI) and may be considered representative for locations in comparable terrain in the north and central parts of the Netherlands (Boersma's and our measurements), Denmark (Jakobsen *et al*) and the Swedish Uppsala plain (Larsson *et al*). The KNMI provided us with a data file containing 30 minute averages of the Monin-Obukhov length L over one year (1987). From this the dimensionless height $\zeta = z/L$ can be calculated and then the stability factor Ψ (see text below equation VIII.6). In figure VIII.9 the frequency distribution is shown of all 17520 (= 2·24·365) values of Ψ, for two altitudes: 2 m and 5 m. Also the frequency distribution is shown of the 42 values of Ψ resulting from our fitting procedure. The distribution of our fitted values resemble the distribution of actually occurring values (in 1987) and thus seems plausible.

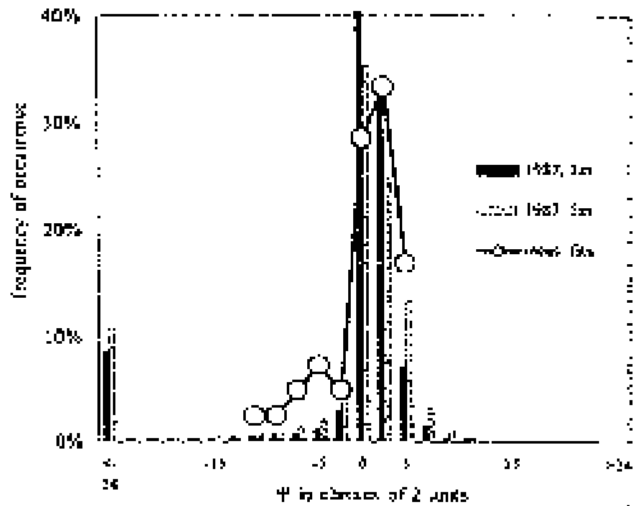


Figure VIII.9: frequency distributions of stability factor Ψ at 2m and 5 m height, based on ½ hour observations over 1987 and resulting from fitted spectra

Two constants are not known accurately: α, assumed to have a value 0.25, and the ratio of screen diameter and eddy size at the corner frequency, where 3 was used. If the Sr-related slopes are as in equation VIII.9b, the best fit of all data points in figure VIII.5 at Sr < 2.5 is a line $L_{red,1/3} = -6.7\cdot\log(Sr) - 10\cdot\log[1+(3.8\cdot Sr)^2] + 62.0$. This fit is within 2.2 dB of the calculated value (equation VIII.9b). It follows that the ratio ℓ/D (3.8) where screen averaging over eddies sets in may be greater than assumed (*viz.* 3), and the constant term may be somewhat smaller, which could be a result of a lower value of α than assumed (0.24 instead of 0.25.

For 2.5 < Sr < 16 the best fit is on average 2.1 dB above the calculated value. The standard deviation of the measured 1/3 Strouhal octave band levels is less than 3.5 dB at Sr < 2.5 and up to 7 dB at 2.5 < Sr < 16.

VIII.5 Applications

As microphone wind noise appears to be closely correlated to atmospheric turbulence, acoustic measurements can alternatively be used to measure turbulence spectra or turbulence strength, especially in the inertial subrange. This provides a new way to determine (*e.g.*) friction velocity or atmospheric stability. As the measured signal decreases above the corner frequency $f_c = V/(3D)$ this frequency is best chosen high, which can be achieved with a small, bare microphone.

The present model can be used to distinguish wind induced noise from other wind related sound. An application is the measurement of wind turbine sound or (without an operating wind turbine) ambient background sound in relatively strong winds. If the measurement is on a wind exposed site it is probable that at high wind velocities wind induced noise influences or even dominates either wind turbine sound or proper ambient sound. A measured level can now be corrected for wind induced sound with a calculated wind noise level. In less exposed sites it is usually not clear in what degree the measured levels are influenced by wind induced noise. To calculate wind induced noise levels additional measurements are necessary to determine roughness height and atmospheric stability. Stability can be estimated from wind velocity measurements on two heights, using equation VIII.6. Roughness height can be estimated from tabulated values or from wind velocity measurement at two heights in a neutral atmosphere, at times when the logarithmic wind profile is valid (equation VIII.6 with $\Psi = 0$). In neutral and stable conditions wind induced noise levels are not very sensitive to errors in roughness height: with an error of a factor of 2 in $z_0 = 10$ cm, the level changes less than 2 dB if microphone height is 3 m or more.

VIII.6 Conclusion

Measured spectra, reduced with a term for wind velocity and turbulence strength, coincide well with calculated values for unscreened as well as screened microphones in the range where the theoretical model (equation VIII.9) is valid. To test the model more thoroughly, measurements should include a determination of roughness length and atmospheric stability, in addition to the usual measurement of wind velocity and measurement height.

The model shows that to avoid high wind induced pressure levels, measurements are best performed at low wind velocity and with a large diameter wind screen, which is common knowledge in acoustics. The overall reduction ΔL_A from a bigger wind screen relative to a smaller one is determined by the ratio of the screen diameters D_1 and D_2: $\Delta L_A = 20 \cdot \log(D_2/D_1)$ (from equation VIII.11b, D > 5 cm). A wind screen does not reduce noise from atmospheric turbulence at frequencies $f < V/(3D)$.
The model also shows that, to reduce wind induced sound, it helps to measure over a low roughness surface and at night (stable atmosphere), as both factors help to reduce turbulence, even if the (average) wind velocity on the microphone does not change. With reduced turbulence, wind induced pressure levels will finally reach the level given by Strasberg (equation VIII.1 or VIII.2), where turbulence is the result of the wake caused by the wind screen.
One might be tempted to think that a higher measurement altitude would also help to reduce wind noise (as this would make G(z) in equation VIII.11b more negative, thus reducing $L_{a,LA}$). However, in practice increasing altitude will lead to higher wind velocities, especially so in a stable atmosphere, and the first term in equation VIII.11b would more then compensate the decrease in G(z). It is therefore preferable to measure at low altitude if less wind noise is desired.

IX GENERAL CONCLUSIONS

The research aims formulated in the introductory chapter (section I.6) have been addressed separately in the previous chapters. In this chapter we present an overview of all results. The results are presented in a logical order, which is not entirely in the sequence of the previous chapters.

IX.1 Effect of atmospheric stability on wind turbine sound

It is customary in wind turbine noise assessment to calculate the sound level on neighbouring premises by assuming hub height wind velocities predicted using a logarithmic wind profile. This wind profile depends only on surface roughness and is valid in a neutral atmosphere. However, it is not a predictor for wind profiles in either an unstable or stable atmosphere. Especially in a stable atmosphere a wind profile can be very different from the logarithmic, neutral profile and the hub height wind velocity is higher than predicted by the neutral profile. As more wind at hub height makes a variable speed wind turbine rotate at a higher speed, the sound power level may be significantly higher in a stable atmosphere at the same wind 10-m velocity V_{10} (which usually occurs when the sun is down and no strong near-ground wind is present) than in an unstable atmosphere (usually when the sun is up). This is especially relevant for modern, that is: tall and variable speed, wind turbines.

A stability dependent wind profile predicts the wind velocity at hub height more accurately. When a correct wind profile is used, calculated immission sound levels agree with measured night-time sound immission levels.

Sound immission measurements have been made at distances up to 2 km from the Rhede wind farm containing seventeen 98 m hub height, variable speed wind turbines, and at 280 m from a single 45 m hub height, two speed wind turbine at Boazum. Measured immission sound levels at 400 m west of the Rhede wind farm almost perfectly match (average difference: 0.1 dB) sound levels calculated from measured emission levels near the turbines. At distances up to 2 km the calculated level may underestimate the measured level, but the discrepancy is small: 1.5 dB or less.[1] Thus, from the measurements both the emission and immission sound levels could be determined accurately. As both levels can be related through a propagation model, it may not be necessary to measure both: immission measurements can be used to assess immission as well as emission sound levels of an entire wind farm.

The level of aerodynamic wind turbine noise depends on the angle of attack: the angle between the blade and the incoming air flow. Increasing atmospheric stability also creates greater changes in the angle of attack over each rotation, resulting in stronger turbine sound fluctuations. It can be shown theoretically for a modern turbine rotating at high speed that, when the atmosphere becomes very stable, the fluctuation in turbine sound level increases to approximately 5 dB. This value is confirmed by measurements at a single wind turbine where the maximum sound level periodically rises 4 to 6 dB above the minimum sound level within short periods of time. At some distance from a wind farm the fluctuations from two or more turbines may arrive simultaneously for a period of time and increase the fluctuation level further at the observer's position up to approximately 9 dB. This effect develops in a stable atmosphere because the spatial coherence in wind velocity over distances at the size of an entire wind farm increases. As a result turbines in the farm are exposed to a more constant wind and rotate almost synchronously. Because of this near-synchronicity, the fluctuations in sound level will for some time coincide at some locations, causing an amplification of the fluctuation. The place where such an amplification occurs will sweep over the area with a velocity determined by the difference in rotational frequency. The magnitude of this effect thus depends on stability, but also on the number of wind turbines and their distances to the observer.

Blade passing frequency is the parameter determining the modulation frequency of wind turbine sound. Human perception is most sensitive to

[1] In one night the sound level at over 2 km from the wind farm was much higher than calculated, probably because of an inversion layer adding more downward refracted sound. This apparently rare occurrence at the Rhede wind farm could be more significant where high inversion layers occur more often.

modulation frequencies close to 4 Hz and the modulated sound has a frequency of approximately 1000 Hz. The hypothesis that fluctuations are important is supported by descriptions given by naïve listeners as well as residents: turbines sound like 'lapping', 'swishing', 'clapping', 'beating' or 'like the surf'. It is probable that this fluctuating character is responsible the relatively high annoyance caused by wind turbine sound and a deterioration of sleep quality.

Atmospheric stability also affects the energy yield of wind turbines: relative to the 'standard' (neutral) atmosphere, a stable atmosphere increases the yield, especially for modern tall turbines. The reverse is true for an unstable atmosphere, though to a lesser degree. Perhaps atmospheric stability was not recognized as an important determinant for wind power as the underestimated night time yield is compensated partly by the overestimated daytime yield. The annual effect will depend on the average magnitude as well as the prevalence of atmospheric stability.

IX.2 Effect of atmospheric stability on ambient background sound

The change in wind profile at night also results in lower ambient background levels then expected: at night the wind velocity near the ground may be lower than expected from logarithmic extrapolation of the wind velocity at 10 m, resulting in lower levels of wind induced sound from low vegetation. The contrast between wind turbine and ambient sound levels is therefore at night more pronounced.

IX.3 Wind noise on a microphone

To avoid high wind induced pressure levels in windy conditions, outdoor measurements are best performed with a large diameter wind screen. The overall reduction from a bigger wind screen relative to a smaller one is determined by the ratio of the screen diameters. A wind screen does not reduce noise from atmospheric turbulence at very low frequencies.[1]

In a stable atmosphere the low near-ground wind velocity creates less wind noise on the microphone. As a result, sound measurements during a stable night are much less influenced by wind induced microphone noise (and other sounds as well, since nights are usually more quiet) than in a neutral or unstable atmosphere. The results in this book shows that wind turbine sound can be measured accurately at great distances (up to 2 km) if the atmosphere is stable.

The model developed in this thesis shows that, in order to reduce wind induced sound, it helps to measure over a low roughness surface and in a stable atmosphere, as both factors help to reduce turbulence, even if the average wind velocity on the microphone does not change. But in a stable atmosphere near-ground wind velocities will usually be low, decreasing wind induced noise further. With increasing stability, wind induced pressure levels will drop and finally reach a low level determined by turbulence in the wake of the wind screen.

IX.4 Degree of atmospheric stability

Stability is a property of the atmosphere, in principle occurring all over the earth. It depends on surface properties and weather conditions which determine the magnitude and evolution over time of the heat balance in the atmospheric boundary layer. Most important are differences in heat transfer at the surface (water, soil) and in the atmosphere (atmospheric humidity and clouds, wind mixing). With current knowledge, the effects of stability on the wind profile over flat ground can be modelled satisfactorily. In mountaineous areas terrain induced changes on the wind profile influence the stability related changes and the outcome is less easily predicted: these changes can weaken as well as amplify the effect of atmospheric stability.

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[1] frequencies below V/(3D), where V is the wind speed at the microphone and D the wind screen diameter

Results from various onshore, relatively flat areas show that in daytime the ratio of the wind velocity at 80 m (hub height) and the wind velocity at reference height of 10 m is 1.25 to 1.5. This ratio is in agreement with the usual logarithmic wind profile for low roughness lengths (low vegetation). At night the situation is quite different and the ratio has a much wider range with values from 1.7 to 4.3. At night high altitude wind velocities thus can be (much) higher than expected from logarithmic extrapolation of 10-m wind velocities.

IX.5 Measures to mitigate stability related effects

Presently available measures to decrease the immission sound level from modern turbines are to create more distance to a receiver or to slow down the rotor, preferably by an optimized control mechanism. Quieter blades as such will always be advantageous, but expected changes are modest and will not eliminate the beating or thumping character due to atmospheric stability.

Controlling the stability related sound emission requires a new strategy in wind turbine control and wind farm design. In the present situation there is usually more latitude for sound (and energy) production in daytime, but less during quiet nights. A strategy for onshore wind farms might be to use more of the potential in daytime, less at night.

A control strategy may depend on whether the legally enforced limit is a 10-m wind velocity or an ambient background sound level dependent limit. The 10-m wind velocity or the background sound level can act as the control system input, with blade pitch the controlled variable. In both cases a suitable place must be chosen to measure the input parameter. For background sound level as input it is probably necessary to use two or more inputs to minimize the influence of local (near-microphone) sounds. An ambient background controlled emission level may be the best strategy in relatively quiet areas as it controls an important impact parameter: the level above background or intrusiveness of the wind turbine sound.

Even if the sound emission level does not change, annoyance may be diminished by eliminating the rhythm due to the beating character of the sound. A solution is to continuously change the blade pitch, adapting the

angle of attack to local conditions during rotation. This will probably also be an advantage from an energetic point of view as it optimizes lift at every rotor angle, and it will decrease the mechanical load 'pulses' on the blades accompanying the sound pulses.
Increased fluctuation due to the interaction of sound from different turbines can be eliminated by adding small random variations to the blade pitch or rotor load, mimicking the random variations imposed by atmospheric turbulence in daytime when this effect does not occur.

IX.6 Recommendations

When night time is the critical noise period, wind turbine sound levels should be assessed taking into account stable atmospheric conditions. When the impulsive character of the sound is to be assessed, this should be carried out in times of a stable atmosphere, as that is the relevant condition for impulsiveness.

When ambient sound is considered as a sound masking wind turbine sound, neither sound should be related to wind velocity at 10 meter reference height via a (possibly implicit) neutral or 'standard' wind profile. A correct, stability dependent wind profile should be used. In flat and certainly in mountainous terrain one should determine directly the relationship between hub height wind velocity on the one hand and ambient background sound at an immission location on the other hand, in order to eliminate any badly correlated, intermediate wind velocity.

Also, in the assessment of wind turbine electrical power production the sole use of a neutral wind profile (a 'standard atmosphere') should be abandoned as it yields data that are not consistent with reality.

When comparing stable and unstable atmospheric conditions, the difference in sound power as well as in sound limits can lead to new control strategies and onshore wind farm concepts. Presently only distance is a factor used to minimize noise impact. A wind farm can be optimized with a strategy that maximizes power output while keeping sound power within limits. When daytime immission levels do comply with the noise limits, but nighttime immission levels do not, a control system can be implemented to reduce the turbine speed when necessary.

In new turbine designs continuous blade pitch control could be applied to increase energy yield and reduce annoyance at the same time by eliminating the thumping character of the emitted sound.

X EPILOGUE

This is the end of my tour of discovery, of over two years of reading about and trying to understand atmospheric physics and wind turbines, of measurements and theory, of applying knowledge and expertise in physics and acoustics to a new topic. Of course there is much more to discover: indeed, it looks like wind turbines have become more fascinating now their sound has proved to be more complex than a simple constant noise from the sky, driven only by wind with a constant profile. This may motivate researchers and consultants to put more effort in better predictions of wind turbine noise, and considering again noise exposure to local residents.

This period began with publishing the results of the measurements at the Rhede wind farm and it ended, seemingly symbolically, with the first International Conference on Wind Turbine Noise in Berlin in October 2005. At that conference there was a general acknowledgment that wind turbine sound is not the simple issue we once thought it was. At the conference many delegates agreed that, looking back, the internationally used 'standard wind profile' might have been misleading people by suggesting it was, everywhere and always, the best wind profile. Although the widely used IEC-61400 standard certainly does not state that, a less careful reader might think it did, finding no alternative profile in the standard. Thus, it becomes a question of careful communication and taking into account that acoustic consultants do (did?) not have the knowledge to apply the standard in 'non standard' conditions. Paul Botha [2005] proposed to do away with 10-m wind velocities entirely and relate background sound directly to hub height wind velocity. This is a sensible idea as it relates the two factors that are most relevant, wind turbine sound and ambient sound, without an intermediate variable (10-m wind velocity). It will lead to better insight in the masking capability of background sound: the ability to mask (= make inaudible) unwanted sound is not only dependent on wind velocity, but also on atmospheric stability and wind direction.

The Berlin conference helped me solve a riddle. Malcolm Hayes had written me before that according to his observations blade swish is caused by the blade that is going down, not by the blade being in the downward position (passing the mast). This seems contradictory to my conclusion that blade beating is due to blades passing the mast. Oerlemans [2005] showed that close to the tower Malcolm was right, but this could not explain blade swish far away from a turbine. So what we heard depended on the distance to the turbine, which is also true for other sound phenomena: further away from the turbine the sound has a lower pitch, the pulses can be amplified by synchronicity of turbines and it can be louder under an inversion layer. This point again illustrates that one must be careful when generalizing observations.

I don't expect the problem of the distinct, beating character of wind turbine sound to be solved easily. Though I am convinced the sound character is a major factor in wind turbine noise annoyance, a 5 dB penalty for an impulsive character of the sound may indeed impede wind farm projects as a wind farm will need more 'empty space'. Also, the sound is not as impulsive as gun shots or hammering are, giving way to a discussion on whether it is 'really' impulsive (5 dB penalty) or not (no penalty). Is it possible to have a truly independent opinion in a legally created dichotomy with such significant consequences?
Several technical possibilities to minimize the noise have been outlined in this book, but we need not just depend on technical solutions. A change in public relations can also make a difference: proponents must accept that wind turbine noise is not (always) 'benign', that the noise may affect people, and that people who are complaining are not always just a nuisance. And no, we still do not understand wind turbine noise immission entirely, so proponents should watch their WARYDU attitude.

"..... about 80 per cent of the population supports wind power in the surveys investigated in this paper. On the local level the support of wind power in areas with operating wind power plants is equally high. (....) This, however, does not mean that protests will not appear. It takes only one devoted opponent to start for instance a legal procedure against a planning permit. This is one of the reasons why public conflicts over wind power plants have become the rule rather than the exception. Lack of communication between the people who shall live with the turbines, and the developers, the local bureaucracy, and the politicians seems to be the perfect catalyst for converting local scepticism, and negative attitudes into actual actions against specific projects. Conversely, information and dialogue is the road to acceptance."

Steffen Damborg (Danish Wind Industry Association) in "Public Attitudes Towards Wind Power", a "survey of surveys" from several countries, 2002; posted on http://www.windpower.org/en/news/articles (consulted December 3, 2005)

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I want to express my sincere gratitude to a number of people.
Foremost is Diek (prof dr ir H Duifhuis) who for 20 years has been a true, though most of the time distant colleague, and who immediately responded positive to my request to be my promotor. The same, but for a shorter period, holds for my second promotor Ton (prof dr A J M Schoot Uiterkamp). Both were very confident in my capacities and my work and they also allowed me to change the subject without much ado.[1] "The point is, Frits", they lectured me, "that you demonstrate your scientific capability, the subject as such is not that important". And it is not by obligation that I also mention my wife Luci, who for two years gracefully took most of my share in cooking and household chores.

There are some others I would like to commemorate. My colleague Aart van der Pol who was always interested in new work and new ideas and sharp in his comments. Terry Matilsky, one of the beleaguered residents, who read the first and the final chapters for language and clarity. My friend Dorothé Faber with whom I discussed my work from a very different, non-technical perspective. And the students and secretaries who had to abide with too little attention devoted to them and me again and again forgetting things. I hope they felt I did try to support them even though I was busy or being elsewhere in my thoughts. Much the same goes for my daughters Inge and Maya, who will meet me at the end of this period as my beloved paranymphs.

Two organizations have supported my research. The province of Groningen has subsidized the measurement project at the Rhede wind farm to support the residents and thus helped to produce a report and after that a scientific publication on the effect of atmospheric stability. The British Renewable Energy Foundation gave a grant to elaborate my thoughts on

[1] Originally my thesis was to be about Sound monitoring in quiet areas, and Diek, Ton and I discussed the nature of sound and quietness and our response to it; this changed when I became ever more involved in wind turbines.

the beating character of wind turbine sound, which led to my second publication on wind turbine noise. The KNMI gave support by providing data that helped me prepare the presentation about the wind statistics.

My Faculty of Mathematics and Natural Sciences allowed me to spend half of my working time for two years on this promotion. Unfortunately there was no money for a substitute, so I had to fit my usual work in the other half of the time. It has been busy sometimes, but I am lucky to have work that I like (well, most of it) and is worthwhile, so I never count the hours from 9 to 5. It is, I think, significant that I have a position in a University based Science Shop, because that position enables me to spend time on projects for the benefit of citizen groups with no net financial return. This book shows that citizens may need the help of science to support their claims and improve their situation, which is not available elsewhere except perhaps at high costs. On behalf of the people I have helped I am grateful our University and Faculty are still firm supporters of the Science Shop idea.[1]

[1] Don't count your chickens before they are hatched! At the time this book was finalized, 21 years after the Science Shop for Physics started, it was announced that because of large financial deficits the Faculty executive board proposed to close down all four faculty science shops.

SUMMARY

Ch. I

This study was started after complaints of residents that the sound of a wind farm was louder and more annoying than predicted, especially when there was little wind in the evening or at night. The explanation appeared to be the occurrence of another wind profile than that used to predict the noise impact (the wind profile describes how the wind velocity increases with height). There are probably several reasons why this was not found earlier: 1) because wind turbines become taller, there is a growing discrepancy between prediction and practice; 2) measurements are usually done in daytime when the wind profile resembles more closely the commonly used standard profile; 3) based on the sound that occurs in daytime, it is hard to imagine the sound can be so different at night; 4) "there are always people complaining", so complaints are not always a reason for a thorough investigation; 5) at least some wind energy proponents prefer to downplay the disadvantages rather than solve them.

Ch. II

According to Dutch legislation and international guidelines the sound production of a wind farm can only be checked by measurements when the wind farm operator cooperates. The consequence is an implicit partiality in favor of the operator detrimental to independent verification. Because of the level of detail of instructions measurements and assessments are hampered and there is no margin for the very expertise of an investigator. For a lay person understanding the jargon was already utterly impossible and he cannot but hire an expensive expert to argue his case.

From this study one can conclude that through the use of a restricted model of reality, *viz.* a forever neutral atmosphere, experts have lost sight (temporarily) of the true reality in which a neutral atmosphere is not very prevalent. It is precisely the occurrence of complaints that may indicate such errors.

Ch. III

The sound of modern wind turbines is generated mainly by the flow of the wind along the blades. In this process a turbulent boundary layer develops at the rear side of the blade where trailing edge sound of relatively high

frequencies originates and which is radiated into the environment. This turbulent boundary layer becomes thicker and produces more sound when the wind flows in at a greater angle.
The inflowing wind is turbulent itself. The blade cuts through these turbulent movements and as a result again sound is generated: in-flow turbulence sound. Here lower frequencies dominate. Finally a blade also radiates sound when the forces on the blade change because of a local variation in wind velocity. This happens every time the blade passes the tower because there the wind is slowed down by the tower. On the one hand this causes more trailing edge sound due to the change in inflow angle, on the other hand more infrasound is generated because of the sudden sideways movement at the rate of the blade passing frequency.

For all these sounds loudness increases when the speed increases. Because the tip has the highest speed the sound of a wind turbine mainly comes from the blade tips. Moreover, for human hearing the trailing edge sound is most important because it is in an area of frequencies that we can hear well.

It is often assumed that there is a fixed relation between the wind velocity at hub height and at a reference height of 10 meter. This is the relation valid in a neutral or 'standard' atmosphere. No other relations are given in legislation or international guidelines for wind turbine sound that are valid in other conditions of the atmosphere, *viz* the stable and unstable conditions.
The atmosphere is *unstable* when in daytime the air near the ground is relatively warm from contact with the surface heated by solar insolation. In that case vertical air movements originate and the wind profile is not equal to the profile in a neutral atmosphere, though it does not differ strongly. A *stable* atmosphere however has a markedly different wind profile. The atmosphere is stable when the air close to the ground is relatively cold due to contact with the ground surface when this cools down at night by radiating heat. A stable atmosphere occurs especially in nights with a partial or no cloud cover and the wind is not too strong (close to the ground). In a stable atmosphere the turbulence has decreased substantially

and as a result layers of air are less strongly coupled. The lower layer of air is thus less taken along with the wind that at higher altitudes keeps on blowing, giving rise to greater differences between wind velocities at different heights.

Ch. IV

The present study was performed mainly near the Rhede wind farm close to the Dutch – German border. The farm consists of 17 1.8 MW turbines of 98 m hub height and three 35 m blades. The level of the incoming sound has been measured at a number of locations. The sound could be measured up to a distance of 2 km. It proved that, contrary to predictions, already at a weak wind (at 10 m height) the turbines could rotate at almost top speed and consequentially produce much sound.
It appeared that a wind profile proper to stable conditions could explain the measured sound levels excellently. At the same wind velocity at a reference height of 10 meter, wind turbines in a stable atmosphere generate more sound than in a neutral atmosphere, while at the same time the wind velocity near the ground is so low that the natural ambient sound due to rustling vegetation is weaker. As a result the contrast between wind turbine sound and natural ambient sound is more pronounced in stable conditions than it is in neutral conditions.

Ch. V

When the wind profile after sunset changes while the atmosphere becomes more stable, the difference in wind velocity over the rotor increases. This causes a change in the level of the trailing edge sound. At the low tip this is reinforced because the inflow angle already was less favourable due to the wind being slowed down by the presence of the mast. The differences in wind speed lead to variations in the sound radiated by the blade tips that reach their highest values when a tip passes the mast. For a modern, tall wind turbine the calculated variation is approximately 5 dB at night, whereas it is approximately 2 dB in daytime. This is perceived as a more pronounced fluctuation of the sound.
A more stable atmospheric boundary layer moreover implies that there is less atmospheric turbulence, so wind turbines in a farm will experience a more equal and constant wind. As a result, in a stable atmosphere wind turbines can, more than in daytime, run almost at the same speed and then

diverge again. With several turbines the fluctuations in sound can reinforce one another when they reach the ear of an observer simultaneously. With two turbines (at the same distance) this leads to an increase in level of 3 dB, with three turbines to an increase of 5 dB.

In measurements this reasoned upon effect indeed occurred. With a single 45 m high wind turbine at a distance of 280 m at night variations of 6 dB were found. Near the wind farm the variations were usually 5 dB, but they could rise to approximately 9 dB, as expected when the fluctuations of several turbines coincide.

From other research and from descriptions of residents one can establish that the sound of a wind turbine or wind farm becomes more annoying because of ' swishing', 'sloshing', 'clapping', 'beating' or ' thumping'. All descriptions mention a periodic variation on top of a constant noisy sound. This corresponds to the calculated and measured modulation of trailing edge sound. From psycho-acoustic research it has been shown earlier that human sensitivity to sound fluctuations is high at frequencies that occur in the night time sound of modern wind turbines. If this fluctuating sound is sufficiently loud in a bedroom it can cause sleep disturbance.

Ch. VI

In the temperate climate zone a stable atmosphere is to be expected between sunset and sunrise over land if there is a -partly- clear sky (because clouds hinder the radiation of heat) and the wind is not too strong (because a strong wind promotes vertical heat exchange). From an analysis of measurements of the KNMI at Cabauw, in the central part of the Netherlands, up to an altitude of 200 m, it appears that there is a diurnal and seasonal pattern in the wind profile that correlates with the diurnal and seasonal variation in the heat exchange between the earth's surface and the atmosphere. The fact that at sunset the wind often lies down is a consequence of the increasing atmospheric stability, and this decrease in wind velocity close to the ground is accompanied by an increase at higher altitudes. This has significant consequences for the energy production of a wind turbines, where the rotor height plays an important part. If one starts from the measured wind velocities at Cabauw at 10 m height and a forever neutral atmosphere, the annually averaged electrical power generated by a 80 m high, 2 MW (reference) wind turbine would amount to almost

500 kW. However, based on the real, measured wind speed at 80 *m* height the annual power in reality amounts to 600 kW. So, because of atmospheric stability there is, relative to a neutral atmosphere, a significantly higher yield at night time hours, that even amply compensates for the lower yield in daytime hours.

The higher wind velocity at night on the rotor also causes a higher level of generated sound. If again one starts from the measured wind velocities at Cabauw at 10 m height and an atmosphere assumed to be neutral, the average sound power level generated by the reference wind turbine is 102 dB(A). In reality, however, it is 2 dB higher. This is also an average over an entire year; in separate nights the difference can be substantially higher, *e.g.* when a turbine rotates at (almost) top speed at a time it was expected to not produce at all because of the low 10 m wind velocity.

The degree of atmospheric stability at Cabauw is hardly different from what was observed at the Rhede wind farm. At other locations in countries in the temperate zone stability occurs to a similar extent. The consequences of atmospheric stability as described here, will thus occur at many wind farms that exist or are to be built in the temperate zone. However, above large bodies of water stability is rather a seasonal than a diurnal phenomenon, en in mountainous terrain the consequences of stability on the wind profile can be strengthened as well as weakened due to changes induced by height variations in the area.

The sound of a wind turbine or wind farm can thus become more annoying after sunset for two reasons: it becomes louder and the sound exhibits stronger fluctuations. At a given rotor diameter a blade can only be made less noisy with a different design or by slowing down the speed. A decrease in speed however reduces the generated electrical power and must therefore be applied only when necessary. To achieve this a control can be applied that lowers the speed when a noise limit is exceeded, increasing the speed again when the limit allows. This control could work on the generator and/or the pitch angle of the blades.

By changing the pitch angle while the blades rotate, the wind can flow in at an optimal angle at any position on the rotor, by which the energetic efficiency will increase on the one hand and the fluctuation strength of the sound will decrease on the other hand, even rendering the fluctuations inaudible. The total sound power will then decrease even relative to a neutral atmosphere, because the in-flow turbulence sound level will be lower due to the relative absence of atmospheric turbulence. Tilting the rotor to change the pitch angle during rotation does not appear to be a fruitful strategy: the tilt must be so great that the disadvantages will dominate.

The fluctuations near a wind farm can be stronger due to interference from the fluctuations of several turbines. This can be prevented by desynchronizing the turbines, as it happens in daytime by large scale atmospheric turbulence, by adding small and uncorrelated variations in the load of the rotors or the pitch angle of the blades of the individual turbines.

Controlling the sound production thus requires a new strategy for managing wind turbines: in daytime there is often more margin available for sound production than at night and this margin can be used in daytime in exchange for more restrictions at night.

Ch. VIII

Finally another, very different problem was addressed: the influence of wind on a microphone in or without a wind screen. When there is sufficient wind the microphone signal contains a low frequency, rumbling sound disturbing the measurement of ambient sound. This rumble is not sound from the environment, but is generated by pressure fluctuations caused by turbulent wind velocity variations. With a pressure sensitive microphone these pressure variations are not distinguishable from acoustical pressure variations. It appears that a wind screen is effective only by damping contributions of small turbulent eddies. A wind screen has no effect when eddies are bigger than the wind screen.

The strength of atmospheric turbulence does not only depend on the (average) wind velocity, but also on the local roughness of the earth surface and the stability of the atmosphere. These last two factors cause friction and thermal turbulence, respectively. The turbulence strength is

well known for an unobstructed wind flow over flat land. Turbulence is weaker in a stable and stronger in an unstable atmosphere.
The 'sound' pressure level based on atmospheric turbulence appears to agree well with measured and published levels of wind induced pressure levels. Thus the influence of wind on a sound measurement in wind can be calculated. In reverse this calculation model yields a new method to measure the strength of atmospheric turbulence.

To conclude, it can be stated that with respect to wind turbine sound an important phenomenon has been overlooked: the change in wind after sunset. This phenomenon will be more important for modern, tall wind turbines and in view of the many wind farms that are planned. If this problem is not recognized and solved it will hamper the expansion of wind energy.

SAMENVATTING

Bobby vraagt: 'Hoort u de windmolens wel eens?'

'Wat voor geluid maken ze?'

'Net als op elkaar slaand metaal, maar als er een echt harde wind staat worden de wieken vager en begint de lucht te schreeuwen van pijn.' Hij siddert.

'Waar zijn de windmolens voor ?'

'Ze zorgen dat alles 't doet. Als je je oor tegen de grond houdt kun je ze horen.'

'Wat bedoel je met alles?'

'De lichten, de fabrieken, de spoorwegen. Zonder de windmolens staat alles stil.' [2]

H. I

Dit onderzoek is tot stand gekomen na klachten van bewoners dat het geluid van een windpark luider en hinderlijker was dan voorspeld, vooral als er 's avonds of 's nachts weinig wind was. De verklaring hiervoor bleek het optreden van een ander windprofiel dan werd gehanteerd bij de voorspelling van de geluidsbelasting (het windprofiel beschrijft hoe de windsnelheid toeneemt met de hoogte). Dat dit niet eerder is gevonden heeft waarschijnlijk meerdere redenen: 1) doordat windturbines hoger en groter worden is er een groeiende kloof tussen voorspelling en praktijk; 2) er wordt normaliter overdag gemeten wanneer het windprofiel meer lijkt op het gewoonlijk gebruikte standaardprofiel; 3) men kan zich, op grond van het overdag optredende geluid, moeilijk voorstellen dat het 's nachts zo anders kan zijn; 4) "er zijn altijd wel mensen die klagen", dus klachten zijn niet altijd een reden tot grondig onderzoek; 5) tenminste een aantal voorstanders van windenergie bagatelliseert liever de nadelen dan ze op te lossen.

H. II

Volgens de Nederlandse wetgeving en internationale richtlijnen kan de geluidsproductie van een windpark alleen door metingen gecontroleerd worden als de exploitant meewerkt. Het gevolg is een impliciete partijdigheid ten gunste van de exploitant en ten nadele van onafhankelijke

[2] 'The suspect', door Michael Robotham, Time Warner Paperbacks, 2003 (p. 151), vertaling G.P. van den Berg

controle. Ook door de gedetailleerdheid van voorschriften worden metingen en beoordelingen bemoeilijkt en is er geen ruimte meer voor de eigen deskundigheid van een onderzoeker. De burger kan het jargon al helemaal niet meer volgen en moet een dure deskundige inhuren om zijn zaak te beargumenteren.

Bij dit onderzoek kan men constateren dat deskundigen door het gebruik van een beperkt model van de werkelijkheid, namelijk een eeuwig neutrale atmosfeer, (tijdelijk) het zicht hebben verloren op de echte werkelijkheid waarin die neutrale atmosfeer niet zo vaak voorkomt. Juist klachten kunnen helpen om dergelijke dwalingen aan te wijzen.

H. III

Het geluid van moderne windturbines wordt vooral opgewekt door de stroming van de wind langs de wieken. Daarbij ontwikkelt zich een turbulente grenslaag aan de achterkant van de wiek waarin relatief hoogfrequent achterrandgeluid ('trailing edge sound') ontstaat dat wordt uitgestraald naar de omgeving. Deze turbulente grenslaag wordt dikker en produceert meer geluid als de wind onder een grotere hoek instroomt.
De instromende wind is zelf ook turbulent. De wiek snijdt door deze turbulente bewegingen heen waarbij weer geluid ontstaat: instromings-turbulentiegeluid ('in-flow turbulent sound'). Hierin domineren lagere frequenties. Tenslotte straalt een wiek ook geluid af als de krachten op de wiek veranderen doordat de windsnelheid lokaal varieert. Dit gebeurt telkens als de wiek de mast passeert omdat daar de wind is afgeremd door de mast. Enerzijds ontstaat daarbij meer achterrandgeluid omdat de instromingshoek verandert, anderzijds ontstaat er ook infrageluid door de plotselinge zijwaartse beweging in het tempo van de wiekpasseerfrequentie.

Bij al deze geluiden neemt de sterkte ervan toe naarmate de snelheid groter is. Omdat de tip de hoogste snelheid heeft is het geluid van een windturbine vooral van de wiektips afkomstig. Voor het menselijk gehoor is bovendien het achterrandgeluid het belangrijkst omdat dat in een frequentiegebied ligt dat wij goed kunnen waarnemen.

Vaak wordt aangenomen dat er een vaste relatie is tussen de wind op ashoogte en op een referentiehoogte van 10 meter. Dit is de relatie die geldig is in een neutrale of 'standaard' atmosfeer. Er worden geen andere relaties gegeven in de wetgeving en in internationale richtlijnen die gelden bij andere toestanden van de atmosfeer, namelijk de stabiele en instabiele toestand.

De atmosfeer wordt *instabiel* als overdag de lucht nabij de grond relatief warm is door contact met het door zoninstraling verwarmde aardoppervlak. Er ontstaan dan verticale luchtbewegingen en het windprofiel is niet meer gelijk aan dat in een neutrale atmosfeer, maar wijkt daar niet sterk vanaf. Een *stabiele* atmosfeer kent echter een duidelijk afwijkend windprofiel. De atmosfeer is stabiel als de lucht nabij de grond relatief koud is door contact met het door warmte-uitstraling afkoelende aardoppervlak 's nachts. Een stabiele atmosfeer treedt vooral op tijdens niet gedeeltelijk of geheel onbewolkte nachten met niet teveel wind (aan de grond). In een stabiele atmosfeer is de turbulentie sterk verminderd met als gevolg dat luchtlagen minder sterk gekoppeld zijn. De onderste luchtlaag wordt daardoor minder meegenomen door de wind die op grotere hoogte gewoon blijft doorwaaien, waardoor er grotere verschillen zijn tussen windsnelheden op verschillende hoogten.

Het hier beschreven onderzoek is grotendeels uitgevoerd bij windpark Rhede vlakbij de Duits-Nederlandse grens. Het park telt 17 1,8 MW turbines met een ashoogte van 98 m en drie wieken van 35 m lengte. Op een aantal punten is het niveau van het invallende geluid langdurig gemeten. Het geluid kon tot op 2 km afstand worden gemeten. Bij een zwakke wind (op 10 m hoogte) bleken de turbines, anders dan voorspeld, al op vrijwel topsnelheid te kunnen draaien en dientengevolge veel geluid te produceren.

Een windprofiel dat bij stabiele omstandigheden past bleek de gemeten geluidsniveaus uitstekend te kunnen verklaren. Bij een gelijke windsnelheid op een referentiehoogte van 10 meter, produceren windturbines in een stabiele atmosfeer meer geluid dan in een neutrale atmosfeer, terwijl dan tegelijkertijd de windsnelheid nabij de grond zo laag is dat het natuurlijke omgevingsgeluid van ruisende vegetatie zwakker is.

Het contrast tussen windturbinegeluid en natuurlijk omgevingsgeluid is daardoor bij stabiele omstandigheden groter dan bij instabiele.

H.V

Als het windprofiel na zonsondergang verandert door een stabieler wordende atmosfeer, wordt het verschil in windsnelheid over de rotor groter. Dit veroorzaakt een verandering in de sterkte van het achterrandgeluid. Bij de lage tip wordt dit nog versterkt doordat de instromingshoek al ongunstiger was vanwege de door de mast verlaagde windsnelheid. De verschillen in windsnelheid leiden tot variaties in het door de tips afgestraalde geluid die het grootst zijn als een tip de mast passeert. Voor een moderne, hoge windturbine bedraagt de berekende variatie ongeveer 5 dB 's nachts, terwijl dit overdag ca. 2 dB is. Dit wordt ervaren als een duidelijker fluctuatie van het geluid.
Een stabielere atmosferische grenslaag betekent bovendien dat er minder atmosferische turbulentie is waardoor windturbines in een park een meer gelijke en meer constante wind ervaren. In een stabiele atmosfeer kunnen windturbines daardoor, méér dan overdag, een tijd nagenoeg gelijk lopen en weer langzaam uiteenlopen. Bij meerdere turbines kunnen de fluctuaties in het geluid elkaar versterken als ze het gehoor van een waarnemer gelijktijdig bereiken. Bij twee turbines (op gelijke afstand) leidt dit tot een 3 dB hoger niveau van de fluctuaties, bij drie turbines tot een 5 dB hoger niveau.
Bij metingen bleek dit beredeneerde effect daadwerkelijk voor te komen. Bij een enkele windturbine van 45 m ashoogte werden op een afstand van 280 m 's nachts variaties gevonden van 6 dB. Bij het windpark bedroegen de variaties meestal 5 dB, maar ze konden oplopen tot ongeveer 9 dB, zoals verwacht wordt bij het samenvallen van de fluctuaties van meerdere turbines.
Uit onderzoek elders en uit beschrijvingen van omwonenden kan men constateren dat het geluid van een windturbine of windpark vooral na zonsondergang hinderlijker wordt door het 'zoeven' of 'klotsen', 'klappen', 'slaan' of 'bonken'. De omschrijvingen vermelden steeds een periodieke variatie bovenop een constant ruisachtig geluid. Dit correspondeert met de berekende en gemeten modulatie van het achterrandgeluid. Uit psycho-akoestisch onderzoek is veel eerder al

gebleken dat de menselijke gevoeligheid voor geluidsfluctuaties hoog is bij frequenties die juist voorkomen in het nachtelijke geluid van moderne turbines. Als dit fluctuerende geluid voldoende luid doordringt in een slaapkamer kan het tot slaapverstoring leiden.

In de gematigde klimaatzone kan men tussen zonsondergang en zonsopgang boven land een stabiele atmosfeer verwachten als er een -gedeeltelijk- onbewolkte hemel is (bewolking verhindert de warmte-uitstraling) en een niet te harde wind (veel wind bevordert de verticale warmtevereffening). Uit een analyse van metingen van het KNMI bij Cabauw, in het midden van Nederland, tot op 200 m hoogte blijkt dat er een dagelijkse en jaarlijkse gang is in het windprofiel die samenhangt met de dagelijkse en seizoensvariatie in de warmte-uitwisseling tussen aardoppervlak en atmosfeer. Dat bij zonsondergang de wind vaak gaat liggen is een gevolg van de toenemende atmosferische stabiliteit, en deze windsnelheidsafname nabij de grond gaat gepaard met een toename van de windsnelheid op grotere hoogte.
Dit heeft belangrijke gevolgen voor de energieproductie van een windturbine, waarbij bovendien de rotorhoogte een rol speelt. Als wordt uitgegaan van de gemeten windsnelheden bij Cabauw op 10 m hoogte en een altijd neutrale atmosfeer, dan zou het over een jaar gemiddelde opgewekte elektrische vermogen van een 80 m hoge 2 MW windturbine bijna 500 kW bedragen. Gebaseerd op de werkelijke, gemeten windsnelheid op 80 m hoogte bedraagt het over een jaar gemiddelde vermogen echter 600 kW. Door atmosferische stabiliteit is er dus, ten opzichte van een neutrale atmosfeer, een aanmerkelijk hogere opbrengst in de nachturen, waardoor zelfs de lagere opbrengst overdag ruim wordt gecompenseerd.

De hogere windsnelheid 's nachts op de rotor veroorzaakt echter ook een hogere geluidsproductie. Als weer wordt uitgegaan van windsnelheden op 10 m hoogte en een neutraal veronderstelde atmosfeer, dan bedraagt het geluidsvermogen van de turbine 's nachts gemiddeld ca. 102 dB(A). In werkelijkheid is het ruim 2 dB hoger. Ook dit is een gemiddelde over een heel jaar; in afzonderlijke nachten kan het verschil veel groter zijn, bijvoorbeeld als een windturbine op (vrijwel) topsnelheid draait, terwijl verwacht was dat deze, gezien de lage windsnelheid op 10 m hoogte, helemaal niet zou produceren. Dit gebeurt vooral in het zomerhalfjaar.

De mate waarin atmosferische stabiliteit optreedt bij Cabauw blijkt nauwelijks te verschillen van wat bij windpark Rhede is waargenomen. Op andere locaties in landen in de gematigde zone blijkt stabiliteit in vergelijkbare mate voor te komen. De beschreven gevolgen van atmosferische stabiliteit zullen dus bij veel windparken optreden die in de gematigde zone staan of nog gebouwd worden. Echter, boven grote wateroppervlakken is stabiliteit eerder een seizoens- dan een dagelijks verschijnsel, en in bergachtig gebied kunnen de gevolgen van stabiliteit op het windprofiel zowel versterkt als verzwakt worden door veranderingen tengevolge van hoogteverschillen in het gebied.

II. VII

Geluid van een windturbine of windpark wordt dus om twee redenen na zonsondergang hinderlijker: het wordt luider en het geluid vertoont sterkere fluctuaties. Bij een gegeven rotordiameter kan een wiek alleen stiller worden door een ander ontwerp of door de snelheid te verlagen. Snelheidsverlaging gaat echter ten koste van het opgewekte elektrische vermogen en moet daarom liefst alleen worden toegepast wanneer dat nodig is. Daartoe kan een regeling worden toegepast die de snelheid verlaagt wanneer een geluidslimiet wordt overschreden, en deze weer verhoogt wanneer de limiet dat toelaat. De regeling zou kunnen ingrijpen op de generator en/of de vaanstand van de wieken.
Door de vaanstand tijdens de rotatie van de wieken te variëren kan op elke positie de wind onder een optimale hoek de rotor instromen, waardoor enerzijds het energetisch rendement toeneemt en anderzijds de fluctuatiesterkte van het geluid afneemt en de fluctuaties zelfs onhoorbaar kunnen worden. Het totale geluidsvermogen zal afnemen, zelfs ten opzichte van een neutrale atmosfeer, omdat het instromingsturbulentie-geluid zal verminderen door de relatieve afwezigheid van atmosferische turbulentie. Het kantelen van de rotor waardoor tijdens een rotatie de vaanstand verandert lijkt geen vruchtbare strategie: de kanteling moet zo groot zijn dat de nadelen overheersen.

Bij een windpark kunnen de fluctuaties sterker zijn door interferentie van de fluctuaties van meerdere turbines. Dit kan worden voorkomen door de turbines te desynchroniseren, zoals dat overdag gebeurt door grootschalige atmosferische turbulentie, door kleine en ongecorreleerde variaties in de belasting van de rotors of in de vaanstand van de wieken van de afzonderlijke turbines.

Het beheersen van de geluidsproductie vergt derhalve een nieuwe strategie bij de regeling van windturbines: overdag is er vaak meer geluidsruimte beschikbaar dan 's nachts en die ruimte kan overdag gebruikt worden als er 's nachts beperkingen worden opgelegd.

Als laatste is nog een geheel ander probleem onderzocht: de invloed van wind op een microfoon, al of niet in een windbol. Bij voldoende wind bevat het microfoonsignaal een laagfrequent, rommelend geluid waardoor de meting van omgevingsgeluid wordt verstoord. Deze 'rumble' is geen geluid uit de omgeving, maar ontstaat door drukvariaties tengevolge van turbulente windsnelheidsvariaties. Met een drukgevoelige microfoon zijn deze drukvariaties niet te onderscheiden van akoestische drukvariaties. Het blijkt dat een windbol alleen effectief is doordat de bijdragen van kleine turbulente wervels worden gedempt. Een windbol heeft geen effect bij wervels die groter zijn dan de windbol.
De sterkte van atmosferische turbulentie hangt niet alleen af van de (gemiddelde) wind snelheid, maar ook van de lokale ruwheid van het aardoppervlak en de stabiliteit van de atmosfeer. De twee laatste factoren veroorzaken respectievelijk wrijvingsturbulentie en thermische turbulentie. De turbulentiesterkte is in de literatuur goed bekend bij een vrije aanstroming van wind over vlak land. De turbulentie is zwakker in een stabiele, sterker in een instabiele atmosfeer.
Het op atmosferische turbulentie gebaseerde 'geluids'drukniveau blijkt goed overeen te komen met gemeten en gepubliceerde niveaus van door wind geïnduceerde drukniveaus. De invloed van wind op een geluidsmeting in wind kan dus worden berekend. Omgekeerd levert het rekenmodel een nieuwe methode om de sterkte van de atmosferische turbulentie te meten.

Tot slot kunnen we concluderen dat er bij het geluid van windturbines een belangrijk fenomeen over het hoofd is gezien: de verandering van de wind na zonsondergang. Dit fenomeen zal belangrijker worden voor moderne, hoge windturbines en met het oog op de vele windparken die worden gepland. Als dit probleem niet wordt onderkend en opgelost zal het de uitbreiding van windenergie bemoeilijken.

REFERENCES

Archer C.L. and Jacobson M.Z. (2003): "Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements", Journal of Geophysical Research **108** (9), pp. 1-20

B&K (1990): "Microphone Handbook", Brüel & Kjaer, Denmark

B&K (1995): "Microphone Handbook", Brüel & Kjaer, Denmark

Baidya Roy S., Pacala S.W. and Walko R.L. (2004): "Can large wind farms affect local meteorology?", Journal of Geophysical Research **109**, pp. 1-6

Boersma H.F. (1997): "Characterization of the natural ambient sound environment: measurements in open agricultural grassland", Journal of the Acoustical Society of America **101** (4), pp. 2104-2110

Botha P. (2005): "The use of 10 m wind speed measurements in the assessment of wind farm noise", proceedings WindTurbineNoise2005, Berlin

Brooks T.F., Pope D.S. and Marcolini M.A. (1989): "Airfoil Self-Noise and Prediction", NASA reference publication 1218, USA

E.On (2004): "Wind report 2004", E.ON Netz GmbH, Bayreuth, Germany

ESB (2004): "Impact of Wind Power Generation in Ireland on the Operation of Conventional Plant and the Economic Implications", ESB National Grid, Ireland

ETSU (1996): "The Assessment & Rating of Noise from Wind Farms" (ETSU-R-97), The Working Group on Noise from Wind Turbines, Department of Trade and Industry, United Kingdom

EWEA (2004): "Wind Energy - The Facts: an analysis of wind energy in the EU-25", European Wind Energy Association (EWEA), European Commission's Directorate General for Transport and Energy (DG TREN)

Garrat J.R. (1992): "The atmospheric boundary layer", Cambridge University Press, Cambridge

Grosveld F.W. (1985): "Prediction of Broadband Noise from Horizontal Axis Wind Turbines", Journal of Propulsion **1** (4), pp. 292-299

Hansen M.O.L. (2000): "Aerodynamics of wind turbines", James & James (Science Publishers) Ltd, London

Harders H. and Albrecht H. J. (2005): "Analysis of the sound characteristics of large stall-controlled wind power plants in inland locations", proceedings WindTurbineNoise2005, Berlin

Health Council (2004): "Effects of noise on sleep and health", Health Council of the Netherlands, publication no. 2004/14, The Hague

Holtslag A.A.M. (1984): "Estimates of diabatic wind speed profiles from near-surface weather observations", Boundary-Layer Meteorology **29**, pp. 225–250

Hubbard H.H. and Shepherd K.P. (2004): "Aeroacoustics of large wind turbines", Journal of the Acoustical Society of America **89** (6), pp. 2495-2508

Hutcheson F.V. and Brooks T.F. (2004): "Effects of Angle of Attack and Velocity on Trailing Edge Noise", proeedings. 42nd Aerospace Sciences Meeting, Reno, January 2004

IEC (1998): "International Standard 61400-11, Wind Turbine Generator Systems - Part 11: Acoustic Noise Measurement Techniques", IEC 61400-11:1998(E)

ISO (1995): "Acoustics — Frequency-weighting characteristic for infrasound measurements" (ISO 7196), International Organization of Standardization

Jakobsen J. and Andersen B. (1983): "Wind Noise. Measurements of Wind-Generated Noise from Vegetation and Microphone System", Danish Acoustical Institute Report no.108, Lyngby

Jakobsen J. (2004): "Low frequency sound from wind turbines", proceedings Low Frequency Noise and Vibration, Maastricht

Jensen N.O. and Busch N.E. (1982): "Atmospheric turbulence", in: E.J. Plate, Engineering meteorology (Elsevier Scientific Publishing Company, Amsterdam, 1982), pp. 179-229

Jorgensen H.K. (2002): "Wind turbine power curve and sound measurement uncertainties", REGA (Renewable Energy Generators Australia Ltd) Forum 2002, Coffs Harbour, Australia

Kaimal J.C., Wyngaard J.C., Izumi Y. and Coté O.R. (1972): "Spectral characteristics of surface-layer turbulence", Quarterly Jounal of the Royal Meteorological Society **98**, pp. 563-589

Kerkers A.J. (1999): "Windpark Rheder Moor; prognose geluidsimmissie vanwege 17 Enercon 66 windturbines" (Wind Farm Rheder Moor; prognosis of sound immission from 17 Enercon 66 wind turbines"), Lichtveld Buis & Partners bv, Utrecht (in Dutch)

Kerkers A.J. and Koffeman A.I. (2002): "Beoordeling van Windturbinegeluid: technische rapportage. Continu, fluctuerend of impulsachtig?" ("Assessment of wind turbine sound: technical report. Continuous, fluctuating or impulsive?", report R060480aaA2.tk, Lichtveld Buis & Partners bv, Utrecht (in Dutch)

Kerkers A.J.: "Beoordeling geluidrapport "Hoge Molens vangen veel wind - Second opinion", report R068168aaA0.tk, Lichtveld Buis & Partners bv, Utrecht (in Dutch)

IEC (1998): "Wind turnbine generator systems – Part 11: Acoustic noise measurements techniques", IEC standard 16400-11:1998(E), Geneva

KNMI (1972): "Climatological data from Dutch stations no.8: Frequency tables of atmospheric stability", KNMI, De Bilt (text partially in Dutch)

KNMI (2005): www.knmi.nl/research/atmospheric_research/pagina_1_Cabauw.html, (last) consulted March 27, 2006

Kühner D. (1998): "Excess Attenuation due to Meteorological Influences and Ground Impedance", Acustica – Acta Acustica **84**, pp. 870-883

Larsson C. and Israelsson S. (1982): "The Effects of Meteorological Parameters on Sound Propagation from a Point Source", Meteorologiska Institutionen Report No. 67, Kungliga Universitet Uppsala, Uppsala

Lowson M.V.(1995): "A New Prediction Model for Wind Turbine Noise", Wind Engineering **18** (2), pp. 51-62

Ljunggren S. (1997): "Expert group study on 'Recommended practices for wind turbine testing and evaluation', 10. Measurement of noise immersion from wind turbines at noise receptor locations", Department of Building Science, The Royal Institute of Technology, Sweden

LLNL (2004): http://www-metdat.llnl.gov/metdat_FAQ.html#stability_class, Lawrence Livermore National Laboratory, (last) consulted March 27, 2006

Morgan S. and Raspet R. (1992): "Investigation of the mechanisms of low-frequency wind noise generation outdoors", Journal of the Acoustical Society of America **92** (2), pp. 1180–1183

Morgan M. S. (1993): "An investigation of the sources and attenuation of wind noise in measurement microphones", dissertation University of Mississippi, Mississippi

Motta M., Barthelmie R. J. and Vølund P. (2005): "The influence of non-logarithmic wind speed profiles on potential power output at Danish offshore sites", Wind Energy **8**, pp. 219 – 236

Nanahara T., Asara M., Sato T., Yamaguchi K., Shibata M. and Maejima T. (2004): "Smoothing effects of distributed wind turbines, part 1", Wind Energy **7**, pp. 61-74

Nanahara T. (2004): personal communication, June 14 2004

Oerlemans S.: "Localisation And Quantification Of Noise Sources On A Wind Turbine", proceedings First International Meeting on Wind Turbine Noise: Perspectives for Control, Berlin (October 2005)

Pedersen E. and Persson Waye K. (2003): "Perception and annoyance of wind turbine noise in a flat landscape", Proceedings of Internoise 2002, Dearborn

Pedersen E. (2003): "Noise annoyance from wind turbines - a review", Swedish Environmental Protection Agency

Pedersen E. and Persson Waye K. (2004a): "Perception and annoyance due to wind turbine noise – a dose-response relationship", Journal of the Acoustical Society of America **116** (6), pp. 3460-3470

Pedersen E., Persson Waye K. and Hallberg L.R.M. (2004b): "Living close to wind turbines – a qualitative approach to a deeper understanding", proceedings Internoise2004, Prague

Pérez I.A., García M.A., Sánchez M.L. and De Torre B. (2005): "Analysis and parameterisation of wind profiles in the low atmosphere", Solar Energy **78** (6), pp. 809-821

Persson Waye K. and Öhström E. (2002): "Psycho-acoustic characters of relevance for annoyance of wind turbine noise", Journal of Sound and Vibration **250** (1), pp. 65-73

Petersen E.L., Mortensen N.G., Landberg L., Højstrup J. and Frank H.P. (1998): "Wind Power Meteorology: Part I: Climate and Turbulence", Wind Energy **1**, pp. 2-22

Rudolphi E. (1998): "Wind turbine noise emission. Wind speed measurents below hub hight give poor accuracy", Proceedings of the Nordic Acoustical Meeting, Stockholm

SDC (2005): "Wind power in the UK", Sustainable Development Commission, London

Schepers J. G., Curvers A.P.W.M., Oerlemans S., Braun K., Lutz Th., Herrig A., Würz W., Méndez López B. (2005): "Sirocco: Silent Rotors By Acoustic Optimalisation", proceedings Wind Turbine Noise2005, Berlin

Smedman A., Högström U. and Bergström H. (1996): "Low Level jets – A Decisive Factor for Off-Shore Wind Energy Siting in the Baltic Sea", Wind Engineering **20** (3), pp. 137-147

Smith K., Randall G., Malcolm D., Kelly N. and Smith B. (2002): "Evaluation of Wind Shear Patterns at Midwest Wind Energy Facilities" (preprint), National Renewable Energy Laboratory NREL/CP-500-32492, USA

Strasberg M. (1979): "Nonacoustic noise interference in measurements of infrasonic ambient noise", Journal of the Acoustical Society of America **66**, pp. 1487-1493

Strasberg M. (1988): "Dimensional analysis and windscreen noise", Journal of the Acoustical Society of America **83** (2), pp. 544–548

TA-Lärm (1998): "Technische Anleitung zum Schutz gegen Lärm" ("Technical Guideline for Noise Protection") (in German)

TA-Luft (1986): "Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz – Technische Anleitung zur Reinhaltung der Luft" ("First General Directive to the Federal Immission Protection Act – Technical Guideline for Clean Air") (in German)

Troen I. and Petersen E.L. (1989): "European Wind Atlas", Risø National Laboratory, Roskilde

Van As M., Duijn M., Ellen G.J., Pot M., Puylaert H. and Werksma H. (2005): "Wind gewogen – Tussenevaluatie BLOW" ("Wind weighted –

interim evaluation of BLOW"), TNO Bouw en Ondergrond (report EPS 2005-10, 2nd revised edition), Delft (in Dutch)

Van den Berg, G.P. (2000): "Wiens brood men eet ….. Een pleidooi voor onafhankelijke geluidsadviseurs" ("Not biting the hand that feeds ... A plea for independent acoustical advisors"), Geluid 23 (3), pp. 103-105 (in Dutch)

Van den Berg F. and De Graaf R. (2002): "Hoge molens vangen veel wind II – geluidsbelasting door windturbines in de nacht" , Natuurkunde-winkel RuG ("High mills catch strong winds II – sound immission by wind turbines at night", Science shop for Physics, University of Groningen), Groningen (in Dutch, a German version is also available)

Van den Berg G.P. (2003): "Wind turbines at night: acoustical practice and sound research", Proceedings Euronoise2003, Naples

Van den Berg G.P. (2004a): "Effects of the wind profile at night on wind turbine sound", Journal of Sound and Vibration 277 (4-5), pp. 955-970

Van den Berg G.P. (2004b): "Statistics of wind-related sound in outdoor monitoring", proceedings Internoise2004, Prague

Van den Berg, G.P. (2004c): "Windturbines: een verschil van dag en nacht" ("Wind turbines: a difference between night and day"), Geluid 27 (1), pp. 14-18

Van den Berg, G.P. (2005a): "The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines", Journal of Low Frequency Noise, Vibration And Active Control 24 (1), pp. 1-24

Van den Berg, G.P. (2005b): "Wind gradient statistics up to 200 m altitude over flat ground", proceedings WindTurbineNoise2005, Berlin

Van den Berg, G.P. (2005c): "Mitigation measures for nighttime wind turbine noise", proceedings WindTurbineNoise2005, Berlin

Van den Berg, G.P. (2006): "Wind induced noise in a screened microphone", Journal of the Acoustical Society of America 119 (2), pp. 824-833 (2006)

Van Ulden A.P., Van der Vliet J.G. and Wieringa J. (1976): "Temperature and wind observations at heights from 2m to 200m at Cabauw in 1973", De Bilt

Van Ulden, A.P. and Wieringa J. (1996): "Atmospheric boundary-layer research at Cabauw", Boundary-layer Meteorology **78**, 39-69

Vestas (2003): brochure "V80-2.0 MW", 10/03

VROM (1999): "Handleiding meten en rekenen Industrielawaai" ("Manual for measuring and calculating industrial noise"), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer (VROM), den Haag (in Dutch)

Wagner S., Bareiss R. and Guidati G. (1996): "Wind turbine noise", Springer, Berlin

Wilson D.K. and Thomson D.W. (1994): "Acoustic propagation through anisotropic, surface-layer turbulence", Journal of the Acoustical Society of America **96** (2), pp. 1080-1095

Wolsink M. (1990): "Maatschappelijke acceptatie van windenergie; houdingen en oordelen van de bevolking" ("Social acceptance of wind energy: attitudes and judgments of the population"), Thesis Publishers, Amsterdam (in Dutch)

WHO (2000): "Guidelines for Community Noise", World Health Organization (Geneva) and Institute of Environmental Epidemiology (Singapore)

Zhang H., Chen J. and Park S. (2001): "Turbulence structure in unstable conditions over various surfaces", Boundary-Layer Meteorology **100**, pp. 243–261

Zheng Z. C. and Tan B.K. (2003) "Reynolds number effects on flow/acoustic mechanisms in spherical windscreens", Journal of the Acoustical Society of America **113** (1), pp. 161-166

Zwicker E. and H. Fastl H. (1999): "Psycho-Acoustics, Facts and Models", Springer-Verlag, Berlin

APPENDICES

Appendix A

List of symbols

Symbol: definition [unit]

α: angle of attack [radian] or [degree];
also: rotor pitch angel [radian] or [degree]
also: constant relating wind velocity to pressure [-]

δ_t^*: displacement thickness of turbulent boundary layer [m]

η_s: Kolmogorov size [m]

κ: von Karman's constant [0.4]

ν: kinematic viscosity of air [$m^2 \cdot s^{-1}$]

ρ: correlation coefficient (1/3 octave band level vs. L_A) [-];
also: air density [kg/m^3]

$\Psi(\zeta)$: stability function [-]

θ: rotor tilt angel [radian] or [degree]

ζ: dimensionless height (h/L) [-]

Ω: turbine rotor angular velocity [$rad \cdot s^{-1}$]

a: induction factor ($1 - V_h/V_h$) [-]

b: correction factor for boundary layer thickness (value: 2 – 4)

c: velocity of sound in air [$m \cdot s^{-1}$]

C: blade chord length [m]; also: air density dependent constant
($C = 20 \cdot \log(0.215\kappa\alpha\rho V_o^2/p_{ref})$ [dB])

C_p: constant ($C_p = 20 \cdot \log(0.215\kappa\alpha) - 9.5$) [dB]

D: diameter [m]

D_h: directivity function [-]

$D_{j,k}$: decrease in octave band sound level j of turbine k with distance [dB]

D_{geo}: decrease in sound level due to geometrical spreading [dB]

D_{air}: decrease in sound level due to air absorption [dB]

D_{ground}: decrease in sound level due to ground absorption and reflection [dB]

dB(A): unit of level after A-weighting

dB(G): unit of level after G-weighting

f: frequency [Hz]

f_{mod}: modulation frequency [Hz]

$f_{peak,TE}$: peak frequency of trailing edge sound [Hz]

$f_{peak,IF}$: peak frequency of in-flow turbulence sound [Hz]

f_m : middle frequency of 1/3 octave band [Hz]

f_B: blade passing frequency [Hz]

f_c: screen size related corner frequency ($f_c = 0.3V/D$) [Hz]

f_t: α-dependent factor for TE layer thickness [-]

f_{log}: ratio v_{98}/v_{10} valid in a neutral atmosphere [-]

$f_{(un)stable}$: ratio v_{98}/v_{10} valid in an (un)stable atmosphere [-]

F_{bb}: fluctuation strength [vacil]

F(z): turbulence related function:

$$F(z) = -20 \cdot \log[(z/D)^{1/3} \cdot (\ln(z/z_o) - \Psi)] \text{ [dB]}$$

G(z): turbulence related function:

$$G(z) = -20 \cdot \log[0.2 \cdot (z/\ell_o)^{1/3} \cdot (\ln(z/z_o - \Psi)] \text{ [dB]}$$

h: height [m]

H: turbine height [m]

h_{ref}: reference height for wind velocity (and direction) [m]

k: integer number (of harmonic frequency) [-];
also: exponent of wind velocity in relation with associated turbulent pressure [-]

K_1: constant (128.5 dB)

K_α: α dependent increase in trailing edge sound level [dB]

ℓ: eddy length scale [m]

ΔL: increase in sound level [dB]

L: Monin-Obukhov length [m]

L_A: broad band A-weighted sound level [dB(A)]

L_{A5}: 5-percentile of broad band sound levels over a period [dB(A)]

L_{A95}: 95-percentile of broad band sound levels over a period [dB(A)]

$L_{at}(u)$: pressure level due to atmospheric turbulence [dB]

$L_{at,1/1}(f)$: pressure level due to turbulent wind per octave band [dB]

$L_{at,1/3}(f)$: pressure level due to turbulent wind per 1/3 octave band [dB]

$L_{at,A}$: broad band A-weighted pressure level [dB]

L_{imm}: immission sound level [dB(A)]

L_{eq}: equivalent sound level; $L_{eq,T}$: over time T [dB(A)]

$L_{p,1/3}$: turbulent pressure level at microphone per 1/3 octave band [dB]

$L_{red,1/3}$: 'meteorologically reduced' 1/3 octave band pressure level [dB]

$L_{red,1/1}$: 'meteorologically reduced' octave band pressure level [dB]

L_W: sound power level [dB(A)]

L_{Wj}: j-th octave band sound power level [dB(A)]

M: Mach number = air flow velocity/c (at radius R: M = ΩR/c) [-]

m: stability exponent [-]

$m_{h1,h2}$: *m* determined between heights h_1 and h_2 [-]

mf: modulation factor [-]

n: dimensionless frequency (n = fz/V) [-]

N: number of blades [-]; rotational speed (ΩR/2π) [s^{-1}]

Ph: Power at height h; Ph,lpp; Ph,hp [W]

p: (sound) pressure [Pa]

p_{fr}: rms pressure in narrow frequency band centered at frequency f [Pa]

$p_{f1/3}$: rms pressure in 1/3 octave band [Pa]

p_{ref}: reference (sound) pressure [20 μPa]

p(0): rms pressure at center of wind screen [Pa]

r: distance [m]

R: rotor radius = blade length [m]

ΔR: increment in R [m]

R_X: range between maximum and minimum sound levels (X= bb or f) [dB]

$R_{X,90}$: range between 5- and 95-percentile of sound levels (X= bb or f) [dB]

Re: chord based Reynolds number (Re = ΩRC/ν); wind screen diameter based Reynolds number [-]

S: ratio of distance along blade and chord length [-]

Sp_i: 1/3 octave band weighing function for TE sound [dB]

SPL_i: sound pressure level of source i [dB]

Sr: Strouhal number [-]

u: longitudinal (along wind) component of turbulent wind velocity [$m \cdot s^{-1}$]

u_f: rms longitudinal component of turbulent wind velocity per unit frequency [$m \cdot s^{-3/2}$]
u^*: friction velocity [$m \cdot s^{-1}$]
U: instantaneous wind velocity: U = <U> + u [$m \cdot s^{-1}$]
V: air flow velocity or wind velocity [$m \cdot s^{-1}$]
V_o: reference velocity [1 $m \cdot s^{-1}$]
V_b: induced wind velocity at turbine blade [$m \cdot s^{-1}$]
V_h, V_{xx}: wind velocity at height h or height xx m [$m \cdot s^{-1}$]
$V_{h,b}$, $V_{xx,b}$: induced wind velocity at turbine blade or height h [$m \cdot s^{-1}$]
V_{hub}: wind velocity at wind turbine hub height h [$m \cdot s^{-1}$]
V_i: local (induced) velocity at blade = 2V/3 [$m \cdot s^{-1}$]
V_{ref}: wind velocity at reference height [$m \cdot s^{-1}$]
<x>: time average of variable x
z_o: roughness height; altitude [m]

Subscripts:
1/1: frequency octave band
1/3: 1/3 frequency octave band
A: A-weighted
at: atmospheric turbulence
bb: broad band
f: at frequency of (1/3) octave band
h: at height h, hub
i: component of TE sound (i = p, s, α)
if: in-flow
p: pressure, pressure side
ref: reference
s: suction side
TE: trailing edge

Appendix B
Dominant sources of wind turbine sound

With modern wind turbines there are three important mechanisms that produce sound. These will be reviewed here up to a detail that is relevant to the text in this book.

B.1 Infrasound: thickness sound

When a blade moves through the air, the air on the forward edge is pushed sideways, moving back again at the rear edge. For a periodically moving blade the air is periodically forced, leading to 'thickness sound'. Usually this will not lead to a significant sound production as the movement is smooth and thus accelerations relatively small.

When a blade passes the turbine tower, it encounters wind influenced by the tower: the wind is slowed down, forced to move sideways around the tower, and causes a wake behind the tower. For a downwind rotor (*i.e.* the wind passes the tower first, then the rotor) this wake causes a significant change in blade loading.

The change in wind velocity near the tower means that the angle of attack of the air on a blade changes and lift and drag on the blade change more or less abruptly. This change in mechanical load increases the thickness sound power level at the repetition rate of the blade passing frequency f_B. For modern turbines $f_B = N \cdot \Omega/(2\pi)$ typically has a value of approximately 1 Hz. As the movement is not purely sinusoidal, there are harmonics with frequencies $k \cdot f_B$, where k is an integer. Harmonics may occur up to 30 Hz, so thickness sound coincides with the infrasound region (0-30 Hz). Measured levels at 92 m from the two-bladed 2 MW WTS-4 turbine showed that measured sound pressure levels of the individual blade harmonics were less than 75 dB, and well predicted by calculations of wind-blade interaction near the turbine tower [Hubbard *et al* 2004, Wagner *et al* 1996]. The envelope of the harmonics peaks at the fifth harmonic (k = 5 with f_B = 1 Hz), indicating a typical pulse time of (5 Hz)$^{-1}$ = 0,2 s which is 20% of the time between consecutive blade passages. The WST-4 is a downwind turbine with an 80 m tubular tower, where the wind velocity deficit was estimated to be 40% of the free wind velocity [Hubbard *et al* 2004]. For modern, upwind rotors the velocity deficit in front of the tower is smaller. As a consequence the change in blade loading is less than for downwind turbines. From data collected by Jakobsen it appears that the infrasound level at 100 m from an upwind turbine is typically 70 dB(G) or less, whereas near downwind turbines it is 10 to 30 dB higher. As 95 dB(G) corresponds to the average infrasound hearing threshold [Jakobsen 2004], infrasound from (upwind) wind turbines does not appear to be so loud that it is directly perceptible.

B.2 Low frequencies: in-flow turbulent sound

Because of atmospheric turbulence there is a random movement of air superimposed on the average wind velocity. The contribution of atmospheric turbulence to wind turbine sound is named 'in-flow turbulence sound' and is broad band sound stretching over a wide frequency range. For turbulent eddies larger in size than the blade this may be interpreted as a change in the direction and/or velocity of the incoming flow, equivalent to a deviation of the optimal angle of attack. This leads to the same phenomena as described in section B.1, but changes will be random (not periodic) and less abrupt. For turbulent eddies the size of the chord length and less, effects are local and do not occur coherently over the blade. When the blade cuts through the eddies, the movement normal to the wind surface is reduced or stopped, given rise to high accelerations and thus sound.

In-flow turbulence sound has a maximum level in the 1/3 octave band with frequency

$$f_{peak,if} = (St \cdot 0.7R \cdot \Omega)/(H - 0.7R) \qquad \text{(B.1)}$$

where Strouhal number St is 16.6 [Grosveld 1985, Wagner *et al* 1996]. Most sound is produced at the high velocity, outer parts of the blades. For a modern, tall, three-bladed wind turbine with hub height H = 100 m, blade length R = 35 m and angular velocity $\Omega = 2\pi f_B/3 = 2\ \text{rad} \cdot s^{-1}$ (20 rpm), $f_{peak,if}$ = 11 Hz which is in the infrasound region. Measured fall-off from $f_{peak,if}$ is initially approx. 3 dB per octave, increasing to 12 dB per octave at frequencies in the audible region up to a few hundreds of hertz [Grosveld 1985, Wagner *et al* 1996].

B.3 High frequencies: trailing edge sound

Several flow phenomena at the blade itself or in the turbulent wake behind a blade cause high frequency sound ('airfoil self-noise'). Most important for modern turbines is the sound from the turbulent boundary layer at the rear of the blade surface where the boundary layer is thickest and turbulence strength highest. Trailing edge sound has a maximum level in the 1/3 octave band with frequency

$$f_{peak,TE} = 0.02 \cdot \Omega \cdot R / (\delta^* \cdot M^{0.6}) \qquad \text{(B.2)}$$

where Mach number M is based on airfoil velocity. The displacement thickness of the turbulent boundary layer is:

$$\delta^* = b \cdot 0.37 \cdot C \cdot Re^{-0.2} / 8 \qquad \text{(B.3)}$$

for a zero angle of attack. Re is the chord based Reynolds number [Brooks *et al* 1989]. The experimental factor b accounts for the empirical observation that the boundary layer is a factor 2 to 4 thicker than predicted by theory [Lowson 1995, Wagner *et al* 1996]. For air of 10 °C and atmospheric pressure, a typical chord length C = 1 m, and other properties as given above (section B.2), $f_{peak,TE}$ = 1700/a Hz. With b = 2 to 4, $f_{peak,TE}$ is 450 – 900 Hz. The spectrum (see Sp_i below) is symmetrical around $f_{peak,TE}$ and decreases with 3 dB for the first octave, 11 dB for the next; the contribution from further octave bands is negligible [Brooks *et al* 1989].

According to Brooks *et al* [1989] trailing edge sound level can be decomposed in components SPL_p and SPL_s due to the pressure and suction side turbulent boundary layers with a zero angle of attack of the incoming flow, and a component SPL_a that accounts for a non-zero angle of attack α. For an edge length ΔR each of the three components of the immission sound level at distance r can be written as [Brooks *et al* 1989]:

$$SPL_i = 10 \cdot \log(\delta_i^* \cdot M^5 \cdot \Delta R \cdot D_h / r^2) + Sp_i + K_1 - 3 + K_i \qquad \text{(B.4)}$$

and total trailing edge immission sound level as:

$$SPL_{TE} = 10 \cdot \log(\Sigma_i \, 10^{SPL_i/10}) \qquad \text{(B.5)}$$

where the index i refers to the pressure side, suction side or angle of attack part ($i = p, s, \alpha$). The directivity function D_h equals unity at the front of the blade ($\theta = 180°$) and falls off with $\sin^2(\theta/2)$. Because of the strong dependence on M ($\sim M^5$, equation B.4) trailing edge sound is dominated by sound produced at the high velocity parts: the blade tips.

Sp_i gives the symmetrical spectral distribution of the trailing edge sound spectrum centered on $f_{peak,TE}$ and is maximum (0 dB) at this centre frequency. The constant $K_1 - 3 = 125.5$ dB applies when the chord based Reynolds number exceeds $8 \cdot 10^5$ and the pressure-side turbulent boundary displacement thickness $\delta_i^* > 1$ mm, as is the case for modern tall turbines. K_i is non-zero only if $i = \alpha$.

For positive angles of attack $\alpha < 10°$ the boundary layer thickness δ^* shrinks with a factor $f_p = 10^{-0.042\alpha}$ at the pressure-side and δ^* grows at the suction-side with a factor $f_s = 10^{0.068\alpha}$. Because $\delta_\alpha^* = \delta_s^*$, $f_\alpha = f_s$. K_α has a large negative value for $\alpha = 0$. For $1° < \alpha < 10°$ and $M = 0.2$ the calculated values of K_α (see formula 49 in [Brooks *et al* 1989] with $K_\alpha = K_7 - K_1 + 3$) are plotted in figure B.1 and these can be approximated by:

$$K_\alpha = -0.35 \cdot \alpha^2 + 5.5 \cdot \alpha - 14.4 \text{ (}\alpha\text{ in degrees)} \qquad \text{(B.6)}$$

With equation B.4, equation B.5 can be rewritten as:

$$SPL_{TE} = 10 \cdot \log(\delta^* \cdot M^5 \cdot \Delta R \cdot D_h / r^2) + K_1 - 3 +$$

$$+ 10 \cdot \log(\Sigma_i \, 10^{(10 \cdot \log(f_i) + Sp_i + K_i)/10}) \qquad \text{(B.7)}$$

The last term in B.7 is the α-dependent part. For the peak frequency 1/3 octave band level ($Sp_i = 0$) the last term in equation B.7 is 3 dB for $\alpha = 0$ and 3.4 dB for $\alpha = 1°$, then increasing with 1.5 dB per degree to 14.5 dB at $\alpha = 9°$. The level increase $\Delta SPL_{TE}(\alpha) = SPL_{TE}(\alpha) - SPL_{TE}(\alpha{=}0)$ is given in table B.1 and plotted in figure B.1. The best lineair approximation in the range $1° < \alpha < 10°$ is:

$$\Delta SPL_{TE}(\alpha) = 1.5\cdot\alpha - 1.2 \text{ (dB)} \qquad \text{(B.8)}$$

with α in degrees (or $\Delta SPL_{TE}(\alpha) = 86\cdot\alpha - 1.2$ dB with α in radians).

Table B1: increase of trailing edge sound level with angle of attack α

A	1°	2°	3°	4°	5°	6°	7°	8°	9°
$\Delta SPL_{TE}(\alpha)$ (dB)	0.4	1.4	2.9	4.6	6.4	8.0	9.4	10.6	11.5

The blade swish that is audible near a turbine is a variation in level of less than 3 dB (in daytime) [ETSU 1996]. It must correspond to a change in sound level of 1 dB to be heard at all. An increase of 1 dB corresponds to an increase in α with 0.7°, an increase of 3 dB corresponds to 2.9°. So, for a swish level of 2 ± 1 dB, we estimate the change in α at the tower passage as 1.8° ± 1.1°. Part of this is due to the lower wind velocity at the lower blade tip relative to the rotor average, the rest is due to the slowing down of the wind by the tower.

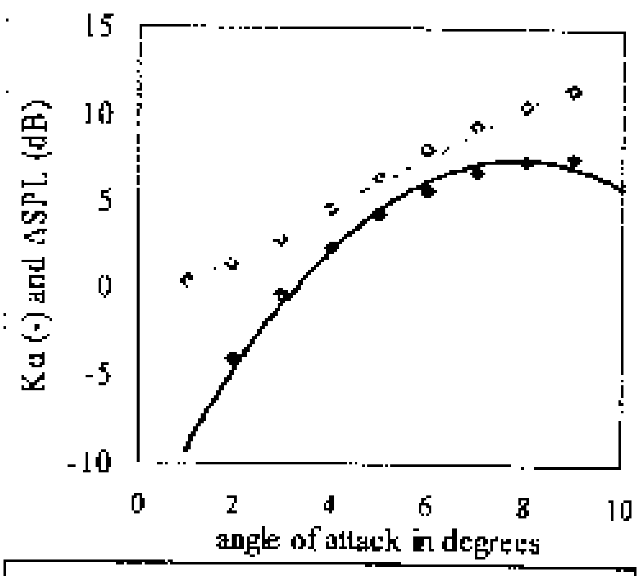


Figure B.1. non-zero angle of attack correction K_α (black diamonds) and resulting added sound pressure level ΔSPL (gray diamonds) with best fits in range 1° < α < 10°

For small angles the change of wind velocity with angle of attack α at radius R is $dV_{wind} = \Omega\cdot R\cdot d\alpha$, or

$$dV_{wind} = 0.017\cdot\Omega\cdot R\cdot d\alpha \qquad \text{(B.9)}$$

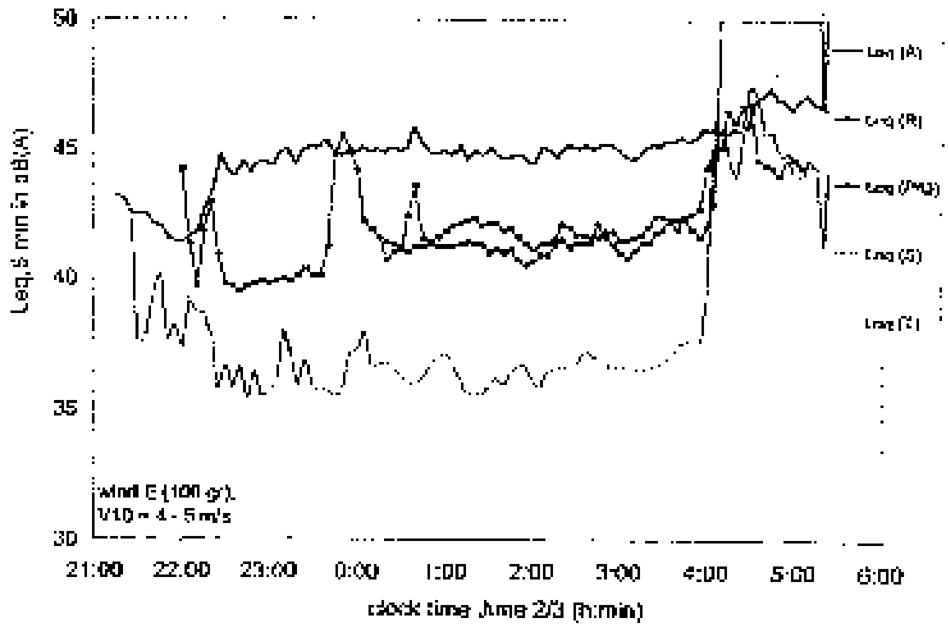
with α in degrees.

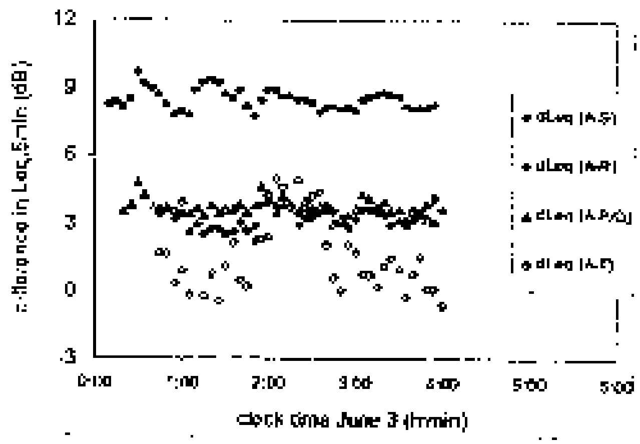
So for a modern turbine at high speed ($\Omega \cdot R \approx 70$ m/s at tip at 20 rpm) the wind velocity deficit where the blade tip passes the tower and $\alpha = 1°$ (0.017 radians) is 1.2 m/s. In a free 14 m/s wind, *i.e.* 9.3 m/s at the rotor, this is 13%. This deficit is due to the influence of the tower as well as the (daytime) wind profile.

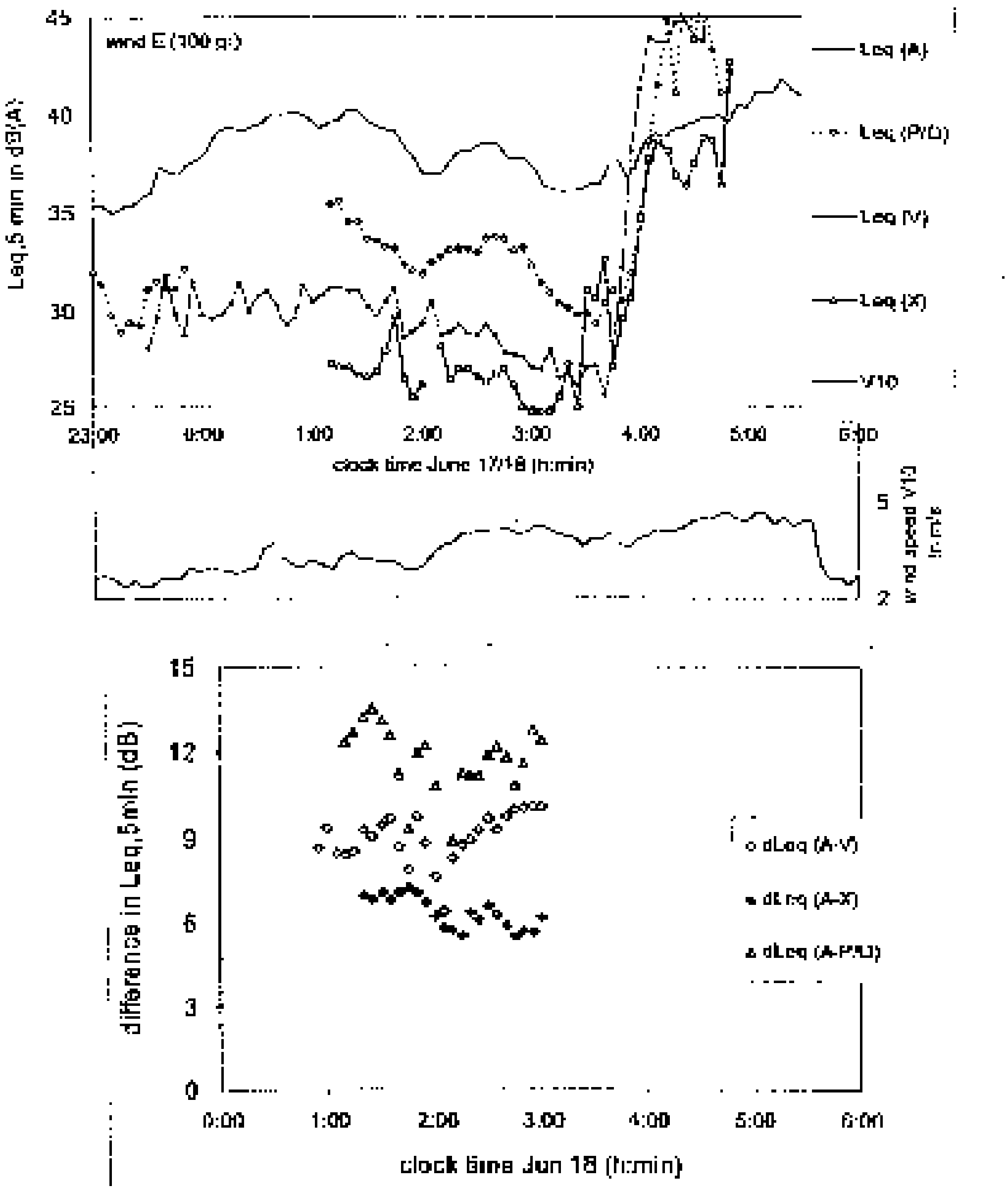
Appendix C

Simultaneous registrations of sound immission level

Additional information to section IV.10: measurements at locations A and P through X (see map figure IV.2) in year 2002. Graphs show measured values of $L_{eq,5min}$ at locations near Rhede wind farm and differences relative to measured value at location A. Wind velocity and wind direction and time of measurement are mentioned in the figures.






wind E (100 g.)
Leq,5 min in dB(A)
Leq (A)
Leq (P/D)
Leq (V)
Leq (X)
V10
clock time June 17/18 (h:min)
wind speed V10 in m/s
difference in Leq,5min (dB)
dLeq (A-V)
dLeq (A-X)
dLeq (A-P/D)
clock time Jun 18 (h:min)

Appendix D
Publications by the author

D1 *Published and conference papers*

D1.1 Single author

Stiltegebieden, Noorderbreedte juni 1991, pp. 35-39

Onduidelijke stralingsnormen leiden tot onrust, Intermediair vol. 27 nr. 35 (30 augustus 1991), pp. 27-28

Hoogspanningslijnen en overheidsbeleid, NVS-Nieuws 17e jaargang nr. 5 (december 1992), pp. 11-12

Waar of niet: mogelijk of vermeend, NVS-Nieuws 18e jaargang nr. 2 (april 1993) pp. 8-9 (reactie op artikel)

Noise from the Marnewaard shooting range: a review of sound and annoyance measurements, proceedings Internoise93, Leuven, pp. 1145-1148

A home kit for road traffic noise, proceedings Euronoise95, Lyon, pp. 163-168

Laagfrequent geluid-een onderschat probleem, Geluid mrt 1996, pp.14-18

Straling - één pot nat; Psychologische effecten van elektromagnetische straling, NVS-Nieuws, 22e jaargang nr.4, oktober 1997, pp. 11-14

Natural ambient background sound near the Waddensea, proceedings Internoise97, Budapest, pp. 791 - 794

Bommen op Vlieland, Geluid dec. 1997, pp.140-142

Sound exposure measurements in cases of low frequency noise complaints, proceedings Internoise 1998, Christchurch

Long range outdoor propagation and interference of low frequency tonal sound, proceedings Internoise 1998, Christchurch

Case control study in low frequency sound measurements, proceedings Internoise 1999, Fort Lauderdale

Streefwaarden voor laagfrequente geluidsafstraling door trillingen in de woonomgeving, proceedings Geluid en trillingen in Nederland en Europa, Rotterdam 1999

Wiens brood men eet, ... Een pleidooi voor onafhankelijke geluidsadviseurs, Geluid juli 2000, pp. 103-105

Measurement and analysis of natural ambient sound levels and weather parameters, proceedings Internoise 2000, Nice

Low frequency sounds in dwellings: a case control study, Journal of Low Frequency Noise, Vibration and Active Control, Vol. 19 no. 2, 2000

Tinnitus as a cause of low frequency noise complaints, proceedings Internoise 2001, den Haag

Hoorbaar infrageluid door heien in zand – Zevenaar zucht onder heislagen, Land + Water juli/augustus (nummer 7/8), 2001

Last van een lage toon: tinnitus of een motor ?, Contactblad Tinnitus & Hyperacusis (nr. 2002 – 2), NVVS

Low frequency sound and health effects from low noise pile driving, proceedings Internoise 2002, Dearborn

Science and society - the science shop approach (La science et la societe - l'approche "boutique de science"), proceedings CEPAPE workshop, september 2002, Ouagadougou

Wind turbines at night: acoustical practice and sound research, proceedings Euronoise2003, Naples

Effects of the wind profile at night on wind turbine sound, Journal of Sound and Vibration vol. 277 (4-5), pp 955-970 (2004)

Windturbines: een verschil van dag en nacht, Geluid, jaargang 27, nr. 1 (2004)

Statistics of wind-related sound in outdoor monitoring, proceedings Internoise2004, Prague (2004)

Observed prevalence of transport sounds in quiet areas, proceedings Internoise2004, Prague (2004)

Do wind turbines produce significant low frequency sound levels?, proceedings 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht (2004)

The beat is getting stronger: The effect of atmospheric stability on low frequency modulated sound of wind turbines, Journal of Low Frequency Noise, Vibration and Active Control, Vol. 24, pp. 1-24 (2005)

Kwaliteit van Omgevingsgeluid, Lawaaibeheersing Handboek voor Milieubeheer. B1100 (2004)

Wind gradient statistics up to 200 m altitude over flat ground, proceedings First International Meeting on Wind Turbine Noise: Perspectives for Control, Berlin (2005)

Mitigation measures for nighttime wind turbine noise, proceedings First International Meeting on Wind Turbine Noise: Perspectives for Control, Berlin (2005)

Prevalence and level of transport sounds in Dutch quiet areas, submitted to Applied Acoustics (2005)

Monitoring van geluid in stille gebieden, proceedings NAG-lezingendag, Utrecht (2005)

Wind induced noise in a screened microphone, Journal of the Acoustical Society of America 119 (2), pp. 824-833 (2006)

D1.2 Co-author

Stralingsniveaus in tandartspraktijken: G.P. van den Berg, S. Last, L.V. Arnold; Nederlands Tijdschrift voor Tandheelkunde, vol. 96, pp. 219-222 (1987).

Lawaai van laagvliegende straaljagers: G.P. van den Berg, M.P.J. Pulles, G. Barkema, M. Engel; Geluid en Omgeving, vol.12 (2), pp. 75-78 (1989)

Penetration of radon from crawl space to higher levels in dwelling, E. Veermans, G.P. van den Berg, R.J. de Meijer en L.W. Put; Radiation Protection Dosimetry vol.30 (1), pp. 45-50 (1990)

Ontwikkelingen en metingen bij de vliegbasis Laarbruch, G.A. van Rossum, G.P. van den Berg, N. Nassar en E. Vogelezang, Geluid vol. 21 (3), pp.108-110 (1998)

Assessment of low frequency noise complaints, G.P. van den Berg, W. Passchier-Vermeer (TNO Prevention and Health), proceedings Internoise 1999. Fort Lauderdale

D2. Science Shop reports and memoranda

D2.1 Single author, reports

Geluidsbelasting van woningen Eemskanaal N.Z. report NWU-7, 1987

Vochtproblemen in woningen Venuslaan, report NWU-8, 1987

De cesiumsluier van Tsjernobyl, report NWU-9, 1987

Radon uit gipsplaten en uit de kruipruimte, report NWU-20A, 1988

Radonkoncentraties in een woning gebouwd op vliegas, report NWU-18, 1988

Radonkoncentraties in 9 woningen in Beijum (Groningen), report NWU-33, 1990

Verslag bezoek Wit Rusland, report NWU-37, april 1991

Overzichtsrapport schietlawaai Marnewaard: Overzicht van onderzoeken naar knalnivo's, geluidbelasting, beleving, en effekten op vogels; stand van zaken 1991, report NWU-39, 1992

Hoogspanningslijnen gevaarlijk ? De resultaten van bevolkings-onderzoeken, report NWU-58, 1994

Laagfrequent geluid en hinder – informatiebundel, report NWU-71, 1996

Overlast door ventilatorgeluid van een kippenschuur, report NWU-73, 1997

Verkeerslawaai complex Strevelsweg / Lange Hilleweg (Rotterdam), report NWU-74, februari 1997

Hinder door machinale, laagfrequente buurgeluiden, report NWU-75, maart 1997

Analyse van knallen van ontploffingen bij oefeningen op de Vliehors, report NWU-77, 1997

Lawaai afzuiginstallaties timmerfabriek Winschoten, report NWU-78, 1997

Gezondheidseffecten van radiofrequente straling - De zendmast te Jirnsum, report NWU-79, 1997

The Science Shop for Physics: an interface between practical problems in society and physical knowledge, report NWU-1980, 1998

Meten van laagfrequent geluid in woningen - voorstel voor een richtlijn, report NWU-84, 1999

Metingen laagfrequent geluid te Apeldoorn, report NWU-95, 1999

Metingen laagfrequent geluid te Deventer, 2000

Geluid en trillingen tengevolge van het heien voor de spoortunnel te Zevenaar, report NWU-105, 2001

Op zoek naar stilte - meting van stilte-indicatoren in recreatieve (natuur) gebieden in de Randstad, report NWU-107, 2002

Karakterisering van het omgevingsgeluid: verstoring en monitoring in het Horsterwold, report NWU-111, 2003

Verkeerslawaai Ceintuurbaan Meppel, report NWU-113, 2003

D2.1 Single author, memoranda

Aantekeningen bij rapport 2243M99.R02 van Jansen Raadgevend Ingenieursbureau: geluidniveaus vanwege een Lagerwey LW18/80 windturbine (etc.); 17-04-1998

Kommentaar akoestisch rapport Windturbines Wester-Koggenland; 21-10-1999

Aantekeningen bij het rapport "Akoestisch onderzoek met betrekking tot het geprojecteerde windmolenpark Delfzijl-Zuidoost" van Peutz & Associes (rapport F4758-2 van 11-10-1999); 29-111999

Kommentaar op geluidsaspecten n.a.v. de milieuvergunning voor een windturbinepark Noordermeerdijk; 30-05-2000

Opmerkingen n.a.v. het geluids- en trillingsonderzoek Spoortunnel Zevenaar op 16-1-2001; 17-01-2001

De invloed van atmosferische stabiliteit op de hoorbaarheid van windturbines; 06-02-2001

Heien van de spoortunnel Zevenaar: de herkomst van het laagfrequent geluid; 14-02-2001, 15-03-2001

Trillingsmetingen in de Van der Haerstraat 5, den Haag; notitie NWN 4-10-2001

Geluidsbelasting tengevolge van bakkerij "De Korenschoof", Kollum; 05-12-2001

Voorlopige resultaten geluidsmetingen bij Bellingwolde / Windpark Rhede; 08-06-2002

Magnetische velden tengevolge van de elektriciteitsvoorziening in de Persoonstraat, Bocholtz; 18-11-2002

Reactie op 'second opinion' van A.J. Kerkers (LBP) op ons rapport "Hoge molens vangen veel wind II - geluidsbelasting door windturbines in de nacht", 14-02-2003

Geluidsbelasting van een windturbine bij Suderdyk 2 te Boazum; 14-01-2004

Gezondheidseffecten tengevolge van het geluid van windturbines – een quick scan van de literatuur; 23-03-2004

Windpark Windenergie Rooi: opmerkingen bij de VGA-rapportage, 25-05-2004

Geluidsbelasting tengevolge van muziek in 't Syl en het Flevohuis in Lemmer, 8-12-2004

Elektromagnetische velden en gezondheidseffecten, 2004

Windturbine Boazum: commentaar op verslag StAB; 29-10-2004

Geluidsbelasting tengevolge van Windpark A7 in polder De Eendracht, 14-03-2005

Laagfrequent geluid tengevolge van houtmotafzuiging in het Hout- en Meubileringscollege Amsterdam, 12-04-2005

Geluidsbelasting tengevolge van windturbinepark De Locht - Kerkrade, 27-10-2005

Metingen Omgevingsgeluid Noordhorn, 16-12-2005

Proposed construction of 6 x 120m high wind turbine generators and miscellaneous works at Skitfield Rd. Guestwick, Norfolk; Proof of Evidence of G. P. van den Berg for the Guestwick Parish Meeting - Noise issues, 9-12-2005

Public inquiry into the proposed construction of 2 wind turbines at Wood Farm Shipdham, Norfolk; Proof of Evidence of Frits van den Berg for Campaign Against Turbines at Shipdham and Scarning (CATSS), 19-02-2006

D2.2 Co-author

Tsjernobyl -een ramp voor Nederland ?, G.P. van den Berg e.a., report NWU-3, 1986

Radon en porisosteen, L.W. Put, G.P. van den Berg, report NWU-11, 1987

Radon en Porisosteen; bewonersrapport; G.P. van den Berg, L.W. Put, report NWU-11A, 1987

ICRP 46: denken over de toekomst; J.C. Groote, W. Soppe, G.P. van den Berg, report NWU-12, 1987

Beoordeling berekeningsmethode schietlawaai in de Lauwersmeer; A. van der Pol, G.P. van den Berg, report NWU-15; 1987

Reaktie op de notitie-TOR; G.P. van den Berg, W. Soppe, J.C. Groote, report NWU-17; 1987

De invloed van gipsplaten en bodem op het radongehalte in twee rijen woningen; E. Veermans, G.P. van den Berg, R.J. de Meijer, L.W. Put, report NWU-20; 1988 (uitgebracht in reeks Stralenbescherming van ministerie V.R.O.M.)

Verkeerslawaai Larserdreef Lelystad; G.P. van de Berg, J. Lijzenga, J.K. Kleuver, report NWU-21, 1988

Vocht in woningen; Redaktie: S. Morel, G.P. van den Berg, report NWU-26; 1989

Effecten van laagvlieglawaai op onze gezondheid; B.J.D. van Dijk, G.P. van den Berg, report NWU-32; 1990

Schietlawaai in het oostelijk Waddengebied; G.P. van den Berg en A. van der Pol, report NWU-35; 1991

Helicopterlawaai; E. Siegersma, G.P. van den Berg, report NWU-41; 1992

Het open houden van wakken met minimale energietoevoer; A.Mohammed, J. van Klinken, G.P. van den Berg, report NWU-42; 1992

Het berekenen van wegverkeerslawaai -Handleiding bij SRM1: een Doe-Het-Zelf computerprogramma; B. van Oerle, G.P. van den Berg, report NWU-57; 1994

Karakterisering van natuurlijk achtergrondgeluid: metingen in kweldergebied; J.W. van de Rijke, R.A. Bolt, G.P. van den Berg, report NWU-76; 1997

Science Shops in Groningen - a Dutch connection; Frits van den Berg, Henk Mulder, report NWU-82; 1999

'Stil geluid' - Laagfrequent geluid in woningen; G.P. van den Berg, R.R. Nederhoed, P.W.G. Altena, report NWU-83; 1999

Metingen laagfrequent geluid te Paterswolde; G.P. van den Berg, R.R. Nederhoed, report NWU-86; 1999

Metingen laagfrequent geluid te Borgsweer; G.P. van den Berg, R.R. Nederhoed, report NWU-87; 1999

Metingen van laagfrequent geluid in Broek op Langendijk; G.P. van den Berg, R.R. Nederhoed, report NWU-88; 1999

Karakterisering van natuurlijk achtergrondgeluid: metingen in het Horsterwold; H.J. Kaper, G.P. van den Berg, report NWU-89; 1999

Gezondheidseffecten van radiofrequente straling - GSM telefonie; G.P. van den Berg., H.J. Kaper, G. Schut, report NWU-90; 1999

Metingen laagfrequent geluid te Lelystad; G.P. van den Berg, R.R. Nederhoed, report NWU-92; 1999

Achtergrondgeluid te Noordwolde (Gn): meting van het L_{95}; G.P. van den Berg, H.J. Kaper, report NWU-101, 2000

Karakterisering van natuurlijk achtergrondgeluid: metingen in de Wieringerwaard; R. Uitham, G.P. van den Berg, report NWU-104; 2000

Omgevingsgeluid en referentieniveau in stadsdelen van Groningen; memorandum 20-06-2001, S. de Jong en G.P. van den Berg, 2001

Hoge molens vangen veel wind: wind- en geluidmetingen bij een hoge windturbine; Herman Kloosterman, Derek Land, Joost Massolt, Georg Muntingh, Frits van den Berg, report NWU-106; 2002

Onderzoek naar klachten over laagfrequent geluid in Groningen; Peter Veenstra, Frits van den Berg, report NWU-108; 2002

Metingen laagfrequent geluid te Landsmeer; Peter Veenstra, Frits van den Berg, report NWU-109, 2002

Hoge molens vangen veel wind II: geluidsbelasting door windturbines in de nacht, Frits van den Berg, Richard de Graaf, report NWU-110, 2002

Op zoek naar stilte: indicatoren van stilte in De Wieden/Weerribben, NP Utrechtse Heuvelrug en de Zak van Zuid-Beveland; C.P. Lanting, G.P. van den Berg, report NWU-114, 2003

Metingen van het achtergrondgeluid in de Bearsterpolder; memorandum 03-05-2004, D. de Graaf, H. Wiltens en F. van den Berg, 2004

Geluidsimmissie tengevolge van het Natuur- en Scheikundegebouw (complex Nijenborgh 4), memorandum 13-10-2005, G.P. van den Berg, R. Ramaker

Metingen bij woning Korreweg van geluid van Poolcentrum Raxx, memorandum 30-11-2005, G.P. van den Berg, R.Ramaker

Op zoek naar stilte: indicatoren van stilte in NP Dwingelderveld, het Reitdiepdal en NP De Groote Peel; R.Ramaker, G.P. van den Berg, report NWU-117, 2006

Geluidsmetingen bij Snookercentrum Raxx te Groningen; R.Ramaker, G.P. van den Berg, report NWU-118, 2006

Op zoek naar stilte: indicatoren van stilte in stiltegebieden in Friesland; J. Oudelaar, G.P. van den Berg, report NWU-119, 2006

Stellingen behorende bij het proefschrift "The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise" van Godefridus Petrus van den Berg

1. Exploitanten van windparken weten verbazend weinig van wind.

2. Het 'klappen' van de wieken is 's nachts het hinderlijkste aspect van windturbinegeluid en vereist een net zo voortvarende aanpak als eerder het geval was bij het machinale, tonale geluid van windturbines.

3. Het optimaliseren van windparken op zoveel mogelijk opgewekte energie én zo weinig mogelijk overlast voor omwonenden is noodzakelijk om de exploitatie van windenergie op land te laten slagen.

4. De meest effectieve manier om bij geluidsmetingen aan windturbines het windgeluid op de microfoon te reduceren is over het hoofd gezien: 's nachts meten.

5. Het materiaal van een windbol voor een microfoon doet er niet toe, als het maar geluid doorlaat en wind tegenhoudt.

6. Van teveel luisteren naar hun opdrachtgevers worden geluidsadviseurs slechthorend.

7. Van marktwerking in het openbaar vervoer is alleen de overheid beter geworden.

8. Duurzame groei van welvaart bestaat niet.

9. De overgang naar een duurzame energievoorziening kan niet zonder hoge prijzen voor fossiele brandstoffen

10. Ingewikkelde wetgeving is goed voor de werkgelegenheid van adviseurs.

Brain Res. 2004 Jan 16;996(1):126-37.

Projections from the parabrachial nucleus to the vestibular nuclei: potential substrates for autonomic and limbic influences on vestibular responses.

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Previous anatomical studies in rabbits and rats have shown that the superior vestibular nucleus (SVN), medial vestibular nucleus (MVN) and inferior vestibular nucleus (IVN) project to the parabrachial nucleus (PBN) and KÃ¶lliker-Fuse (KF) nucleus. Adult male albino rabbits and Long-Evans rats received iontophoretic injections of biotinylated dextran amine, Phaseolus vulgaris leucoagglutinin, Fluoro-Gold or tetramethylrhodamine dextran amine into either the vestibular nuclei or the PBN and KF nuclei. The results were similar in both rats and rabbits. Injections of retrograde tracers into the vestibular nuclei produced retrogradely labeled neurons bilaterally in caudal third of the medial, external medial, and external lateral PBN in both species, with more variable labeling in KF. Rats also had consistent bilateral (predominantly contralateral) labeling in the ventrolateral PBN. The most prominent labeling was produced from injections that included the SVN, with fewer labeled neurons observed from injections in the caudal MVN and the IVN. Anterograde transport of BDA from injections into the PBN and KF nuclei of rabbits revealed prominent projections to the SVN, dorsal aspect of the rostral MVN, caudal MVN, pars beta of the LVN and IVN. These connections appear to contain a component that is reciprocal to the vestibulo-parabrachial pathway and a non-reciprocal component to regions connected with the vestibulocerebellum and vestibulo-motor reflex pathways. These connections support the concept that a synthesis of autonomic, vestibular and limbic information is an integral property of pathways related to balance control in both the brain stem and forebrain. It is suggested that these projections may contribute broadly to both performance tradeoffs in vestibular-related pathways during variations in the behavioral context and affective state and the close association between anxiety and balance function.

PMID: 14670639 [PubMed - indexed for MEDLINE]

Laryngoscope. 2003 Oct;113(10):1714-8.

Which comes first? Psychogenic dizziness versus otogenic anxiety.

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SUMMARY: OBJECTIVE To investigate the hypotheses that physical neurotologic conditions may trigger anxiety disorders (otogenic pattern of illness), that psychiatric disorders may produce dizziness (psychogenic pattern), and that risk factors for these syndromes may be identified.STUDY DESIGN Retrospective review of all patients (N = 132) treated at a tertiary care balance center from 1998 to 2002 for psychogenic dizziness with or without physical neurotologic illnesses.METHODS All patients underwent comprehensive neurotologic and psychiatric evaluations with attention to the longitudinal course of symptoms and risk factors for psychopathology. Patients were grouped according to the condition first causing dizziness. Risk factors were compared across groups.RESULTS Three equally prevalent patterns of illness were found: anxiety disorders as the sole cause of dizziness (33% of cases), neurotologic conditions exacerbating preexisting psychiatric disorders (34%), and neurotologic conditions triggering new anxiety or depressive disorders (33%). Panic disorder and agoraphobia were significantly more prevalent than less severe phobias in the first two groups, whereas the opposite pattern existed in the third group (P <.0001). More patients in the first two groups had risk factors for anxiety disorders (P <.05). Depression was not a primary cause of dizziness in any patient. Vestibular neuronitis, benign paroxysmal positional vertigo, and migraine were the most common neurotologic conditions.CONCLUSIONS These data support the hypothesis that physical neurotologic conditions may trigger psychopathology as often as primary anxiety disorders cause dizziness. A third pattern appears to be equally common wherein physical neurotologic conditions exacerbate preexisting psychiatric illnesses. Individuals at risk for anxiety disorders may be more likely to have primary psychopathology.

PMID: 14520095 [PubMed - indexed for MEDLINE]

Physiol Behav. 2002 Dec;77(4-5):469-75.

Neural substrates linking balance control and anxiety.

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This communication provides an update of our understanding of the neurological bases for the close association between balance control and anxiety. New data suggest that a vestibulo-recipient region of the parabrachial nucleus (PBN) contains cells that respond to body rotation and position relative to gravity. The PBN, with its reciprocal relationships with the extended central amygdaloid nucleus, infralimbic cortex, and hypothalamus, appears to be an important node in a primary network that processes convergent vestibular, somatic, and visceral information processing to mediate avoidance

conditioning, anxiety, and conditioned fear responses. Noradrenergic and serotonergic projections to the vestibular nuclei also have parallel connections with anxiety pathways. The coeruleo-vestibular pathway originates in caudal locus coeruleus (LC) and provides regionally specialized noradrenergic input to the vestibular nuclei, which likely mediate effects of alerting and vigilance on the sensitivity of vestibulo-motor circuits. Both serotonergic and nonserotonergic pathways from the dorsal raphe nucleus and the nucleus raphe obscurus also project differentially to the vestibular nuclei, and 5-HT(2A) receptors are expressed in amygdaloid and cortical targets of the PBN. It is proposed that the dorsal raphe nucleus pathway contributes to both (a) a tradeoff between motor and sensory (information gathering) aspects of responses to self-motion and (b) a calibration of the sensitivity of affective responses to aversive aspects of motion. This updated neurologic model continues to be a synthetic schema for investigating the neurological and neurochemical bases for comorbidity of balance disorders and anxiety disorders

Publication Types:

- Review
- Review, Tutorial

PMID: 12526985 [PubMed - indexed for MEDLINE]

Arch Otolaryngol Head Neck Surg. 2002 May;128(5):554-60.

Serotonin reuptake inhibitors for dizziness with psychiatric symptoms.

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OBJECTIVE: To investigate the efficacy and tolerability of selective serotonin reuptake inhibitors (SSRIs) for the treatment of patients with dizziness and major or minor psychiatric symptoms, with or without neurotologic illnesses. DESIGN: Review of 60 consecutive cases of patients with dizziness who were treated with an SSRI for at least 20 weeks during the 30-month period from July 1998 to December 2000. SETTING: Tertiary care, multidisciplinary referral center. PATIENTS: Sixty men and women, aged 13 to 81 years, with (1) psychogenic dizziness, (2) dizziness due to a neurotologic condition, as well as significant psychiatric symptoms, or (3) idiopathic dizziness. INTERVENTIONS: Open-label treatment with an SSRI titrated to 1 of 3 end points: optimal clinical benefit, intolerable adverse effects, or no therapeutic response. MAIN OUTCOME MEASURE: Change in dizziness and psychiatric symptoms measured by the 7-point, clinician-rated, Clinical Global Impressions-Improvement Scale. RESULTS: Thirty-eight (63%) of 60 patients in the intent-to-treat sample and 32 (84%) of 38 patients who completed treatment improved substantially. The response rates did not differ between patients with major psychiatric disorders and those with lesser psychiatric symptoms. Patients whose only diagnosis was a psychiatric disorder and those with coexisting peripheral vestibular conditions or migraine headaches fared better than patients with central nervous system deficits. Before being treated with an SSRI, two thirds of the study patients took meclizine hydrochloride and/or benzodiazepines, with minimal benefit. CONCLUSIONS: Treatment with SSRIs relieved dizziness in patients with major or minor psychiatric symptoms, including those with peripheral vestibular conditions and migraine headaches. Patients fared far better with SSRI treatment than with treatment with vestibular suppressants or benzodiazepines.

PMID: 12003587 [PubMed - indexed for MEDLINE]

J Anxiety Disord. 2001 Jan-Apr;15(1-2):9-26.

A clinical taxonomy of dizziness and anxiety in the otoneurological setting.

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Dizziness can be associated with otologic, neurologic, medical, and psychiatric conditions. This paper focuses on the interface between otologic and psychiatric conditions. Because dizziness often is situation specific, concepts of space and motion sensitivity (SMS), space and motion discomfort (SMD), and space and motion phobia (SMP) are needed to understand the interface. We present a framework involving several categories of interactions between balance and psychiatric disorders. The first category is that of dizziness caused by psychiatric disorder (psychiatric dizziness), including hyperventilation-induced dizziness during panic attacks. The second category involves chance cooccurrence of a psychiatric disorder and a balance disorder in the same patient. The third category involves problematic coping with balance symptoms (psychiatric overlay). The fourth category provides psychological explanations for the relationship between anxiety and balance disorders, including somatopsychic and psychosomatic relationships. The final category, neurological linkage, focuses on the overlap in the neurological circuitry involved in balance disorders and anxiety disorders.

Publication Types:

- Review
- Review, Tutorial

PMID: 11388360 [PubMed - indexed for MEDLINE]

J Anxiety Disord. 2001 Jan-Apr;15(1-2):81-94.

Visual influences on balance.

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This paper discusses the impact of vision on balance and orientation in patients with vestibular disorders and in anxiety patients with space and motion discomfort (SMD). When the vestibular system is impaired, vision has a greater influence on standing postural control, resulting in greater sway when individuals are presented with erroneous or conflicting visual cues. Studies have shown that individuals with other motion sensitivities, such as motion sickness, also tend to rely on vision for balance and do not disregard erroneous visual cues. Recently, patients with anxiety disorders that include SMD also have been shown to have increased postural sway in conflicting visual environments, similar to patients with vestibular disorders. Thus, while specific vestibular deficits are not always directly associated with SMD, data regarding the impact of vision on balance suggest that some patients with SMD may have an underlying balance disorder.

Publication Types:

- Review
- Review, Tutorial

PMID: 11388359 [PubMed - indexed for MEDLINE]

J Anxiety Disord. 2001 Jan-Apr;15(1-2):53-79.

Neurological bases for balance-anxiety links.

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This review paper examines neurologic bases of links between balance control and anxiety based upon neural circuits that are shared by pathways that mediate autonomic control, vestibulo-autonomic interactions, and anxiety. The core of this circuitry is a parabrachial nucleus network, consisting of the parabrachial nucleus and its reciprocal relationships with the extended central amygdaloid nucleus, infralimbic cortex, and hypothalamus. Specifically, the parabrachial nucleus is a site of convergence of

vestibular information processing and somatic and visceral sensory information processing in pathways that appear to be involved in avoidance conditioning, anxiety, and conditioned fear. Monoaminergic influences on these pathways are potential modulators of both effects of vigilance and anxiety on balance control and the development of anxiety and panic. This neurologic schema provides a unifying framework for investigating the neurologic bases for comorbidity of balance disorders and anxiety

Publication Types:

- Review
- Review, Tutorial

PMID: 11388358 [PubMed - indexed for MEDLINE]

Noise Health. 1998;1(1):47-55.

Fatigue after work in noise - an epidemiological survey study and three quasi-experimental field studies.

Kjellberg A, Muhr P, Skoldstrom B.

National Institute for Working Life, S-171 84 Solna, Sweden.

The contribution of noise exposure to fatigue at work was studied in a survey study and three field studies. The survey study was based on a questionnaire covering symptoms and work place exposure answered by 50 000 state employees. Noise exposure was also estimated from their type of job and self-rated noise exposure. Fatigue and headache were found to be more common among the noise exposed groups even after control for the effects of other critical variables. Study 2 compared reaction times before and after a week's work in high noise exposure and one in low exposure exposure in a group of aeroplane mechanics. Reaction times were prolonged after work in the noise week, whereas an opposite trend was seen in the control week. Study 3 showed a gradual increase of reaction times during a week of noise exposure in a group of aeroplane technicians. Study 4 compared reaction times and subjective fatigue among naval crews on a day with low and a day with high noise exposure. In one of the studied boat types the development of fatigue during the work day was accentuated on the day with high exposure.

PMID: 12689367 [PubMed - as supplied by publisher]

Otolaryngol Clin North Am. 1996 Jun;29(3):455-65.

Update on tinnitus.

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The study of a disorder such as tinnitus is fraught with difficulties. Tinnitus, like pain, is a subjective symptom. The problem is compounded because several different mechanisms must operate to cause the persistent sensation of tinnitus. Therefore, it is difficult to measure objectively any improvements in the condition. For example, it has been reported previously that sectioning the eighth cranial nerve does not abolish tinnitus in a majority of patients; therefore, central mechanisms must act to preserve the tinnitus. Finally, we know that tinnitus can occur in a host of conditions other than ototoxicity, aging, and noise exposure. Other conditions that may produce tinnitus are migraine

headache with auditory aura, temporal lobe seizures, and head injuries. Therefore, it is naive to conceptualize that tinnitus is a disorder with a unitary origin and a unitary "cure".

Publication Types:

- Review
- Review, Tutorial

PMID: 8743344 [PubMed - indexed for MEDLINE]

J Behav Med. 1986 Apr;9(2):203-12.

Subjective stress sensitivity and physiological responses to an aversive auditory stimulus in migraine and control subjects.

Rojahn J, Gerhards F.

Subjective stress sensitivity and physiological parameters were compared between 24 migraine subjects and 24 matched headache-free controls during a multifrequency 85-dB (A) aversive auditory stressor and during a recovery period. Measures consisted of frontalis EMG, temporal artery blood volume pulse, heart rate, a stress sensitivity questionnaire, stress reaction during the stress-expectation period, and ratings of noise aversiveness. Migraine subjects showed a higher level of general stress sensitivity, increased situational stress sensitivity, and higher ratings of noise aversiveness; this supports the general notion that migraine sufferers are psychologically more sensitive toward stress stimulation than nonheadache controls. Physiologically, the migraine subjects differed from the control group only with regard to the temporal blood volume pulse during stress stimulation; this finding is consistent with Wolff's weak-link theory.

PMID: 3712430 [PubMed - indexed for MEDLINE]

Noise Health. 2000;2(8):1-8.

A Review of Environmental Noise and Mental Health.

Stansfeld SA, Haines MM, Burr M, Berry B, Lercher P.

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The question of whether environmental noise exposure causes mental ill-health is still largely unanswered. This paper reviews the studies of environmental and industrial noise and mental ill-health published between 1993 and 1998 and suggests possibilities for future research. Recent community based studies suggest high levels of environmental noise are associated with mental health symptoms such as depression and anxiety but not with impaired psychological functioning. Several studies find that self-reported noise sensitivity does not interact with noise exposure to lead to increased vulnerability to mental ill-health. Chronic aircraft noise exposure in children impairs quality of life but does not lead to depression or anxiety. Further research on environmental noise and mental health should be accompanied by more accurate and detailed measurement of noise exposure and consideration of the impact of other environmental stressors and careful measurement of confounding factors such as social class. Target study populations exposed to noise should be chosen to avoid those where noise exposure is likely to have led to noise sensitive individuals moving away from the area. There should also be greater use of standardised instruments to measure a wider range of mental health outcomes. Also other physiological outcomes such as hormonal measures could with benefit be measured simultaneously.

PMID: 12689457 [PubMed - as supplied by publisher]

Aviat Space Environ Med. 1978 Apr;49(4):582-6.

Effects of infrasound on cognitive performance.

Harris CS, Johnson DL.

The cognitive performance of 40 subjects was measured during exposure to infrasound and noise in three experiments. In the first experiment, 12 subjects were exposed for 15 min to each of four experimental conditions while performing a Serial Search Task. The conditions were: 65 dB ambient noise (AN), a low-frequency background noise (BN) at 110 dB, a 7-Hz tone at 125 dB + AN, and the 125 dB tone + BN. The second experiment was the same as the first except a Complex Counting Task was used and the exposure duration was increased from 15 min to 30 min. In the third experiment, the Complex Counting Task was used and the subjects were exposed for 15 min to each of the following four conditions; BN, 125 dB at 7 Hz plus BN, 132 dB at 7 Hz plus BN, and 142 dB at 7 Hz plus BN. No decrements in performance were obtained in any of the three experiments, and there were no subjective reports of dizziness or disorientation as suggested in some of the previous literature. The authors conclude that adverse effects of infrasound have been exaggerated and the current levels of infrasound components as produced by modern jet aircraft are not considered in themselves a practical problem.

PMID: 637817 [PubMed - indexed for MEDLINE]

Acta Otolaryngol. 1994 Nov;114(6):579-85.

Vestibular findings associated with chronic noise induced hearing impairment.

Shupak A, Bar-El E, Podoshin L, Spitzer O, Gordon CR, Ben-David J.

Israel Naval Medical Institute, Haifa.

Histological and functional derangements of the vestibular system have been reported in laboratory animals exposed to high levels of noise. However, clinical series describe contradictory results with regard to vestibular disturbances in industrial workers and military personnel suffering from noise induced hearing loss (NIHL). The purpose of the

present study was to evaluate vestibular function in a group of subjects with documented NIHL, employing electronystagmography (ENG) and the smooth harmonic acceleration (SHA) test. Subjects were 22 men suffering from NIHL and 21 matched controls. Significantly lower vestibulo-ocular reflex gain ($p = 0.05$), and a tendency towards decreased caloric responses were found in the study group. No differences in the incidence of vertigo symptoms, spontaneous, positional and positioning nystagmus, directional preponderance and canal paresis in the ENG, or the SHA test phase and asymmetry parameters were observed between the groups. These results demonstrated a symmetrical centrally compensated decrease in the vestibular end organ response which is associated with the symmetrical hearing loss measured in the study group. Statistically significant correlations were found between the average hearing loss, the decrement in the average vestibulo-ocular reflex gain ($p = 0.01$), and ENG caloric lateralization ($p = 0.02$). These correlations might indicate a single mechanism for both cochlear and vestibular noise-induced injury. The results imply subclinical, well compensated malfunction of the vestibular system associated with NIHL.

PMID: 7879613 [PubMed - indexed for MEDLINE]

Am J Otol. 1987 Mar;8(2):87-9

Tinnitus and vertigo in healthy senior citizens without a history of noise exposure.

Sataloff J, Sataloff RT, Lueneburg W.

The prevalence of tinnitus and dizziness in healthy elderly adults has been uncertain. This study investigated 267 people between the ages of 57 and 91 1/2 years. The subjects had no history of noise exposure, systemic diseases associated with tinnitus or disequilibrium, and had normal otoscopic examination results. Twenty-four percent reported tinnitus. Five percent experienced dizziness. Additional studies will help clarify the prevalence of these symptoms in the elderly "normal" population.

PMID: 3591925 [PubMed - indexed for MEDLINE]

Br J Audiol. 1982 Nov;16(4):227-32.

Vestibular implications of noise-induced hearing loss.

Oosterveld WJ, Polman AR, Schoonheyt J.

An extensive vestibular examination was carried out in a group of 29 noise-exposed technicians. A spontaneous nystagmus was found in 18 persons, and 24 had a positional nystagmus exceeding a velocity of the slow phase of 5 degrees/s in three or more positions. In 17 subjects a cervical nystagmus could be provoked, while a nystagmus

preponderance of more than 20% in the rotation test was found in seven persons. A difference in excitability between the labyrinths of more than 20% was shown by seven subjects. None of the subjects showed pathology in the tests for central vestibular disorders. The technicians were divided into four groups, according to the severity of their hearing loss. No correlation was found between the grade of the hearing loss and the vestibular function disturbance. This can be explained in terms of the adaptive properties of the vestibular system. All subjects showed pathology in one or more of the vestibular tests. The medico-legal aspects of vestibular involvement in noise-induced hearing loss can be of some importance. Hearing loss itself does not affect work capability directly; however, a vestibular disorder might well do so. In consequence, noise-exposed individuals could be disabled because of vertigo or balance disorder--an important and perhaps neglected aspect of noise-induced hearing damage.

PMID: 6984349 [PubMed - indexed for MEDLINE]

Hearing at Low and Infrasonic Frequencies

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The human perception of sound at frequencies below 200 Hz is reviewed. Knowledge about our perception of this frequency range is important, since much of the sound we are exposed to in our everyday environment contains significant energy in this range. Sound at 20-200 Hz is called low-frequency sound, while for sound below 20 Hz the term infrasound is used. The hearing becomes gradually less sensitive for decreasing frequency, but despite the general understanding that infrasound is inaudible, humans can perceive infrasound, if the level is sufficiently high. The ear is the primary organ for sensing infrasound, but at levels somewhat above the hearing threshold it is possible to feel vibrations in various parts of the body. The threshold of hearing is standardized for frequencies down to 20 Hz, but there is a reasonably good agreement between investigations below this frequency. It is not only the sensitivity but also the perceived character of a sound that changes with decreasing frequency. Pure tones become gradually less continuous, the tonal sensation ceases around 20 Hz, and below 10 Hz it is possible to perceive the single cycles of the sound. A sensation of pressure at the eardrums also occurs. The dynamic range of the auditory system decreases with decreasing frequency. This compression can be seen in the equal-loudness-level contours, and it implies that a slight increase in level can change the perceived loudness from barely audible to loud. Combined with the natural spread in thresholds, it may have the effect that a sound, which is inaudible to some people, may be loud to others. Some investigations give evidence of persons with an extraordinary sensitivity in the low and infrasonic frequency range, but further research is needed in order to confirm and explain this phenomenon.

Keywords: low-frequency sound, infrasound, hearing thresholds, equal-loudness-level contours, binaural advantage, sensitive persons

Introduction

It is traditionally said that the human hearing covers a certain frequency range, called the *audible range* or the *audio frequency range*. The lower limit of this range is usually given as 16 or 20 Hz, and the upper limit is typically said to be 16 or 20 kHz.

The upper limit is fairly sharp in the sense that the hearing threshold rises rather steeply above the upper limit - meaning that the hearing almost "stops" at this frequency. The lower limit is more smooth, and the hearing threshold follows a curve that gradually goes to higher levels for decreasing frequency. As a surprise to most people (even to many acousticians), the threshold curve continues below 20 and even 16 Hz, and - as it will be seen in the following sections - humans can perceive sound at least down to a few Hertz. This applies to all humans with a normal hearing organ, and not just to a few persons.

Since the threshold curve goes up for decreasing frequency, it reaches quite high sound pressure levels at the lowest frequencies. Even when rather high sound pressure levels are needed to cause a perception, there are many sources in our everyday environment that do produce audible sound in this frequency range. Engines, compressors, ventilation systems, traffic and musical instruments are examples of man-made sources, but also natural sources exist like thunder, ocean waves and earthquakes. Driving a car at highway-speed with an open window is a situation, where many people expose themselves to perceivable levels of 10-20 Hz sound.

The ear is most sensitive in the frequency range from 200-300 Hz to around 10 kHz, and this is the frequency range we mainly use in communication. As a natural consequence it is also the frequency range, where most hearing research has been made. However, it is important to have insight in the hearing function also outside this frequency range, in particular at frequencies below, since much of the sound that we are exposed to in our everyday environment contains significant energy in this range. The present article gives a review of studies of the hearing function below 200 Hz, focussing on the hearing threshold and the loudness function.

Terminology

Sound with frequencies below 20 Hz is called *infrasound*, infra being Latin and meaning below. Thus the term refers to the widespread understanding that these frequencies are below the range of (audible) "sound". As mentioned, this understanding is wrong, and the use of the term infrasound for these frequencies has resulted in many misunderstandings. Nevertheless, the term is widely used, and it will also be used in this article. For sound in the frequency range 20-200 Hz, the term *low-frequency sound* is used. Since there is no sharp change in hearing at 20 Hz, the dividing into infrasound and low-frequency sound should only be considered as practical and conventional.

Sensation of sound at low and infrasonic frequencies

Everyone knows from his everyday environment the feeling of hearing sound at low and infrasonic frequencies. The following are examples of typical low-frequency sound sources: ventilation systems, compressors, idling trucks and the neighbour's stereo. Infrasound at an audible level is usually found on the car deck of a ferry and when driving a car with an open window. However, infrasound is most often accompanied by sound at other frequencies, so the experience of listening to pure infrasound is not common.

The subjective quality of the sound varies with frequency. In the low-frequency range pure tones still result in a tonal sensation, and - like at higher frequencies - a sensation of pitch is connected to the sensation. If the frequency is gradually lowered from 20 Hz, the tonal sensation disappears, the sound becomes discontinuous in character and it changes into a sensation of pressure at the eardrums. At even lower frequencies it turns into a sensation of discontinuous, separate puffs, and it is possible to follow and count the single cycles of the tone. Some early descriptions of these phenomena were given by Brecher (1934) and by Wever and Bray (1936). However, the lower limit of tonality has been known much longer, e.g. it has influenced the building of musical instruments, where the largest organ pipes are tuned to a frequency around 17 Hz.

Yeowart et al. (1967) described pure tones above 20 Hz as smooth and tonal, at 5-15 Hz a rough sound with a popping effect was reported, and tones below 5 Hz were described as chugging and whooshing. Below 5 Hz a sensation like "motion of tympanic membrane itself" was reported. The perception of noise bands was investigated by Yeowart et al. (1969). For an octave band around 125 Hz the random noise was perceived as banded noise, while at 63 Hz the character changed into a sensation of a fluctuating tone. The octave bands around 32 Hz and 16 Hz were described as traffic rumble, at 16 Hz with a fluctuating flutter, while the band at 8 Hz was described as a rough peaky tone. For the octave-band noise around 4 Hz separate random peaks were perceived.

The early qualitative descriptions are well in line with later descriptions in the literature as well as with reports from numerous experimental subjects in the authors' laboratory and with the authors' experience from exposure of themselves.

It is mentioned by many authors and easily verified in a laboratory with suitable equipment that the loudness of low-frequency and infrasonic sound grows considerably faster above threshold than sound at higher frequencies. Yeowart et al. (1967) mentioned that at 4 Hz a 1 dB change in level was sufficient to cover the whole range from inaudible to definitely detectable. The faster growth of loudness is reflected in the equal-loudness-level contours, where the distance between the curves decreases with decreasing frequency (see separate section 'Studies of equal-loudness-level contours'). An implication of this compression is that if a low-frequency sound is just audible, then a relatively small increase in level will result in a much louder sound.

The sensation mechanism

It has been a matter of interest, how we sense the lowest frequencies, and the key question is, if we sense them with our ears and in the same way as we sense higher frequencies.

There is no doubt that the ear is the organ that is most sensitive to sound at these frequencies. This is seen from the fact that hearing thresholds are the same, whether the whole body or only the ears are exposed (see the section 'Do we sense with our ears'). It is more difficult to determine whether the sensory pathway belongs to the auditory system or not. Békésy (1936) noted that it is difficult to distinguish whether the sensation is of a pressure or tactile nature, or of an auditory nature. He argued, though, that touching two symmetrical places on for example the entrance to the external meatus results in two separate sensations, while binaural exposure to infrasound fuses into a single impression localized in the middle of the head. Therefore he concluded that it is in fact an auditory sensation. However, he also observed that at higher sound pressure levels the auditory sensation is accompanied by a "true" sensation of touch at each of the ears. If the level of the sound is increased even further, a sense of tickling or prickling is observed. That the sensation at low levels is auditory is further supported by the fact that perception thresholds for deaf people are much higher than for people with normal hearing (see section 'Non-auditory perception').

It seems fair to conclude that the sense of hearing is the primary sense for detecting sound at low and infrasonic frequencies. However, it has often been proposed that we do not sense infrasound directly, but that we simply hear higher harmonics produced by distortion in the middle and the inner ear (see e.g. Johnson (1980)). If this were true, it would then be reasonable to assume that the subjective quality of a 15-Hz tone would be comparable to that of a tone or a combination of tones at higher harmonics like 30 and 45 Hz. However, to the authors' knowledge such similarity has not been reported, and in an informal listening test with the authors and colleagues as listeners, such sounds were perceived as clearly different in timbre, pitch and general quality. Thus, the theory is not supported.

Modulation of hearing

One way in which the presence of infrasonic sound can be detected at levels around or possibly below the hearing threshold is by modulation of higher frequencies. The infrasound moves the eardrum and the middle ear bones, and the displacement may be so large that their mechanical properties and the transmission change. As a consequence, sounds at higher frequencies are amplitude-modulated with the infrasound. This effect is easily demonstrated in a suitable laboratory, and it emphasises the need of very quiet conditions, when perception of infrasound is studied.

Speech modulation

Another modulation effect is sometimes mentioned in connection with infrasound, namely modulation of speech. Whereas the effect mentioned in the previous paragraph relates to a person as a sound detector, this effect relates to a person's generation of sound. When a person speaks in the presence of infrasound, the pressure from the infrasound may create a small pulsating airflow in the throat. This flow adds to the natural flow from breathing and speaking, and it modulates the speech. The effect is only noticed at high levels of infrasound.

Studies of hearing threshold

The threshold is most likely the single characteristic of the hearing that is investigated most and best known. However, it is not trivial to produce a well-controlled exposure at low frequencies, and many original investigations have a bad coverage of this frequency region. The number of investigations in the infrasonic region is even more limited.

Thresholds are usually given in terms of the pressure of a free plane wave, in which the listener is exposed horizontally and from the front. The pressure is measured without the listener being present in the sound field. A threshold given this way is called the *minimum audible field*, or the MAF. Another possibility is to specify the threshold in terms of the actual pressure at the eardrum during exposure - in principle without specific requirements to the nature of the sound field. This is called the *minimum audible pressure*, or the MAP.

At high frequencies the presence or absence of a person has a substantial impact on the sound field, and there is a significant difference between the MAF and the MAP. Furthermore, the difference depends on the nature of the sound field (e.g. free or diffuse), direction to sound source(s) etc. At low frequencies, however, the listener's head and body have little or no impact on a free plane wave, and it is expected that MAP and MAF will have the same value.

Measurements of MAP may in principle be carried out in any sound field. However, they are usually done either in a pressure-field chamber that encloses the entire body of the listener, or with the sound created in a cavity that is coupled to the ear (or to both ears). If, in the latter case, the cavity is very small, e.g. like that of a supra-aural audiometric earphone, physiological activity around the ear seems to result in noise under the earphone that elevates the threshold, in particular at low frequencies (see e.g. Anderson and Whittle (1971)). Therefore MAP measurements with sound applied in very small volumes have not been included in the following.

Sivian and White (1933) gave a review of earlier studies of hearing thresholds. These investigations differ much in means of exposure and calibration as well as experimental method, and they are now mainly of historical interest. Nevertheless it is interesting to see how close the results of at least some of these studies are to threshold data obtained in more recent years. These early studies will not be further reported here.

Common to all studies mentioned in the following is that they have been made with sinusoidal tones, and that the duration of the tones has been so long that the temporal integration of the ear is expected not to have any impact on the result (usually a duration of 0.5-2 s or longer).

Most studies have been made in a free or an approximately free sound field (e.g. an anechoic room) using an electrodynamic transducer (usually a loudspeaker) as sound source. Data obtained under such conditions have been presented by Sivian and White (1933) (100 Hz-15 kHz, 14 subjects monaural, five subjects binaural), Fletcher and Munson (1933) (60 Hz-15 kHz, 11 subjects), Churcher et al. (1934) (100 Hz-6.4 kHz, 48 subjects), Churcher and King (1937) (54 Hz-6.4 kHz, 10 subjects), Robinson and Dadson (1956) (25 Hz-15 kHz, up to 120 subjects depending on frequency, lowest frequencies measured in a duct), Teranishi (1965) (63 Hz-10 kHz, 51 subjects), Anderson and Whittle (1971) (50-1000 Hz, ten subjects), Brinkmann (1973) (63 Hz-8 kHz, up to 58 subjects depending on frequency), Betke and Mellert (1989) (40 Hz-15 kHz, up to 44 subjects depending on frequency) (reported in more detail by Betke (1991)), Fastl et al. (1990) (100-1000 Hz, 12 subjects), Watanabe and Møller (1990a) (25-1000 Hz, 12 subjects), Takeshima et al. (1994) (31.5 Hz-20 kHz, below 1 kHz: 17-69 subjects depending on frequency) (partly reported on earlier occasions, e.g. by Suzuki et al. (1989)), Lydolf and Møller (1997) (50 Hz-8 kHz, 27 subjects), Poulsen and Han (2000) (125 Hz-16 kHz, 31 subjects) and Takeshima et al. (2001) (31.5 Hz-16 kHz, below 1 kHz: seven to eight subjects). Most likely the study by Bellmann et al. (1999) (40-160 Hz, 12 subjects) was also carried out in a free-field, although it was not specifically reported.

Especially at the lowest frequencies it is difficult to produce sufficiently high sound pressure levels in a free field, and the walls of even the best anechoic room become reflective. As a consequence no free-field data were reported below 25 Hz, and most investigations did not even go down as far as that.

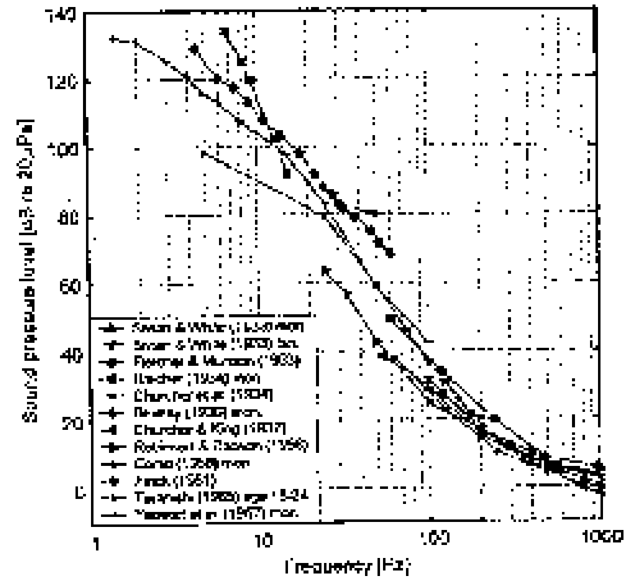

Figure 1. Low-frequency hearing thresholds measured in the period from 1933 to 1967.

Some investigators have produced the sound in a pressure chamber connected to the outer ear(s) either directly or by means of tubes. Data obtained under such conditions have been reported by Brecher (1934) (6.7-15.1 Hz, one subject, monaural), Békésy (1936) (4.5-61 Hz, one subject, monaural), Corso (1958) (5-200 Hz, 15 subjects), Finck (1961) (25-50 Hz, five subjects, binaural), Yeowart et al. (1967) (1.5-100 Hz, six to ten subjects depending on frequency, monaural) and Yeowart and Evans (1974) (5-100 Hz, five subjects, binaural). In the study by Brecher (1934) the sound was generated by a membrane driven by an eccentric wheel. Unlike other investigators, Brecher kept the level constant and varied the frequency to obtain the threshold. Békésy (1936) excited the pressure chamber by either a thermophone or a pistonphone. (A thermophone uses an amplitude-modulated alternating current to produce temperature variations in a conducting wire or foil. The surrounding air expands and contracts with the modulation, thereby creating pressure variations at the modulation frequency). The later studies used electrodynamic transducers to generate the sound.

Another group of studies used a larger pressure-field chamber that covered the entire body of the subjects. This applies to studies by Whittle et al. (1972) (3.15-50 Hz, up to 58 subjects depending on frequency), Yeowart and Evans (1974) (2-20 Hz, 12 subjects), Okai et al. (1980) (8-50 Hz, 28 subjects), Yamada et al. (1980) (8-63 Hz, 24 subjects), Nagai et al. (1982) (2-40 Hz, 62 subjects), Landström et al. (1983) (4-25 Hz, ten subjects), Watanabe and Møller (1990b) (4-125 Hz, 12 subjects), Watanabe et al. (1993) (5-40 Hz, 20 subjects) and Lydolf and Møller (1997) (20-100 Hz, 14 subjects plus nine added after publication). All studies made in whole-body pressure-field chambers used electrodynamic loudspeakers to generate the sound. Most studies had the loudspeakers mounted directly in the chamber, while in two (Whittle et al. (1972) and Yamada et al. (1980)) the sound was generated in one box that was connected to the exposure chamber by a tube. The two-box construction was used to reduce high-frequency noise from the amplifier by acoustic filtering. The exposure chamber used by Landström et al. (1983) had an opening to the outside, thereby forming a Helmholtz resonator that was tuned to the exposure frequency.

Figures 1-3 show all the thresholds that have been reported above. Although mainly frequencies below 200 Hz are considered in the present article, data up to 1 kHz are shown. Monaural and binaural data are shown as observed (i.e. with no correction), no distinction is made between data for men and women, and no distinction is made between MAF and MAP. For studies that have reported data for different

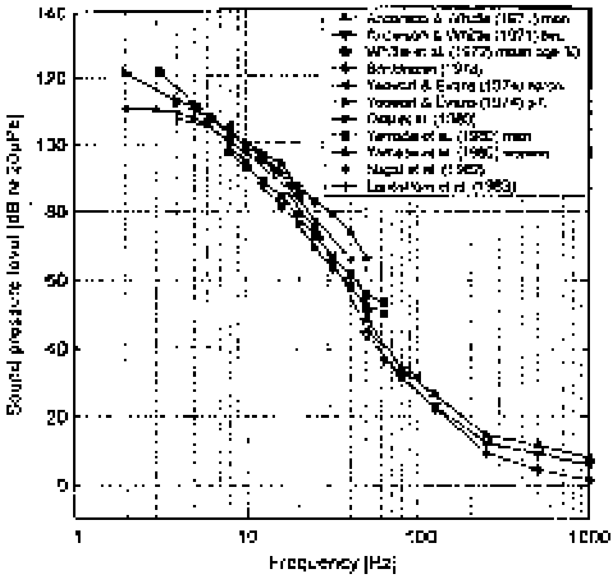

Figure 2. Low-frequency hearing thresholds measured in the period from 1971 to 1983.

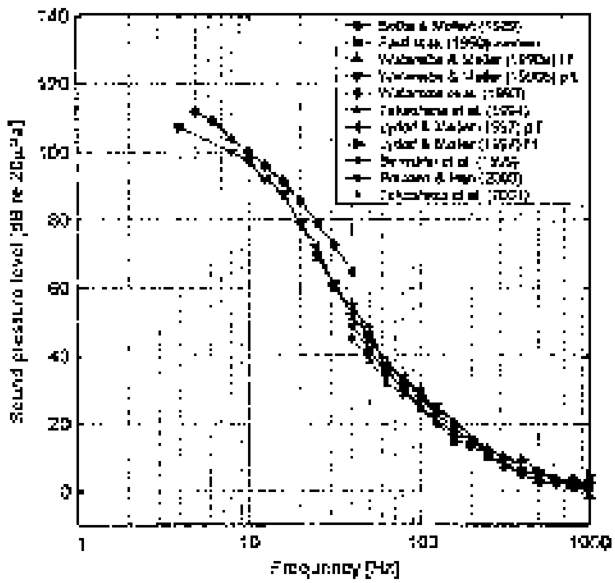

Figure 3. Low-frequency hearing thresholds measured in the period from 1989 to 2001.

age groups, the youngest group is shown (Teranishi et al. (1965), Whittle et al. (1972)).

It is obvious from Figures 1-3 that differences between investigations exist. However, one should have in mind that the data are obtained in a period of 70 years with very different techniques. Not surprisingly the largest discrepancies are found in the low and infrasonic frequency region, because it is much more difficult to produce the stimuli needed for this region. The demand on higher sound pressure levels with less harmonic distortion (due to the steep slope of the threshold curve) are difficult to meet as the production of higher sound pressure levels usually causes more harmonic distortion. Other differences between investigations can be found, e.g. in background noise level, sound field, subjects (number, age, selection process), psychometric method, instruction of the subjects, whether mean or median threshold is reported, and number of repetitions.

The differences between the investigations are so large that comparisons across investigations of the results cannot give answers to questions like

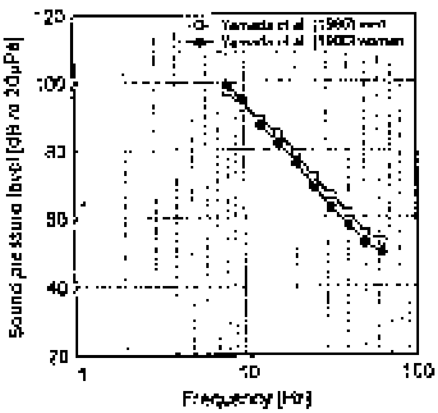

Figure 4. Low-frequency hearing thresholds for men and women.

the effect of gender, effect of age, monaural versus binaural exposure, effect of sound-field, and differences between persons. Therefore the following sections will deal with single investigations that focus on these specific issues.

Significance of gender

Most investigations have included both male and female subjects. Robinson and Dadson (1956) noted that there was no systematic difference between thresholds of men and women, but they did not show data separately for the two genders. Only Yamada et al. (1980) reported data separately. Figure 4 shows their data for the two genders. Women seem to be around 3 dB more sensitive than men except at 8 and 10 Hz, where men are around 2dB more sensitive. The standard deviation between subjects is not specified, so a statistical test cannot be performed on these data. However, large differences between persons are mentioned in the study, and when the relatively low number of subjects (16 men and eight women) is recalled, it is most likely that the differences between genders are not statistically significant.

Significance of age

Several investigations have studied thresholds for different age groups. Robinson and Dadson (1956) had many subjects in a wide age range (16-63 years), and they concluded that there was no effect of age at frequencies below 1 kHz. Consequently only data above this frequency were reported separately for different age groups. Yamada et al. (1980) mentioned threshold differences of 2-6 dB between people below and above 30 years, but he did not mention details about group sizes and age ranges, and the only original data reported are for subjects around 20 years.

Teranishi (1965) reported data separately for five age groups with 10 or 11 subjects in each group. Whittle et al. (1972) reported data for two groups, one with mean age 30 years (25 subjects) and one with mean age 47 years (35 subjects). The data from these two investigations are seen in Figure 5. This data suggests that up to 1000

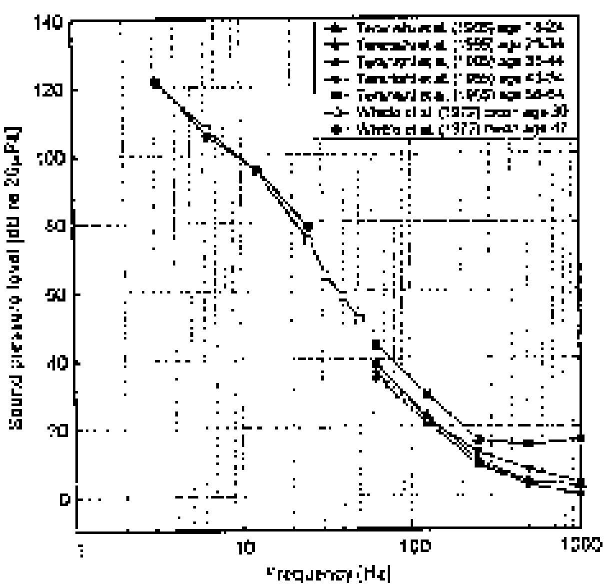

Figure 5. Low-frequency hearing thresholds for different age groups.

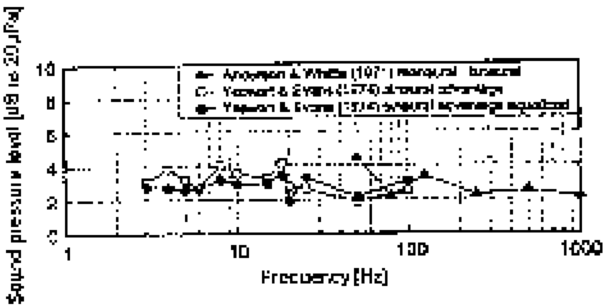

Figure 6. The difference in thresholds between monaural and binaural exposure. (The data by Yeowart and Evans (1974) marked "equalized" refer to the condition, where signals have been adjusted to obtain equal sensation at the two ears during the binaural exposure).

Hz there is no effect of age up to about 55 years.

Monaural versus binaural hearing

It is well accepted that binaural thresholds are slightly lower than monaural thresholds. The difference is called the binaural advantage, and it is said to be in the order of a few decibels, quite often around 3 dB. Some of the investigations already reported have studied the binaural advantage at low and infrasonic frequencies.

Sivian and White (1933) simply concluded that binaural thresholds were similar to monaural thresholds for the person's best ear. This was observed for only two subjects, and it was most likely too general and inaccurate. Anderson and Whittle (1971) measured for the same 10 subjects both monaural and binaural thresholds. Yeowart and Evans (1974) measured also monaural and binaural thresholds for the same group of subjects (3-4 depending on frequency). The binaural thresholds were measured in two situations, one with equal sound pressure at each of the two ears, and one where a level difference was applied between the two ears corresponding to the difference between ears in the monaural thresholds. The binaural advantage as observed in these two investigations is displayed in Figure 6 (for Anderson and Whittle (1974) calculated by the present authors as the difference between mean monaural and mean binaural thresholds). It is seen that a binaural advantage around 3 dB is probably applicable also at low and infrasonic frequencies.

Significance of sound field

Whittle et al. (1972) observed a large difference between their thresholds obtained in a whole-body pressure-field chamber and thresholds for free-field exposure given in ISO R226:1961. In order to see whether this was an effect of the sound field they also measured free-field thresholds for their own subjects. Measurements were made in four series, where the psychometric method and the set of included frequencies varied. A difference of several decibels was seen between thresholds obtained in the two sound fields. However, differences of the same order of magnitude were seen between different series in the same sound field, and no conclusion could be drawn about the effect of sound field.

Watanabe and Møller (1990b) studied for a group of 12 subjects thresholds with exposure in a free field and in a whole-body pressure-field chamber, keeping all other conditions constant. The results are shown in Figure 7. It is seen that there is a very good agreement between the two data sets in the overlapping frequency region. Thus, the data give no reason to suspect any effect of the sound field.

Do we sense with our ears?

Connected to the issue of the perception pathway is the question, whether the same thresholds are obtained if the whole body or only the ears are exposed. Yeowart and Evans (1974) measured thresholds in a whole-body chamber and with a binaural earphone. The number of subjects was not the same (12 and five respectively), and it is not stated whether there is overlap between the groups. Nevertheless, psychometric method and conditions in general were probably very similar. The data are seen in Figure 8. It is seen that the agreement between the two data sets is very

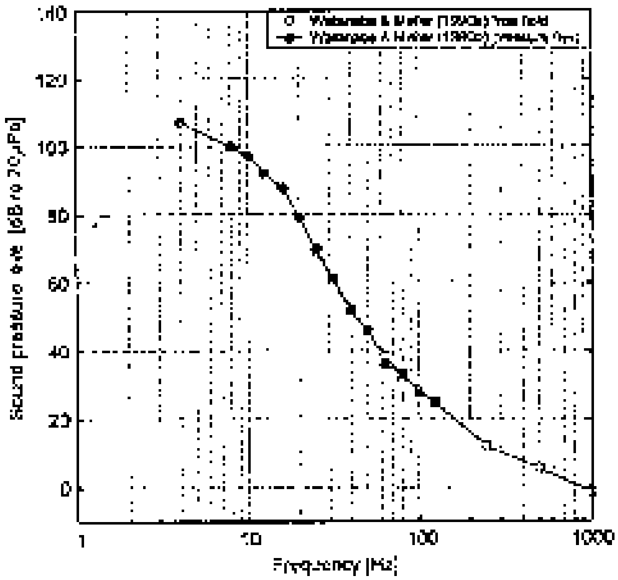

Figure 7. Low-frequency hearing thresholds measured in free-field and pressure-field conditions.

good. This supports the assumption that also these low frequencies are actually sensed by the ears.

Standardization of hearing thresholds

The first document that expresses an international agreement about the human hearing threshold is ISO R226:1961. The document covered not only the hearing threshold but also equal-loudness-level contours. Like all later standards it does not cover frequencies below 20 Hz. The bibliography of the document includes all relevant studies available at that time (Sivian and White (1933), Fletcher and Munson (1933), Churcher and King (1937), Robinson and Dadson (1956)), but data reflect only the study by Robinson and Dadson (1956).

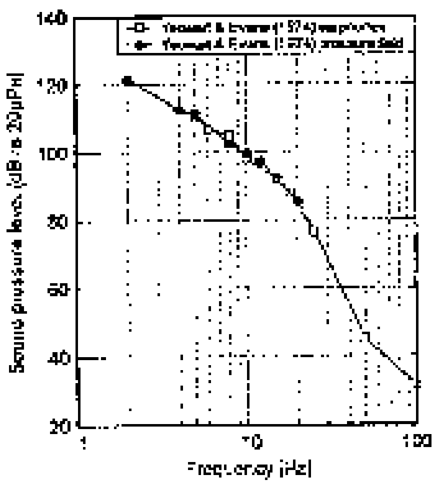

Figure 8. Low-frequency hearing thresholds measured in ear-only exposure (earphone) and whole-body pressure-field conditions.

In 1987 ISO R226:1961 was revised and issued as ISO 226:1987. The revision was a major editorial renewal, but the data were unchanged, except that they were specified at slightly different frequencies (the then new standard third-octave frequencies), and the highest frequency had been lowered from 15 kHz to 12.5 kHz. The unused studies had been removed from the bibliography.

In 1996 a standard was issued that covered only the hearing threshold and not the equal-loudness-level contours (ISO 389-7:1996). This was based on data from Robinson and Dadson (1956), Brinkmann (1973), Betke and Mellert (1989), Suzuki et al. (1989), Fastl et al. (1990), Vorländer (1991) (only frequencies above 8 kHz), Watanabe and Møller (1990a) and Watanabe and Møller (1990b). Deviations from previous standards were small (max. 2.9 dB at 20 Hz). An explanatory overview of the aggregation and processing of the data for the standard is given by Brinkmann et al. (1994).

Most recently agreement has been obtained for a complete set of hearing thresholds and equal-loudness-level contours, and a revised ISO 226

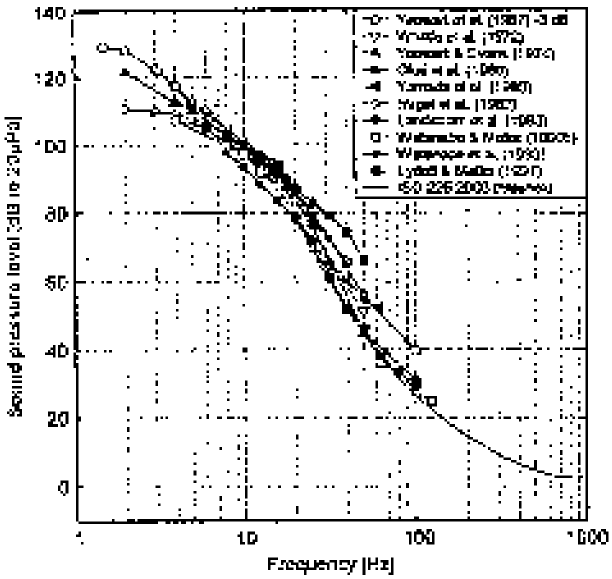

Figure 9. Standardized hearing threshold above 20 Hz (ISO 226:2003) and results from recent investigations covering frequencies at and below 20 Hz. (Whittle et al. (1972): weighted average of 30- and 43-year groups; Yeowart and Evans (1974): weighted average of ear and full-body exposures; Yamada et al. (1980): weighted average of men and women).

was issued in 2003 (ISO 226:2003). The hearing threshold is based on the same investigations as ISO 389-7:1996 with the addition of Teranishi (1965), Takeshima (1994), Poulsen and Thøgersen (1994) (only above 1 kHz), Takeshima et al. (2002) (only above 1 kHz), Lydolf and Møller (1997), Poulsen and Han (2000) and Takeshima et al. (2001). There are only small differences (max. 2.1 dB, at low frequencies max. 0.6 dB) between the threshold in this document and in ISO 389-7:1996. In order to avoid two different thresholds being standardized (although they are close), a formal revision has been initiated to make the thresholds of ISO 389-7 identical to those of ISO 226:2003.

The threshold of the most recent standard (ISO 226:2003) is included for reference in the following figures.

Proposed normal hearing threshold below 20 Hz

As no standardized hearing threshold exists for frequencies below 20 Hz, it is adequate at this place to propose a normal threshold for the lower frequencies, based on the existing data. Figure 9

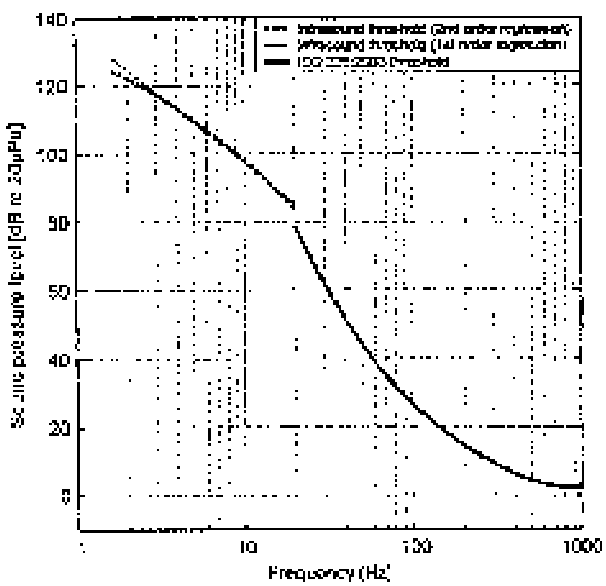

Figure 10. Standardized hearing threshold above 20 Hz (ISO 226:2003) and proposed normal hearing thresholds for frequencies below 20 Hz.

shows the most recent investigations of hearing thresholds that have data in the infrasonic frequency range, together with the hearing threshold of ISO 226:2003. (The monaural data from Yeowart et al. (1967) have been adjusted to binaural conditions by subtraction of 3 dB).

Some investigations have obtained values that are clearly too high in the 30-100 Hz range, but there is a remarkably good agreement between investigations in the 5-20 Hz range. Below 5 Hz there are very few investigations, and unfortunately they differ somewhat.

In Figure 10 the bold dashed line shows a second-order polynomial regression curve as an approximation to the data of Figure 9. As seen it does not connect precisely to the curve of ISO 226:2003. There are data that agree well with the standard (Yamada et al. (1980) and Watanabe and Møller (1990)), but other data are higher. It is not possible from the existing data material to give a definitive solution in the area around 20 Hz. The proposed curve is also somewhat uncertain below 5 Hz, where more data would be needed to give more conclusive values. Despite these uncertainties, the curve is probably correct within a few decibels, at least in most of the frequency range.

The thin dashed line gives the more coarse linear regression (approximation of a straight line). The slope of the line is 11.9 dB per octave which is very close to the 12-dB-per-octave slope of the G-weighting filter for infrasound (ISO 7196:1995). The thin dashed line corresponds to a G-weighted sound pressure level of approximately 97 dB.

Individual differences

Several hearing threshold studies have reported standard deviations between subjects. A summary of these is given in Figure 11.

In general the standard deviations between subjects are in the order of 5 dB nearly independent of frequency, maybe with a slight increase at 20-50 Hz. Only the study by Sivian and White (1933) shows considerably higher values (in the range 200-1000 Hz), a result that is most likely due to the experimental conditions in this early study.

Nagai et al. (1982) reported that out of 62 subjects 39 had a threshold that followed the general trend with increasing threshold for decreasing frequency, whereas the threshold of the remaining 23 subjects did not increase further below 5 Hz. For the latter group the threshold was claimed to flatten out or even decrease with decreasing frequency. For the same subjects no flattening was observed in

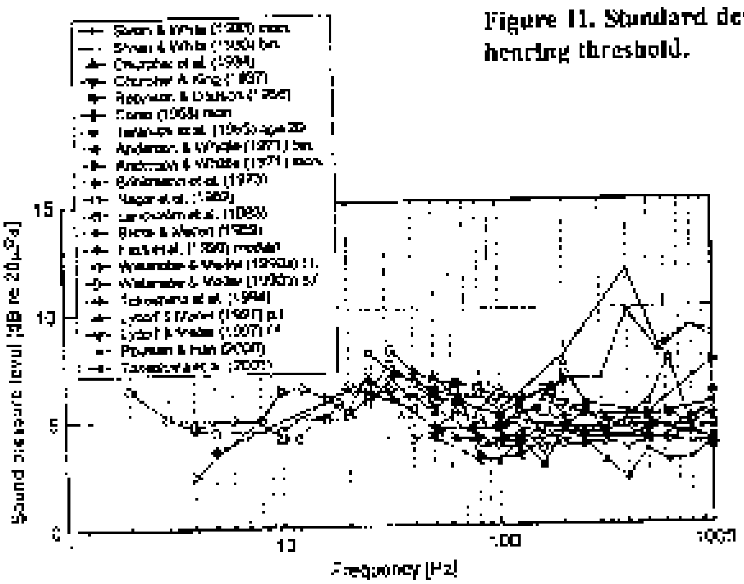

Figure 11. Standard deviations between subjects of the hearing threshold.

hearing thresholds for low-pass-filtered white noise, where data were similar to those of the rest of the subjects.

Especially sensitive persons

A few studies mention persons with extraordinary high hearing sensitivity at low frequencies. Okai et al. (1980) report of two subjects being especially sensitive to low-frequency sound, and Yamada et al. (1980) report of one subject. In addition, a subject has been observed in our laboratory with a repeatable, very low threshold (Lydolf, unpublished 1997). Figure 12 shows three of these cases compared to the ISO 226:2003 and the proposed normal threshold at infrasonic frequencies from above. (One of Okai's two subjects seems normal when compared to these data and is not shown in the figure). Assuming that the hearing threshold is normal distributed around the mean with a standard deviation of 5 dB, then the probability for a person to have a threshold around 20 dB below the mean - as seen in this figure - is extremely low, and most likely another explanation than the natural spread should be sought.

Extraordinary sensitivity to low-frequency sound might be explained by abnormalities in the person's hearing organs. A theoretical example could be an abnormally small aperture in the helicotrema at the apex of the cochlea. For low-frequency sound the helicotrema acts like a kind of pressure equalization vent for the perilymph in the cochlea, equalizing the pressure between the scala tympani and the scala vestibuli. If the helicotrema is unusually narrow or blocked, it cannot equalize the pressure fast enough, and an unusually high pressure will build up between the scala tympani and the scala vestibuli. The result is a greater mechanical excitation of the basilar membrane, and thus a higher sensitivity to these sounds is expected. For examples of simulations of the effect of the size of helicotrema see e.g. Schick (1994).

Hearing threshold microstructures

Another explanation for an apparently high sensitivity to low-frequency sound might be found in so-called microstructures in the individual hearing threshold. Frost (1987) showed that the hearing threshold as a function of frequency is not a smooth continuous line, but has peaks and dips of sometimes several decibels spread over the frequency spectrum. The irregularities were reported to be repeatable and not the result of experimental spread. An example showing microstructures in two persons' hearing thresholds is given in Figure 13. Although these particular persons do not have an especially good hearing, the microstructure is clearly seen. It is evident that for some persons the phenomenon of microstructures may lead to an extreme sensitivity at particular frequencies.

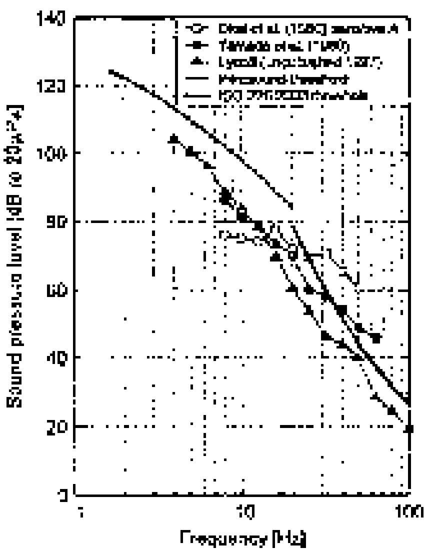

Figure 12. Hearing thresholds of three especially sensitive persons.

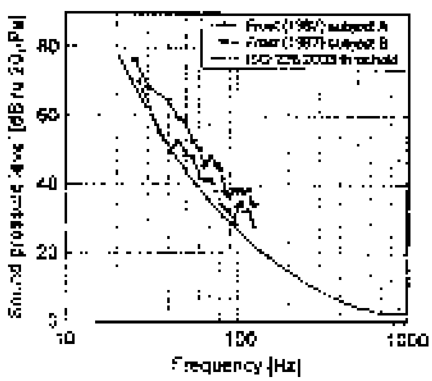

Figure 13. Example of microstructures in the hearing threshold for two persons.

Thresholds for non-sinusoidal sound

Only few threshold measurements exist for low-frequency non-sinusoidal sound. Yeowart et al. (1969) measured thresholds for octave-band-filtered random noise with center frequencies in the range 4-125 Hz and pure-tone thresholds for the same subjects. For center frequencies down to 32 Hz they found no significant difference between pure-tone thresholds and octave-band noise thresholds. In the range 4-16 Hz they found a significantly lower threshold for octave-band noise in the order of 4 dB. An explanation could have been that it is the higher frequency end of an octave band that is most audible, and comparison is then to be made with the threshold at that frequency rather than at the centre frequency of the noise band. With this explanation, the difference will be largest in the frequency range with the highest slope of the hearing threshold, i.e. 20-63 Hz. This was however not the range where the difference was seen, and the theory was thus not supported. This led to the idea, that for frequencies from 16 Hz and down, it might be the individual peaks in the sound pressure that we detect. Yeowart et al. (1969) modelled the hearing with appropriate time constants of the loudness perception and showed that the peak-detection theory could explain the 4 dB lower noise thresholds. The theory is in agreement with the subjective impression of sensing the individual oscillations at the lowest frequencies.

Nagai et al. (1982) made measurements with lowpass-filtered white noise with a lower limit of 2 Hz and upper limits of 5, 10, 20 and 40 Hz. Furthermore pure-tone thresholds were found for the same subjects. These measurements show the opposite pattern as that observed by Yeowart et al. (1969). For the random noise with upper limits of 20 and 40 Hz the threshold was lower than the pure-tone threshold (7-10 dB), but for the 2-5 Hz random noise the threshold was higher than the pure-tone threshold (about 6 dB).

Generally low-frequency and infrasonic sounds from everyday life are not pure tones alone, but rather combinations of different random noises and tonal components. It is however, impossible to make thresholds for all imaginable

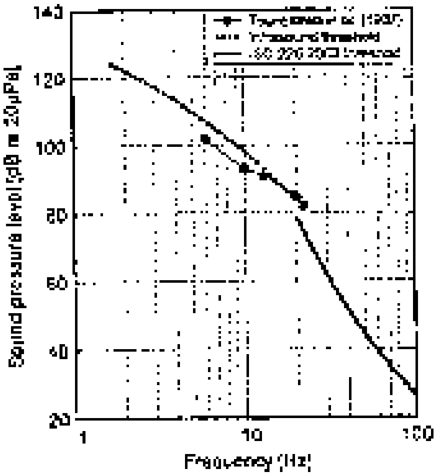

Figure 14. Hearing thresholds measured in the field by Tsunekawa et al. (1987).

combinations of sounds that exist, and as seen above there is no final conclusion about possible higher or lower sensitivity to noise bands than to pure tones. Anyway, differences seem to be relatively modest, and the pure-tone threshold can with a reasonable approximation be used as a guideline for the thresholds also for non-sinusoidal sounds.

Field measurements of hearing thresholds

All the investigations reported in the section 'Studies of hearing threshold' have been carried out in the laboratory. Tsunekawa et al. (1997) carried out an interesting study, where they found hearing thresholds using sound that occurred naturally in the field. They used the sound under two bridges, inside an automobile and beside some cooling towers. Of course, their resolution in frequency was determined by the frequencies that occurred naturally. While they recorded the sound they asked subjects to indicate, when the sound was audible and when it was not. They only used responses, when later analyses showed that the sound was sufficiently pure.

The results are given in Figure 14 together with the standardized threshold for frequencies above 20 Hz and the proposed normal hearing threshold for frequencies below 20 Hz. It is interesting to see how close their results are to the results obtained in the laboratory.

Non-auditory perception

As mentioned in the section 'The sensation mechanisms', various attempts have been made to determine the way we sense the low and infrasonic frequencies. An investigation by Landström et al. (1983) deserves special attention. Hearing thresholds were measured for 10 normal-hearing subjects (five of each gender). Furthermore vibrotactile thresholds were measured for the same subjects and for 10 subjects with complete perceptive or sensory-neural deafness. The vibrotactile sensation was described as soft vibrations in different parts of the body, mostly in the lumbar, buttock, thigh and calf regions.

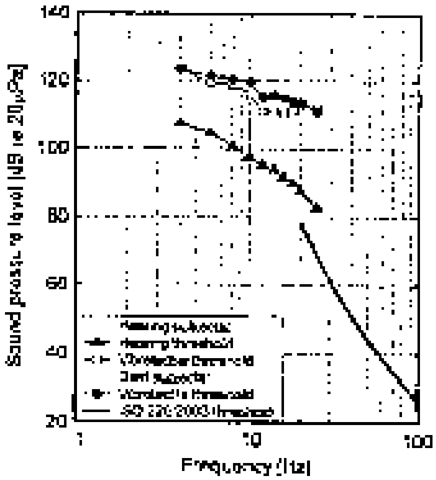

Figure 15. Hearing and vibrotactile thresholds as measured for hearing and deaf subjects by Landström et al. (1983).

The results from Landström et al. are given in Figure 15. It is seen that the vibrotactile thresholds are very similar for the hearing and the non-hearing groups. This suggests that the hearing subjects were really able to distinguish between the two sensations. The findings also support the idea that the sense of hearing is the primary sense for detecting the presence of sound at low and infrasonic frequencies. On the other hand, the results suggest that an additional way of sensation connected to vibration occurs at levels that are only 20-25 dB above the hearing threshold.

Spontaneous reactions from subjects and visitors in the authors' laboratory as well as their own experience suggest that vibrotactile sensations and a feeling of pressure may also occur in the upper part of the chest and in the throat region.

Studies of equal-loudness-level contours

Loudness is a measure of the subjectively perceived intensity of sound. The unit of *loudness level* is phon, and for a given sound it has the same numerical value as the sound pressure level (in dB relative to 20 µPa) of an equally loud reference sound. The reference sound consists of a frontally incident, sinusoidal plane wave at a frequency of 1 kHz. An equal-loudness-level contour is a curve in the sound pressure level versus frequency plane that represents tones of the same loudness level. Most studies are made with the reference tone held at a constant level, while some psychometric procedure is used to find the level of the test tone that makes the two tones appear equally loud to the subject. A few studies have used fixed levels of the test tone and varied the level of the reference tone, in which case interpolation is needed to obtain equal-loudness-level contours.

Initially, it should be mentioned that Kingsbury (1927) was one of the first to attempt measurements of equal-loudness-level contours. However, he used a monaural earphone, and no attempt was made to calibrate it to free-field conditions, thus his results will not be further reported here. Churcher et al. (1934) also made some early studies of loudness, but they used a reference tone of 800 Hz and a mixture of free-field and earphone exposures, thus their results will also not be reported further.

One of the best known studies of equal-loudness-level contours is the early one by Fletcher and Munson (1933). They reported data for the frequency range 62 Hz-16 kHz and loudness range 10-120 phon, based on measurements with 11 subjects. The measurements were performed using earphones, but since these were calibrated to free-field conditions, their data are considered relevant and will be included in the following. (In the review of hearing thresholds given above, studies that used audiometric earphones were excluded due to the risk of interference from physiological noise. This is not considered a problem for loudness comparisons, which take place at levels somewhat above threshold).

Most studies have determined points of equal-loudness-level directly according to the definition, i.e. through comparisons of the test tone and the reference tone in a free or an approximately free field. This applies to the studies of Churcher and King (1937) (54 Hz-9 kHz, 10-90 phon, up to 30 subjects depending on frequency and level), Betke and Mellert (1989) (100 Hz-1 kHz, 30 phon; 50 Hz-12.5 kHz, 40, 50 and 60 phon, 28 subjects), Suzuki et al. (1989) (125 Hz-8 kHz, 40 and 70 phon, 23 subjects; 63 Hz-12,5 kHz, 20 phon, ten subject), Fastl et al. (1990) (100 Hz-1 kHz, 30, 50 and 70 phon, 12 subjects), Watanabe and Møller (1990a) (25 Hz-1 kHz, 20, 40, 60 and 80 phon, 12 subjects), Lydolf and Møller (1997) (50 Hz-1 kHz, 20, 40, 60, 80, 90 and 100 phon, 27 subjects), Takeshima et al. (1997) (31.5-12.5 kHz, 20, 40, 50, 60, 70 and 90 phon, 9-30 subject depending on frequency and loudness level), Bellmann et al. (1999) (100 Hz-1 kHz, 60 phon, 12 subjects) and Takeshima et al. (2001) (50 Hz-16 kHz, 20, 40 and 70 phon, eight subjects).

For the lowest frequencies it is a practical problem to create sound in the same room as the reference tone (anechoic room) at sufficiently high level without significant harmonic distortion. It will be noted that none of the free-field studies mentioned in the previous paragraph had frequencies below 25 Hz, and most studies did not even go that far down. Furthermore, it is often mentioned that it is difficult for subjects to compare tones that are very distant in frequency. Some investigators have overcome these problems by making indirect loudness matches to the 1 kHz reference tone. Points of equal loudness are determined at a low-frequency anchor point of for example 100 Hz through direct comparisons with 1 kHz in an anechoic room. Then the 100 Hz points are used as new references for loudness matches in a pressure-field chamber, where large sound pressure levels can be produced at the lowest frequencies.

Studies that used exposures in pressure field in combination with individual anchor points determined in free field comprise those of Kirk (1983) (2-63 Hz, 20, 40, 60, 80 and 100 phon, anchor points at 63 Hz, 14 subjects), Møller and Andresen (1984) (2-63 Hz, 20, 40, 60, 80 and 100 phon, anchor points at 63 Hz, 20 subjects), Lydolf and Møller (1997) (20-100 Hz, 20, 40, 60, 80 and 100 phon, anchor points at 100 Hz, 14 subjects plus three added after publication) and Bellmann et al. (1999) (16-160 Hz, 60 phon, anchor points at 100 Hz, 12 subjects).

Two studies used experimental designs equivalent of using non-individual anchor points. Robinson and Dadson (1956) measured equal-loudness relations for the frequency range 25 Hz-15 kHz (up to approximately 130 phon and up to 120 subjects depending on frequency). Free-field conditions were used for the higher frequencies, while a suitably terminated duct was used for the lowest frequencies. At the lowest frequencies they used reference tones of 50 or 200 Hz that were converted into phon by means of interpolation in the data material from the free field. Whittle et al. (1972) used a pressure field for their experiments (3.15-50 Hz, up to 32 subjects depending on frequency). They used a reference tone at 50 Hz at three levels (60, 73 and 86 dB) without measuring the connection to 1 kHz. Subsequently they used ISO 226:1961 to find the standardized loudness levels of their reference tones and labelled the contours accordingly (33.5, 53 and 70.5 phon).

Figures 16-18 show the equal-loudness-level contours measured in the investigations mentioned above. It should be noted that the data from Fletcher and Munson (1933) and Robinson and Dadson (1956) are not original data, but data interpolated between original data points. For the data by Whittle et al. (1972) the authors have taken the liberty of plotting them as 20, 40 and 60 phon, respectively, since these loudness levels seem more reasonable than the original labels of 33.5, 53 and 70.5 phon when comparing with the other data in the same frequency area.

The figures clearly show large differences between equal-loudness-level contours from

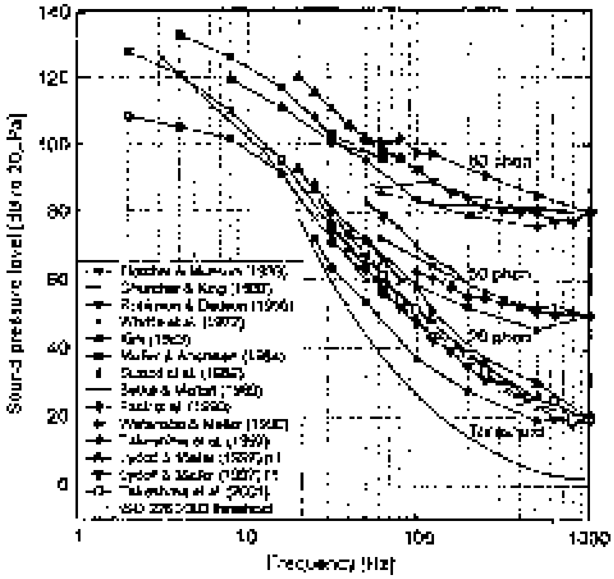

Figure 16. Low-frequency equal-loudness-level contours for 20, 50 and 80 phon.

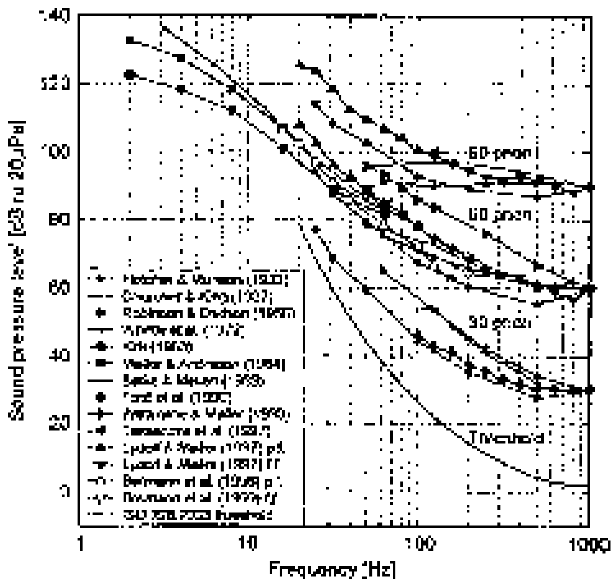

Figure 17. Low-frequency equal-loudness-level contours for 30, 60 and 90 phon.

different investigations. These differences are not only in the low-frequency region but also at higher frequencies.

Standardization of equal-loudness-level contours

The first international standard about equal-loudness-level contours is ISO R226:1961. The contours in this were solely based on the study by Robinson and Dadson (1956), despite the fact that also other studies were present at that time. As already mentioned in the section on standardization of hearing thresholds, the document was revised and issued as ISO 226:1987, however without changes in data.

Virtually all other investigations show data that are significantly higher than those of Robinson and Dadson (1956) in the frequency area below 1 kHz. The difference has been ascribed to the different psychometric methods used. The data from Robinson and Dadson seem significantly biased towards lower levels. Awareness of bias problems and the use of computerized adaptive psychometric methods in later studies have provided data that are believed to be more reliable.

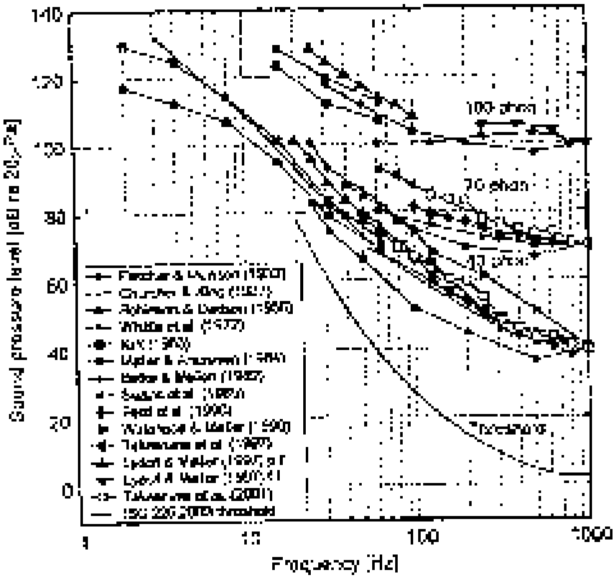

Figure 18. Low-frequency equal-loudness-level contours for 40, 70 and 100 phon.

Most recently agreement has been obtained for a complete set of hearing thresholds and equal-loudness-level contours, and a revised standard has been issued (ISO 226:2003). Below 1 kHz the equal-loudness-level contours are based on the investigations by Kirk (1983), Møller and Andresen (1984), Betke and Mellert (1989), Suzuki et al. (1989), Fastl et al. (1990), Watanabe and Møller (1990), Lydolf and Møller (1997), Takeshima et al. (1997), Bellmann et al. (1999) and Takeshima et al. (2001).

Figure 19 shows the standardized equal-loudness-level contours for the frequency range below 1 kHz, and the difference between the two old and the new standard is obvious.

Proposed normal equal-loudness-level contours below 20 Hz

No standardized equal-loudness-level contours exist for frequencies below 20 Hz, and only four investigations provide data in this frequency region. Whittle et al. (1972) and Møller and Andresen (1984) produce quite similar contours, and the two points provided by Bellmann et al. (1999) at 60 phon, 16 and 20 Hz, fit well with these. The contours by Kirk (1983) deviate considerably, and the authors take the liberty of disregarding these data in the following. The contours from the three other investigations are shown in Figure 20. Based on these data the authors have presented their best guess of general contours of 20, 40, 60 and 80 phon for frequencies below 20 Hz in Figure 21. However, these contours should be taken with great reservation because of the sparse amount of data and the uncertainty connected to the exact phon values they should be labelled with. On the other hand it seems beyond any doubt that the contours are very close in this frequency region.

More definite contours at low and infrasonic frequencies - in particular at high loudness levels - require that more experimental data become

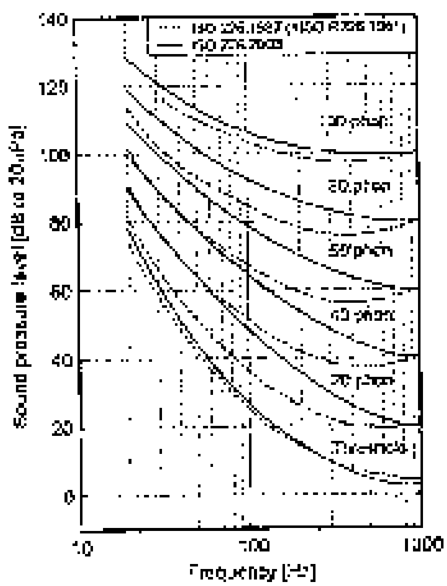

Figure 19. Standardized equal-loudness-level contours.

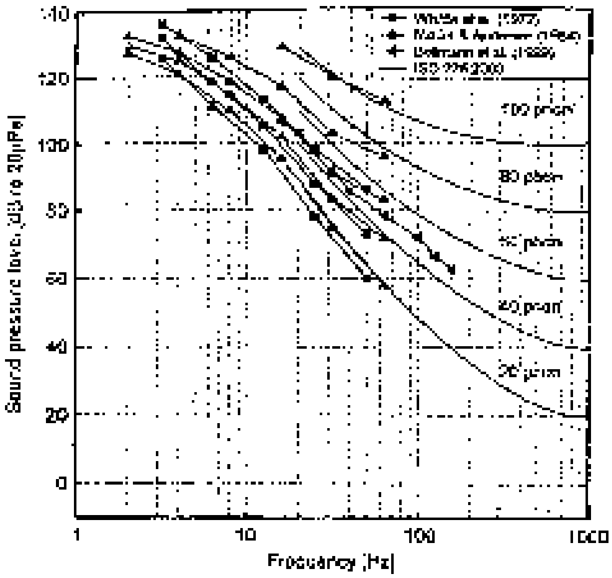

Figure 20. Standardized equal-loudness-level contours above 20 Hz and results from investigations covering frequencies at and below 20 Hz.

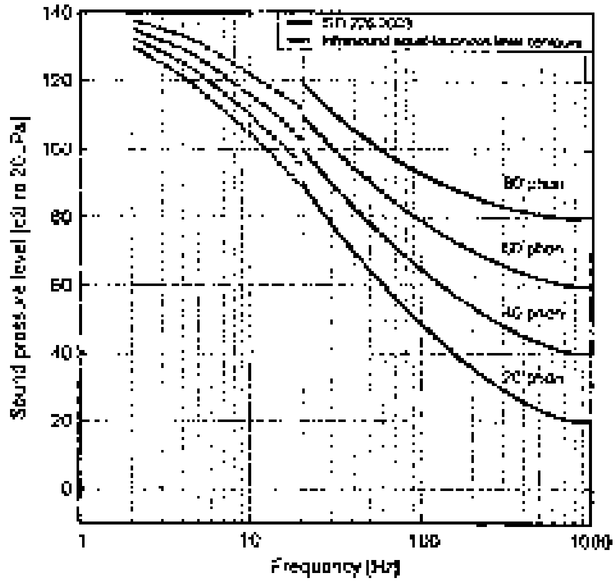

Figure 21. Proposal of equal-loudness-level contours for the infrasonic region together with standardized contours above 20 Hz.

available. Unfortunately, it is not a trivial task to produce the high sound pressure levels needed without significant harmonic distortion.

Conclusion

The human perception of sound below 200 Hz has been reviewed, and on the basis of results from various investigations it is possible to draw some general conclusions.

The hearing becomes gradually less sensitive for decreasing frequency, but there is no specific frequency at which the hearing stops. Despite the general understanding that infrasound is inaudible, humans can perceive sound also below 20 Hz. This applies to all humans with a normal hearing organ, and not just to a few persons. The perceived character of the sound changes gradually with frequency. For pure tones the tonal character and the sensation of pitch decrease with decreasing frequency, and they both cease around 20 Hz. Below this frequency tones are perceived as discontinuous. From around 10 Hz and lower it is possible to follow and count the single cycles of the tone, and the perception changes into a sensation of pressure at the ears. At levels 20-25 dB above threshold it is possible to feel vibrations in various parts of the body, e.g. the lumbar, buttock, thigh and calf regions. A feeling of pressure may occur in the upper part of the chest and the throat region.

There is a reasonable agreement between studies of hearing thresholds. For frequencies down to 20 Hz, a normal threshold has been standardized by ISO, and the present article presents a proposed normal threshold one decade further down in frequency. The proposed curve corresponds roughly to a G-weighted sound pressure level of 97 dB. More data are needed to give a more conclusive curve.

It cannot be finally concluded whether thresholds for noise bands are the same as pure tone thresholds. Below 20 Hz it is possible that the peak sound pressure determines the sensation. The differences are small, though, and it seems reasonable to use the pure-tone threshold as a guideline also for non-sinusoidal sound.

The hearing threshold is the same for men and women. Degradation with age takes place only above 50 years. The threshold is the same in free and pressure field. Like at higher frequencies, the binaural advantage is around 3 dB, and the standard deviation between individuals is around 5 dB. However, there is evidence of individuals that have a hearing that is much better than normal (several times the standard deviation away from the mean). It has also been shown that the hearing threshold may have a microstructure that causes a person to be especially sensitive at certain frequencies. These two phenomena may explain observations from case studies, where individuals seem to be annoyed by sound that is far below the normal threshold of hearing. It should be stressed that the explanation has not been confirmed in specific cases.

Thresholds are the same, whether the whole body or just the ears are exposed, thus is can be concluded that the sensation takes place in the ears even at frequencies below 20 Hz. However, it is not totally clear, whether the sensory pathway for infrasound is the normal pathway for hearing. The observation that deaf people can only detect infrasound through vibrotactile sensation – and for that they have the same threshold as normal-hearing persons – suggests that the normal auditory system is used. A hypothesis that these frequencies are heard in terms of harmonic distortion in the ear is not supported.

In addition to direct detection, infrasound may be detected through amplitude modulation of sound at higher frequencies. This modulation is caused by the movement of the eardrum and middle-ear bones induced by the infrasound, which results in changes of transmission properties. At very high levels, modulation of speech can occur due to a pulsating airflow in the throat caused by the sound.

The perceived intensity of the sound rises more steeply above threshold than at higher frequencies. This is especially pronounced for frequencies below 20 Hz, where a sound only few decibels above threshold may be perceived as quite intense. Combined with the natural spread in thresholds, this may have the effect that a sound, which is inaudible to some people, may be loud to others. The compression of the dynamic range of the auditory system is reflected in the equal-loudness-level contours. Such contours have been standardized for frequencies down to 20 Hz, but there is a reasonable agreement between data also below this frequency, and contours have been proposed down to 2 Hz. However, this is based on only few investigations and more data are needed.

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References

Anderson C.M.B., Whittle L.S. (1971), Physiological noise and the missing 6 dB, Acustica, Vol. 24, 261-272.

Békésy G. von (1936), Über die Hörschwelle und Fühlgrenze langsamer sinusförmiger Luftdruckschwankungen, Ann. Physik, Vol. 26, 554-566 (English translation: Békésy (1960) "Low-frequency thresholds for hearing and feeling", in Békésy G. von, "Experiments in hearing", pp. 257-267, McGraw-Hill, New York, 1960).

Bellmann, M. A., Mellert, V., Reckhardt, C., Remmers, H. (1999), Perception of sound and vibration at low frequencies, Collected Papers from the Joint Meeting "Berlin 99" of ASA, EAA and DAGA, 1999, Berlin, Germany, ISBN 3-9804568-5-4. Abstract in J. Acoust. Soc. Am., Vol. 105, 1297.

Berger, E.H. (1981), Re-examination of the low-frequency (50-1000 Hz) normal threshold of hearing in free and diffuse sound fields, J. Acoust. Soc. Am., Vol. 70(6), 1635-1645.

Betke K. (1991), New hearing threshold measurements for pure tones under free-field listening conditions, J. Acoust. Soc. Am., Vol. 89, 2400-2403.

Betke K., Mellert V. (1989), New measurements of equal loudness contours, Proceedings of Internoise 89, 793-796.

Brecher G.A. (1934), Die untere Hör- und Tongrenze, Pflügers Arch. ges. Physiol., Vol. 234, 380-393.

Brinkmann K. (1973), Audiometer-Bezugsschwelle und Freifeld-Hörschwelle, Acustica, Vol. 28, 147-154.

Brinkmann K., Vorländer M., Fedtke T. (1994), Re-determination of the threshold of hearing under free-field and diffuse-field conditions, Acustica, Vol. 80, 453-462.

Churcher B.G., King A.J., Davies H. (1934), The measurement of noise with special reference to engineering noise problems, J. Inst. Electr. Eng., Vol. 75, 401-446.

Churcher B.G., King A.J. (1937), The performance of noise meters in terms of the primary standard, J. Inst. Electr. Eng., Vol. 81, 57-90.

Corso, J.F. (1958), Absolute thresholds for tones of low frequencies, Am. J. Psychol., Vol. 71, 367.

Fastl H., Jaroszewski A., Schorer E., Zwicker E. (1990), Equal loudness contours between 100 and 1000 Hz for 30, 50 and 70 phon, Acustica, Vol. 70, 197-201.

Fastl, H., Zwicker, E. (1987), Lautstärkepegel bei 400 Hz. Psychoakustische Messung und Berechnung nach ISO 532 B, Proceedings of DAGA 1987, 189-192.

Finck A. (1961), Low frequency pure tone masking - Letter to the Editor, J. Acoust. Soc. Am., Vol. 33, 1140-1141.

Fletcher H., Munson W.A. (1933), Loudness, its definition, measurement and calculation, J. Acoust. Soc. Am., Vol. 5, 82-108.

Frost G.P. (1987), An investigation into the microstructure of the low frequency auditory threshold and of the loudness function in the near threshold region, J. Low Freq. Noise and Vib., Vol. 6(1), 34-39.

ISO 226:1987, Normal equal-loudness level contours, International Organization for Standardization, Genève.

ISO 226:2003, Normal equal-loudness level contours, International Organization for Standardization, Genève.

ISO 389-7:1996, Reference zero for the calibration of audiometric equipment – Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions, International Organization for Standardization, Genève.

ISO 7196:1995, Frequency-weighting characteristic for infrasound measurements, International Organization for Standardization, Genève.

ISO R226:1961, Normal equal-loudness contours for pure tones and normal threshold of hearing under free field conditions, International Organization for Standardization, Genève.

Johnson D.L. (1980), The effect of high-level infrasound, Proceedings of the Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg, Denmark, 47-60.

Kingsbury B.A. (1927), A direct comparison of the loudness of pure tones, Physical Review, Vol. 29, 588-600.

Kirk B. (1983), Hørestyrke og genevirkning af infralyd (in Danish), Institute of Electronic Systems, Aalborg University, Aalborg, Denmark, 1-111, ISSN 0106-0791.

Landström U., Lundström R., Byström M. (1983), Exposure to infrasound - Perception and changes in wakefulness, J. Low Freq. Noise and Vib., Vol. 2(1), 1-11.

Lydolf M., Møller H. (1997), New measurements of the threshold of hearing and equal-loudness contours at low frequencies, Proceedings of the 8th International meeting on Low Frequency Noise and Vibration, Gothenburg, Sweden, 76-84.

Møller H., Andresen J. (1984), Loudness of pure tones at low and infrasonic frequencies, J. Low Freq. Noise Vib., Vol. 3(2), 78-87.

Nagai N., Matsumoto K., Takeuchi H., Takeda S. (1982), The threshold of sensation for infrasound, J. Low Freq. Noise and Vib., Vol. 1(4), 165-173.

Okai O., Saito M., Taki M., Mochizuki A., Nishiwaki N., Mori T., Fujio M. (1980), Physiological parameters in human response to infrasound, Proceedings of the Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg Denmark, 121-129.

Poulsen T., Han L.A. (2000), The binaural free field hearing threshold for pure tones from 125 Hz to 16 kHz, Acustica - acta acustica, Vol. 86, 333-337.

Poulsen T., Thøgersen L. (1994), Hearing threshold and equal loudness level contours in a free sound field for pure tones from 1 kHz to 16 kHz, Proc. Nordic Acoustical Meeting (NAM-94), 195-198.

Robinson D.W., Dadson M.A. (1956), A re-determination of the equal-loudness relations for pure tones, British J. Appl. Phy., Vol. 7, 166-181.

Shick, F. (1994), The Helicotrema and the Frequency Resolution in the inner Ear, Acustica, Vol. 80, 463-470.

Sivian L.J., White S.D. (1933), On minimum audible sound fields, J. Acoust. Soc. Am., Vol. 4, 288.

Suzuki S., Suzuki Y., Kono S., Sone T., Kumagai M., Miura H., Kado H. (1989), Equal loudness level contours for pure tone under free field listening condition (I) - Some data and considerations on experimental conditions, J. Acoust. Soc. Jpn. (E), Vol. 10, 329-338.

Takeshima H., Suzuki Y., Ashihara K., Fujimori T. (2002), Equal loudness contours between 1 kHz and 12.5 kHz for 60 and 80 phons, Acoust. Sci. Tech., Vol. 23, 106-109.

Takeshima H., Suzuki Y., Fujii H., Kumagai M., Ashihara K., Fujimori T., Sone T. (2001), Equal-loudness level contours measured by the randomized maximum likelihood sequential procedure, Acustica - acta acustica, Vol. 87, 389-399

Takeshima H., Suzuki Y., Kumagai M., Sone T., Fujimori T., Miura H. (1994), Threshold of hearing for pure tones under free-field listening conditions, J. Acoust. Soc. Jpn. (E), Vol. 15, 159-169.

Takeshima H., Suzuki Y., Kumagai M., Sone T., Fujimori T., Miura H. (1997), Equal loudness level measured with the method of constant stimuli - Equal-loudness level contours for pure tones under free-field listening condition (II), J. Acoust. Soc. Jpn. (E), Vol. 18, 337-340.

Teranishi R. (1965), Study about measurement of loudness: On the problems of minimum audible sound, Researches of the Electrotechnical Laboratory, No. 658, Tokyo, Japan.

Tsunekawa S., Kajikawa Y., Nohara S., Ariizumi M., Okada A. (1987), Study on the perceptible level for infrasound, J. Sound and Vibration, Vol. 112, No. 1, 15-22.

Vorländer M. (1991), Freifeld Hörschwellen von 8 kHz - 16 kHz, Fortschritte der Akustik, Proceedings of DAGA 91, Bad Honnef, DPG-GmbH, Teil A, 533-536.

Watanabe T., Møller H. (1990a), Hearing thresholds and equal loudness contours in free field at frequencies below 1 kHz, J. Low Freq. Noise Vib., Vol. 9(4), 135-148.

Watanabe T., Møller H. (1990b), Low frequency hearing thresholds in pressure field and in free field, J. Low Freq. Noise Vib., Vol. 9(3), 106-115.

Watanabe T., Ozawa K., Suzuki M., Dendaki T., Kaneko T., Yamada S. (1993), A study on the psychological evaluation of low frequency noise, Proceedings of 7th International Meeting on Low Frequency Noise and Vibration Edinburgh, 14-16 April 1993, 173-178.

Wever E.G., Bray C.W. (1936), The perception of low tones and the resonance-volley theory, J. Psych., Vol. 3, 101-114.

Whittle L.D., Collins S.J., Robinson D.W. (1972), The audibility of low frequency sounds, J. Sound Vib., Vol. 21(4), 431-448.

Yamada S., Kosaka T., Bunya K., Amemiya T. (1980), Hearing of low frequency sound and influence on human body, Proceedings of the Conference on Low Frequency Noise and Hearing, 7-9 May 1980 in Aalborg Denmark, 95-102.

Yeowart N.S., Bryan M.E., Tempest W. (1967), The monaural M.A.P. threshold of hearing at frequencies from 1.5 to 100 c/s, J. Sound Vib., Vol. 6(3), 335-342.

Yeowart N.S., Bryan M.E., Tempest W. (1969), Low-frequency noise thresholds, J. Sound Vib., Vol. 9(3), 447-453.

Yeowart N.S., Evans M.J. (1974), Thresholds of audibility for very low-frequency pure tones, J. Acoust. Soc. Am., Vol. 55(4), 814-818.

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Effects of Low Frequency Noise on Sleep

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Low frequency noise (20-200 Hz) is emitted by numerous sources in the society. As low frequencies propagate with little attenuation through walls and windows, many people may be exposed to low frequency noise in their dwellings. Sleep disturbance, especially with regard to time to fall asleep and tiredness in the morning, are commonly reported in case studies on low frequency noise. However, the number of studies where sleep disturbance is investigated in relation to the low frequencies in the noise is limited. Based on findings from available epidemiological and experimental studies, the review gives indications that sleep disturbance due to low frequency noise warrants further concern.

Keywords: low frequency noise, sleep

Introduction

Noises with a dominant content of frequencies in the range of 20 to 200 Hz (low frequency noise) are emitted by a large range of sources in the society. Many of these sources are related to different means of transportation, such as lorries, diesel-driven busses and trains, airplanes and helicopters. Low frequency noise is also emitted by a range of stationary sources related to heating, cooling or ventilation of buildings. Owing to the low velocity speed, low frequencies may propagate for long distances, with little attenuation apart from distance. Low frequencies will also pass with little attenuation through walls and windows. At long distance from the source, or indoors, the noise spectrum will be selectively attenuated, resulting in a spectrum dominated by low frequencies. Airborne noise of a low frequency character may also occur as a result of vibrations in the ground or in constructions. Indoors, room resonances in the low frequency range will increase the sound pressure levels and also lead to variations of sound pressure level inside the room. In order to assess effects occurring indoors, such as sleep disturbance, it is therefore pertinent to carry out measurements indoors.

There are a large number of studies on effects on sleep and well-being due to transportation noises (e.g. Thiessen and Lapointe 1978, Öhrström *et al* 1990, Griefahn 1991, Öhrström *et al* 1998). However, little is known of the content of low frequencies in these intermittent noises as few studies report of no more than the A-weighted sound pressure levels. Regarding effects of steady state low frequency noise from stationary sources some data are available. In the following, a review of available studies on the effects of low frequency noise and sleep disturbance is given. The selection of studies was based on the description of the noise exposure. Information of the C-weighted sound pressure level or preferable, frequency spectra analyses, in addition to the A-weighted level was set as a criterion for inclusion in the review.

Reports in case studies and epidemiological studies

Several case studies indicate that low frequency noise affects sleep quality, particularly with reference to the time taken to fall asleep and tiredness in the morning (see Berglund *et al.*, 1996, for a review). With the attempt to get more structured information from subjects reported to suffer from infrasound and/or low frequency noise, a questionnaire was distributed to the civic and regional environmental administrations, to the Interest group for infrasound and low frequency noise in Denmark and also available on the internet (Möller and Lydolf 2002). In total 198 valid questionnaires were registered during a period of 16 months in 1998-1999. The answers showed that among this selected group the major symptoms were insomnia and concentration problems, reported by 67.5% and 67% of the sample. As no objective information on the sound exposure was available for most of the cases, it is not possible to exclude that other variables other than physical sound exposure were responsible for the symptoms. More information on this matter will be obtained in a currently ongoing study, where a randomly selected sample of these cases is investigated more closely, through e.g. sound measurements in their homes.

A limited number of epidemiological studies have been carried out which give some support to the findings in the case studies. Verzini *et al.* (1999) found that the energy content of 20 to 160 Hz was significantly related to sleep disturbance, concentration difficulties, irritability, anxiety and tiredness. The study was carried out among 98 subjects living in urban areas with dominant low frequency noise from installations, air condition units, industrial processes and traffic noise from tunnels.

In a cross sectional study comprising a total of 279 persons, no significant differences were detected in reported sleep among people exposed in their homes to flat frequency noise as compared to low frequency noise from ventilation/heat pumps (Persson Waye and Rylander 2001). It was however found that fatigue, difficulty of falling asleep, feeling languid and tensed in the morning were reported to a significantly higher degree among those annoyed by low frequency noise. Furthermore, a significant dose response relationship was found between reported annoyance and disturbed rest and degree of low frequency of the noises. This relationship was still valid after correction for differences in A-weighted sound pressure levels. Third octave band analyses showed that the low frequency exposures were at or above the normal perception threshold (ISO 389-7:1996) in the frequency range of 50 to 200 Hz, while the flat frequency noise was exceeding the normal perception threshold from about 100 Hz and upwards. The sound pressure levels ranged from 26 to 36 dBA and 49 to 60 dBC in dwellings with low frequency noise exposure and from 24 to 33 dBA and 41 to 49 dBC in dwellings with flat frequency noise exposure.

In another investigation, 30 subjects complaining of low frequency noise in their homes were compared to an equal number of subjects of matched age and sex, living in the same block of flats but without the low frequency noise (Mirowska, 1998). A higher occurrence of chronic sleep disturbance and depression was reported among the complainers. The study gives some indications of higher symptoms among complainers, but the results could be confounded by differences between the study populations.

Persson Waye *et al* (2003,a) investigated annoyance and sleep disturbance in an urban study population (n=41) whose flats on one side (backyard) were exposed to low frequency noise from installations and on the other side (street) were exposed to traffic noise It was found that the proportions of people reporting very or extreme annoyance and disturbed rest due to noise from installation noise among those with bedrooms facing the backyard were 44% and 53% respectively. The corresponding percentages for disturbances to traffic noise among those with bedroom facing the street were 26% and 30%. Average measured indoor levels from installation noise were 31 dBA, 50 dBC with window closed and calculated indoor levels from traffic noise during the night amounted to 21 to 31 dB $L_{Aeq(23-0700)}$ and 50-51 dB L_{Amax}. In both groups a large percentage or 63% reported that sleep was disturbed by some noise, the majority of comments referred to noise from installations and traffic. The reported sleep disturbance was similar among those with bedroom facing the street and among those with bedroom facing the courtyard, except for "feeling tired in the morning" that was reported to a significantly higher degree among those with bedroom facing the street. It should however be acknowledged that the sample in this study was very small and that no correction was done for other factors that could have influenced sleep. Further studies are currently carried out including a larger study population where possible confounders for sleep disturbance can be taken into account.

Of special interest is a cross-sectional study recently carried out by Ising and Ising (2002). It is one of the few studies that have tried to relate the low frequency content in heavy vehicle noise to adverse effects and furthermore looked at a group where data on sleep disturbance due to noise is lacking, namely children. In total 56 children aged 7-10 years living either at a busy road with 24 h lorry traffic or in quiet areas were studied. In the bedrooms, measurements were undertaken of short term maximum sound pressure levels (L_{Amax}, L_{Cmax}) and equivalent third octave band sound pressure levels from passing lorries. On average every 2 minutes a lorry passed the house. The indoor noise levels of the exposed half of the children were 26–53 dB L_{Amax} respective 55-78 dB L_{Cmax}, and the frequency spectrum had its maximum below 100 Hz. For the low exposed children the corresponding values were 20-43 dB L_{Amax} and 30-54 dB L_{Cmax}. A significant correlation was found between the maximum levels of low frequencies in the noise, measured as L_{Cmax}, and urine cortisol levels sampled in the first half of the night, while no correlation was found between noise exposure and the excretion of urine cortisol in the second half of the night. The increase of cortisol during the first half of the night was furthermore significantly related to impaired sleep, memory and ability to concentrate. The results indicate that long-term exposure to intermittent low frequency noise at these levels resulted in chronic increases of children's excretion of free cortisol in the first half of the night, and thus disturbance of the circadian rhythm of cortisol.

Experimental studies

In an early study by Inaba and Okada (1988), six subjects were exposed to sinusoidal tones at 10, 20, 40 and 63 Hz with sound pressure levels ranging from 75 to 105 dB for 10 and 20 Hz and from 50 to 100 dB SPL for 40 and 63 Hz. They found no significant difference between the exposure nights and control nights in sleep efficiency index (sleep time/bedtime), number of changes in sleep stage or changes in the proportion of each sleep stage evaluated by electroencephalogram (EEG) recordings. No subjective data on sleep quality, time to fall asleep or tiredness in the morning were recorded.

The effects of night-time exposure to traffic noise and low frequency ventilation noise on the cortisol awakening response and subjective sleep quality were investigated in an explorative study comprising twelve male subjects (Persson Waye *et al* 2003, b). Subjects slept for five consecutive nights in a sleep laboratory. After one night of acclimatisation and one reference night, subjects were exposed to either traffic noise (35dB $L_{Aeq\,22.00-07.00}$, 50dB L_{Amax}) or LFN (40dB $L_{Aeq\,22.00-07.00}$) on alternating nights (with an additional reference night in between). The frequency spectra of the ventilation noise had its highest sound pressure level of 69 dB at 50 Hz, at which frequency a modulated sinusoidal tone had been added to the original recording in order to give the noise a "rumbling" character (100% amplitude-modulated at 2 Hz). The frequency spectra of the traffic noise had its highest sound pressure levels of 47 and 49 dB at 63 and 80 Hz. Salivary free cortisol concentrations were determined in saliva samples taken immediately at awakening and at three 15-minute intervals after awakening. The awakening cortisol response on the reference nights showed a normal cortisol pattern. The awakening cortisol response following exposure to low frequency ventilation noise was significantly attenuated at 30 minutes after awakening, while the cortisol response after traffic noise was moderately attenuated and not significantly different from quiet reference nights. In comparison to the reference night, subjects took longer time to fall asleep during exposure to low frequency ventilation noise while exposure to traffic noise induced greater irritation in the morning. Interestingly it was also found that lower cortisol levels at 30 minutes after awakening were related to lower mood such as 'activity' and 'pleasantness' in the morning after exposure to low frequency ventilation noise, and poorer sleep quality after exposure to traffic noise. However, in a subsequent study comprising a larger number of subjects and the same low frequency ventilation noise, the effect on cortisol response upon awakening was not reproduced (Persson Waye *et al* 2003,c). As the exposures to low frequency ventilation noise in the second study were carried out on different weekdays and a significant effect of weekday for the cortisol response was found, it is possible that the conflicting results between the two studies are due to different response pattern over week days.

In agreement with the previous study, subjective sleep was moderately affected after exposure to a low frequency ventilation noise, mainly with regard to tiredness in the morning and mood. The presence of such circaseptan rhythms has been suggested by Maschke *et al* (2001). There is a need to obtain more precise knowledge of factors affecting the cortisol response in general and the presence of circaseptan rhythms of cortisol in particular before further studies are undertaken.

Recently another study has included low frequency ventilation noise in the experimental design (Öhrström and Skånberg, 2003). The effects on sleep after nocturnal exposure to traffic noise, low frequency ventilation noise and a combination of the two exposures were studied in a laboratory study comprising 18 subjects. The equivalent $_{23\text{-}07h}$ A-weighted sound pressure level from traffic was 39 dB, with A-weighted maximum levels of 55±3 dB, while the corresponding levels for the combined exposure was 43dB and 55±3 dB. The ventilation noise was recorded indoors in an office room facing a courtyard with the window 10 cm opened. It had an A-weighted sound pressure level of 40 dB. The frequency spectra of the ventilation sound and combined had its highest sound pressure level of 61dB around 40 Hz, while the traffic noise had its highest sound pressure level of 58 dB around 50 Hz. Effects on sleep were recorded by wrist-actigraph, type mini-motion- logger actigraph from Ambulatory Monitoring Inc. and questionnaires. The results from the wrist-actigraph showed no difference between quiet reference nights and nights with traffic noise or the combined exposure. Fewer number of wake episodes, longer mean sleep episodes and lower number of sleep episodes were found during nights with ventilation noise as compared to the reference night. Contrary to the data obtained from the wrist-actigraphy, subjective evaluations detected a significant decrease of sleep quality for all exposure sounds including the low frequency ventilation noise.

Concluding comments

The review shows that the numbers of studies where the low frequencies in the sounds can be analysed in relation to effects on sleep are rather limited. This is unfortunate as many of the studies investigating transportation sources could have given more information on this matter had only the noise exposure been more carefully described. The limitations of relevant dose descriptors in many studies are a natural result of the lack of an international agreement both with regard to definition of a low frequency noise and with regard to description of the exposure. Furthermore, in order to get a satisfactory comprehension between sounds and effects, future studies should not only describe the equivalent sound pressure levels in the frequency range, but also evaluate the influence of temporal structures, such as level fluctuations and degree of intermittency.

As the research area is rather new there is a need to investigate mechanisms and models for sleep disturbance due to low frequency noise in experimental studies. Present studies are not conclusive with regard to objectively measured effects. Subjective data do however support the observations in field studies that low frequency noise, at comparatively low sound pressure levels, disturbs sleep. It is however important to continue the search for methods that are reliable, valid and that cannot only be used for acute exposure, but also have some bearing for chronic exposures. In order to overcome some of the disadvantages of experimental exposures, with regard to the novel environment etc there is a movement towards exposing subjects to recorded noise in their home settings. For noise in general and low frequency noise in particular, it is essential to have control of the sound field as the noise exposures otherwise will show large variation between rooms and hence subjects.

Revised epidemiological studies are all except one, based on measurements carried out indoors, which is necessary in order to get a satisfactory assessment of the exposure. These types of studies are therefore time- and resource consuming which may be one reason for the rather small study populations included. However the small sample sizes limit the possibilities to find effects on sleep and health and there is a need for larger studies or new approaches in this field of research. Larger studies are also a prerequisite for the possibility to control for variables that could covary with sleep disturbance. The reported sleep disturbance and findings of dose response relationships between the presence of low frequencies in a noise and annoyance and disturbed rest motivate however further research into this area. There is also some support that the low frequencies in transportation noise may be of relevance for chronic effects related to disturbed sleep.

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References

Berglund B., Hassmén P. and Job R. F. S. (1996). Sources and effects of low frequency noise. *J. Acoust. Soc. Am.* 99: 2985-3002.

Griefahn B. (1991) Environmental Noise and Sleep. Review—need for further research. *Appl Acoustics* 32:255-268.

Inaba R. and Okada A. (1988) Study on the effects of infra- and low frequency sound on the sleep by EEG recordings. *J Low Freq. Noise Vib.*7:15-19

Ising H. and Braun M. (2000) Chronic cortisol increases in the first half of the night caused by road traffic noise. *Noise & Health*. 4:13-21

ISO 389-7:1996. Acoustics Reference zero for the calibration of audiometric equipment Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions

Maschke C., Harder J., Ising H., Hecht K. and Thierfelder W. (2002) Stress hormone changes in persons under simulated night exposure. *Noise & Health* 5: 35-45

Mirowska M. (1998) An investigation and assessment of annoyance of low frequency noise in dwellings. *J. Low Freq. Noise Vibr.* 17: 119-126

Møller H and Lydolf M. (2002) A questionnaire survey of complaints of infrasound and low-frequency noise. *J. Low Freq. Noise Vibr. Active Control*. 21:53-64

Öhrström E., Björkman M. and Rylander R. (1990) Effects of noise during sleep with reference to noise sensitivity and habituation. *Environ Int* 16:477-482.

Öhrström E., Agge A. and Björkman M. (1998) Sleep disturbances before and after reduction of road traffic noise. In: N Carter and RFS Job, editor. Noise Effects '98. Proceedings of the 7th International Congress on Noise a Public Health Problem, Sydney, Australia. 22-26 November, Vol 2, pp. 451–454.

Öhrström E. and Skånberg A. (2004) Sleep disturbance from road traffic and ventilation noise- laboratory and field experiments. *J Sound Vib* 271: 279-296.

Persson Waye K. and Rylander R. (2001) The extent of annoyance and long term effects among persons exposed to LFN in the home environment. *J. Sound. Vib.* 240:483-497

Persson Waye K., Bengtsson J., Agge A., Björkman M. (2003) (a) A descriptive cross-sectional study of annoyance due to low frequency noise installations in an urban environment. *Noise & Health* 5: 20: 35-46.

Persson Waye K., Clow A., Edwards S., Hucklebridge F and Rylander R. (2003) (b) Effects of nighttime low frequency noise on the cortisol response to awakening and subjective sleep quality. *Life Sciences* 72: 863-875

Persson Waye K., Agge A., Clow A., Hucklebridge F. (2003) (c) Cortisol response and subjective sleep disturbance after low frequency noise exposure. In. Ronald G de Jong, Tammo Houtgast, Elly A M Franssen and Wim F Hofman (Eds), the 8[th] International Congress on Noise as a Public Health Problem, 29June-3 July, Rotterdam, the Netherlands, 214-215.

Thiessen GJ., Lapointe AC. (1978) Disturbance of sleep by noise. *J. Acoust. Soc. Am.* 64: 216-222

Vezzani AM., Frascoli CA., Sterp AHD. (1999) A field research about effects of low frequency noises on man. *Acta Acustica* 85:S16

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A Descriptive Cross-Sectional Study of Annoyance from Low Frequency Noise Installations in an Urban Environment

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In order to improve the living conditions for respondents highly exposed to traffic noise, it has been recommended that one side of the building should face a "quiet side". Quiet may, however, be spoilt by noise from installations such as ventilation and air-conditioning systems. The noises generated by installations of this kind often have a dominant portion of low frequencies (20-200 Hz) and may be a source of great annoyance and sleep disturbance. This paper describes the cross-sectional part of an intended intervention study among residents exposed to traffic noise on one side of the building and to low frequency noise from installations on the other side of the building.

A questionnaire masked as a general living environment study was delivered to a randomly selected person in each household. In total 41 respondents answered the questionnaire (71% response rate). Noise from installations was measured indoors in a bedroom facing the courtyard in a selection of apartments and outdoors in the yard. 24h traffic noise outdoor and indoor levels were calculated. The noise levels from installations were slightly above or at the Swedish recommendations for low frequency noise indoors with the window closed and exceeded the recommendations by about 10 dB SPL when the window was slightly opened.

The proportion of persons who reported that they were very or extremely annoyed indoors from noise from installations was more than twice as high as for traffic noise. Installation noise also affected respondents' willingness to have their windows open and to sleep with an open window. The high disturbance of installation noises found in this study indicates the importance of also regulating the noise exposure on the "quiet side" of buildings. Further studies will give a better base for the extent of annoyance and acceptable levels of installation noises.

Keywords: Low frequency noise, annoyance, field study

Background

To minimize the adverse effects of traffic noise on health and sleep among residents exposed to high traffic noise levels, it has been recommended that one side of the building should be a "quiet side" (Kihlman, 1993). However, the quietness may be spoiled by noise from installations such as ventilation, heating and air-conditioning systems, which are often positioned on the side of the building not facing the street. Noises from such installations often have a dominant portion of low frequencies (20-200 Hz) and may be a source of great annoyance and sleep disturbance (see Berglund et al., 1996, for a review). The adverse effects of low frequency noise have been reported in a large number of case studies (e.g. Bryan, 1976; Challis and Challis, 1978; Chatterton, 1979; Cocchi and Fausti et al., 1992). A limited number of epidemiological studies also give some support to the findings of the case studies. Verzini and Frassoni et al. (1999) found that the energy content of the frequency band 20 to 150 Hz was significantly related to sleep disturbance, concentration difficulties, irritability, anxiety and tiredness. The study was carried out among 98 subjects living in urban areas with dominant low frequency noise from installations, air condition units, industrial processes and traffic noise from tunnels. Similar symptoms, except for anxiety, were related to annoyance from low frequency noise in a Swedish cross sectional study comprising a total of 279 people exposed to low or flat frequency noise from ventilation/heat pumps in their homes (Persson Waye and Rylander, 2001). The prevalence of annoyance by low frequency noise was statistically higher and ranged from 15 to 20% as compared to a prevalence of 0 to 4% in reference areas, with ventilation noise of a flat frequency character. The significant difference between the exposed group and the reference group remained when correction was made for differences in A-weighted noise levels. In another investigation, 30 subjects complaining of low frequency noise in their homes were compared to an equal number of subjects of matched age and sex, living in the same block of flats but without the low frequency noise (Mirowska, 1998). A higher occurrence of chronic sleep disturbance and depression was reported among the complainers. The study gives some indications of higher symptoms among complainers, but the results could be confounded by differences between the study populations.

The studies referred to above were carried out with some methodological differences, the most important one related to the assessments of the noise exposure. Of the studies, only two carried out recordings indoors (Persson Waye and Rylander, 2001; Mirowska, 1998). For low frequency noise, it is highly important to relate effects to measurements made indoors, as the attenuation of the facade and the room dimensions will affect the resulting noise indoors. In spite of the methodological differences the investigations do show that low frequency noise in the living environment causes annoyance, while the effects of long-term exposure to sleep and health are less well explored.

This paper describes the first part of a study carried out among residents exposed to traffic noise on one side of the building and to low frequency noise from installations on the other side of the building. The purpose was to evaluate the prevalence of annoyance at home caused by low frequency noise emitted from installation noises outdoors. In subsequent phases of the project, effects on annoyance, health and sleep disturbance will be studied among similar populations in the city of Göteborg and compared to referent groups not exposed to low frequency installation noise. Studies will also be undertaken among some of these populations after actions have been undertaken to reduce installation noises, in order to investigate effects on annoyance, health and sleep disturbance.

Methods

General outline

A cross sectional study was carried out among tenants in blocks of flats with one side facing a trafficked street and the other side facing a courtyard with a large number of fans, compressors and air cooling systems. Subjective responses were collected by questionnaires. Noise levels from the installation sources were measured indoors and outdoors and noise levels from traffic were calculated.

Study area

The study area was three buildings comprising blocks of flats, A, B and C, surrounding a courtyard on three sides. A fourth building, which faced the courtyard, was an office block and was not included in the study. The flats faced the courtyard on one side and a trafficked street on the other. The traffic flow on the street outside block A was 1000 vehicles per 24 h with 5% heavy vehicles, and the traffic flow on the streets outside blocks B and C was 14 500 and 16 500 vehicles per 24 h, respectively, with 4–5% heavy vehicles. The 24h period was an average for a period calculated with data from one calendar year.

In the courtyard, 35 different installations were located on the ground or on the roof of the buildings. The fans and compressors were extracting air or cooling air from restaurants and

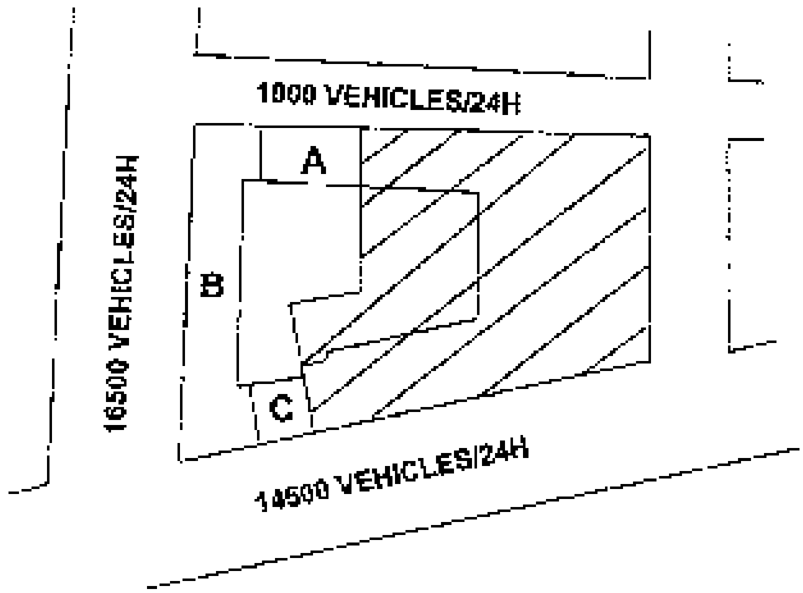


Figure 1 shows an overview of the study area.

small enterprises housed in the ground floor of the buildings. The noises generated were of a predominantly low frequency character.

Source population

The source population comprised a randomly selected person in each household between the ages of 18 and 80 years who had lived in the apartment for a minimum of one year. There were 69 apartments in the three buildings. Six respondents were excluded from the source population because of age, because they did not speak Swedish or because they were hospitalised. Six apartments were not rented on a permanent basis and were therefore also excluded. The total source population thus included 57 households.

Questionnaire

A questionnaire masked as a general living environment study was delivered to the door together with an introduction letter describing the purpose of the study. The respondents were asked to post the questionnaire but, as the response rate after two reminders was still low, we tried to contact them in a personal visit or by telephone. Forty-one questionnaires were returned, which gave a response rate of 71%.

The questionnaire had 35 questions divided into general questions on satisfaction with the dwelling standard and the living environment, disturbance from different environmental factors such as exhaust from motor traffic, cooking smells and noise from music from nearby restaurants, noise from fans and compressors and traffic noise. The questions on noise annoyance from traffic and fans/compressors were posed as: "Thinking about the last three months when you are at home, how much does noise from .... annoy you?" The question was a Swedish translation of the question proposed by Fields et al., (2001). The same phrase was used to ask about annoyance outdoors but with reference to when the respondent spent time outdoors in the courtyard. Questions were also posed on disturbance of rest and relaxation. The answers were given on a five-grade verbal scale, with the alternatives not at all, slightly, moderately, very and extremely. The questions on annoyance were answered on an opinion scale from 0 to 10, where 0 was equivalent to not at all annoyed and 10 equivalent to extremely annoyed (Fields et al., 2001). A section of the questionnaire comprised questions on sleep quality, sleep behaviour and sleep disturbance followed by questions on health. Questions were also posed on how long the respondents had lived at their present address, their occupation, work hours, the number of members in their family, age and sex. The study was carried out in August and September 2000.

In this presentation, descriptive results will be given of the prevalence of effects related to noise disturbance and sleep disturbance. Symptoms that may also be strongly related to other socio-economic factors are not reported, as the sample is too small for conclusions to be drawn about those effects and as there is yet no reference group with which comparisons can be made.

Assessment of noise exposure

Noise measurements were made after the questionnaire study was completed. The low frequency noise sound pressure levels were measured indoors in a bedroom facing the courtyard. Measurements were made in ten different apartments spread equally over the three blocks and representing high and low floors within the range of the 1st to the 5th floor. Measurements were recorded with the window closed and with the window slightly open (5 cm). The measurements were carried out at three positions in the room, one of them where the highest C-weighted noise level was found, in accordance with (SP-REPORT 1996:10). The sounds were recorded for two minutes at each position using a real-time analyser (B&K 2260). The sounds were also stored on digital tapes on a DAT recorder (SONY TCD-DC7). Subsequent analysis of equivalent third octave band sound pressure levels was done within the frequency range of 20 to 10 000 Hz. In the analysis, the three measurement positions in each apartment were in accordance with SP REPORT (1996:10), logarithmically averaged. The different apartments' average levels were then arithmetically averaged, and standard deviations thus represent deviations between flats rather than deviations inside the room. The reason for choosing an arithmetic average of the different flats sound pressure levels was to obtain a measure that would be representative for the area.

The noise levels from the installations were recorded outdoors in the courtyard and on one balcony on the fifth floor over a period of two months (September and October). The equivalent A- and C-weighted levels and the statistical distribution during one-hour intervals were recorded. A remote controlled measuring system (Larsson and Davis model 820) was used, and the microphone B&K 4165 was placed at a height of two meters. The recordings on the balcony were made with the same system, but the microphone was positioned one meter in front of the facade. These recordings were corrected for a facade reflex of 3 dB to allow comparisons with the free field measurements.

Equivalent 24h traffic noise outdoor levels were obtained from calculations made at the local health and environmental authorities. The calculations were made in accordance with the Nordic calculation model (Jonasson and Nielsen, 1996). Calculated levels were obtained at each floor and also included estimations of indoor noise levels based on a 27 dBA reduction by the facade. Noise measurements were also undertaken on two balconies facing the streets during a period of a week, in order to obtain the distribution of traffic noise levels during daytime, 07.00-19.00, evening 19.00-23.00 and night time. On the basis of the distributions obtained, and the 24h calculated noise levels, separate noise levels were calculated for daytime, evening and night time.

Statistical treatment of data

The prevalence of reports of disturbance was analysed for the total sample and for the sample subdivided into respondents with bedrooms facing the courtyard (CY) and respondents with bedrooms and sitting rooms facing a street (ST). Differences between subgroups were tested with the Chi-square or Mann Whitney U-test. Relationships between variables were tested using Spearman's correlation analysis. All tests were two sided and a p-value below 0.05 was considered statistically significant.

Results

General data

The study population comprised 25 households (59%) with one person and of 16 households (39%) with two or more persons. Five families had children below the age of 18. The

Table 1. Average values and standard deviations of indoor equivalent A- and C-weighted noise levels from installation noise.

	dB LAeq		dB LCeq	
Windows	**Closed**	**Slightly opened**	**Closed**	**Slightly opened**
Whole area	31 (2.48)	43 (2.43)	50 (2.27)	56 (2.49)
Block A	30 (2.97)	42 (1.82)	50 (1.84)	55 (1.77)
Block B, C	32 (1.81)	44 (2.32)	51 (2.68)	57 (2.51)

respondents had lived at their present address between 1 and 59 years, the median value being four years. The majority of the respondents (63%) had lived in urban areas before they moved to the present address. Most respondents (88%) were very satisfied or satisfied with their apartments and 71% were very satisfied or satisfied with their living environment. Nearly all respondents, or 98%, answered, however, that they seldom or never used the courtyard for relaxation purposes. Living conditions were considered to be good by 68%, while 29% regarded conditions as not particularly good or bad.

Seventy-one percent of the respondents reported that alterations ought to be made in their home and living environment. The majority of the comments were related to improved conditions in the flats (n=9), less traffic (n=6), reductions of the noise from fans/compressors (n=4) and better handling of garbage (n=4).

Of the 41 respondents, 19 had their bedrooms facing the courtyard, 20 had bedrooms and living rooms facing a street and two had bedrooms facing both the courtyard and a street. These two latter respondents were not classified into either of the categories.

The median age was 43 years in CY and 30 years in ST; the difference was not significant (z=-1.695, p= 0.091). In the CY sample the proportions of men and women were similar, 47% vs 53%, while the ST sample comprised a somewhat higher proportion of women (75%). This difference was however not significant (=2.119, p=0.146). The distribution of other socio-economic factors did not differ between the respondents in the two subgroups.

Among the respondents with bedrooms facing the street, six lived in block A and 12 lived in block B or C and two had bedrooms facing both streets.

Noise exposure

Blocks B and C faced a heavily trafficked street on one side, while block A faced a relatively moderately trafficked street. The levels of installation noise were comparable for blocks B and C while respondents living in block A were exposed to a somewhat lower level. The data on noise measurements were thus calculated for blocks B and C together and for block A separately.

The average indoor equivalent noise levels of the installation noises are shown in Table 1.

The differences in equivalent A-weighted levels between blocks A and blocks B and C were small and in the range of 2 dB. The LCeq levels indoors were 19 to 20 dB higher than the LAeq levels.

The average values of third octave band levels and standard deviations for the measurements in block A and blocks B and C are shown in Figures 2 and 3. The figures include recommended levels in Sweden for low frequency noise indoors (SOSFS 1996:7/E). The curve representing the

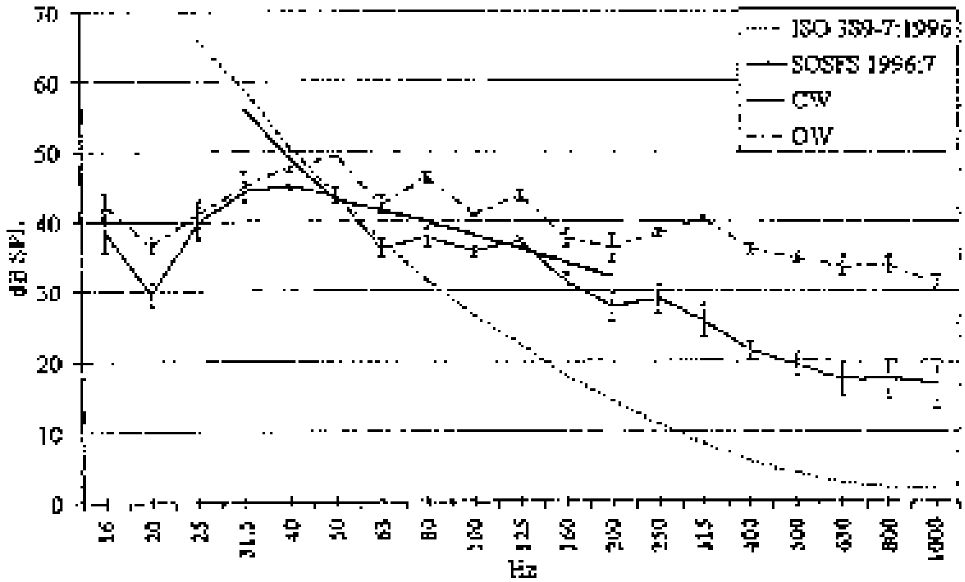


Figure 2. Average values of third octave band sound pressure levels and standard deviations for the measurements in block A. CW=Closed Windows; OW=Open Windows.

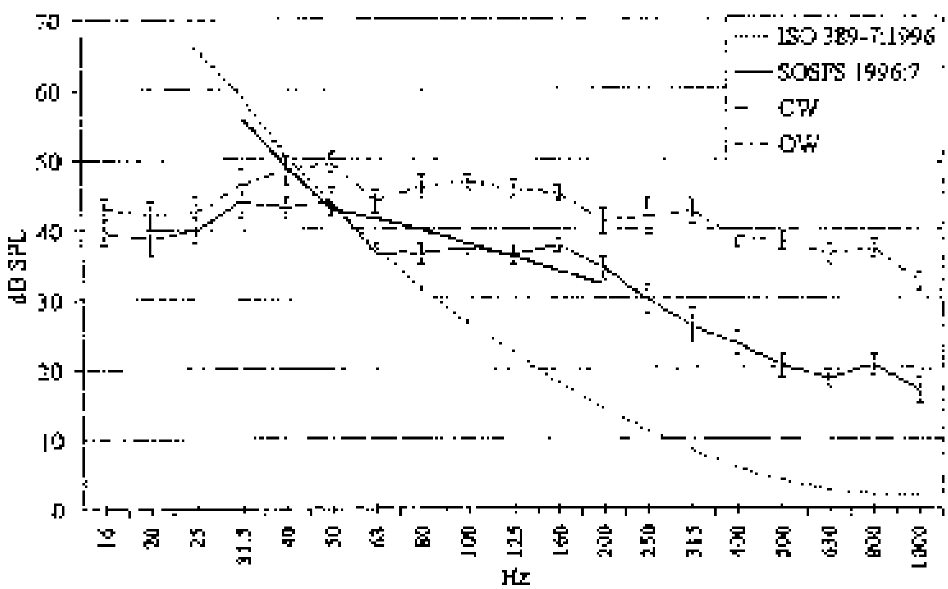


Figure 3. Average values of third octave band sound pressure levels and standard deviations for the measurements in block B and C. CW=Closed Windows; OW=Open Windows.

normal hearing threshold is included for reference (ISO 389-7:1996).

With windows closed, the sound pressure levelsfrom installation noise did only slightly exceed the Swedish recommendations for low frequency noise. When the windows were slightly opened, the sound pressure levels exceeded the recommendations by about 10 dB SPL. The measurements suggest that the sound pressure levels were somewhat higher for blocks B and C as compared to block A. The standard deviations of the third octave band sound pressure levels between the flats in the same block were in the range of 2,6 to 4.8. Data indicated that the sound pressure levels in third octave bands were about 2-4 dB SPL higher on floor 5 compared to floor 1 to 3, but the

Table 2. Calculated outdoor and indoor noise levels from traffic during the day, evening, night and 24h period.

	Outdoor free field, dB LAeq				Indoor, dB LAeq			
Time **Period**	Day 07.00-19.00	Evening 19.00-23.00	Night 23.00-07.00	24h	Day 07.00-19.00	Evening 19.00-23.00	Night 23.00-07.00	24h
Block A	55	54	48	54	28	27	21	27
Block B,C	64	62	57	62	38	36	31	36

measurements were too few to make firm conclusions about this finding.

The outdoor noise level from the installations was 57 dB LAeq 24h. The level during the day (07.00-19.00) was 58 dB LAeq, during the evening (19.00-23-00) 56 dB LAeq, and during the night (23.00-07.00) 57 dB LAeq.

Calculated noise levels outdoor and indoor from the traffic are shown in Table 2.

The LAeq levels were about 10 dB higher for blocks B and C as compared to block A.

The maximum noise levels were similar for block A,B and C and amounted to about 78 dB outdoors and 50-51 dB indoors.

Noise annoyance

The major sources of annoyance indoors were reported for noise from fans/compressors, cooking smell from restaurants, exhaust from traffic and noise from traffic (Table 3).

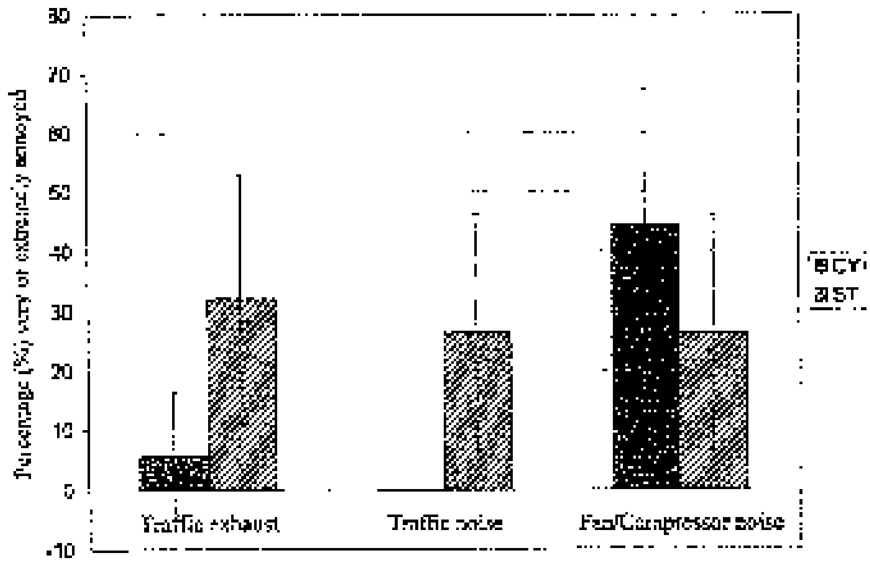
As can be seen in Table 3, more than 1/3 of the respondents reported that they were very or extremely annoyed indoors by noise from fans/compressors. Annoyance from cooking smells from restaurants was reported by about the same number of respondents as annoyance from traffic exhausts. Only three respondents (7.7%) were annoyed by music from neighbours and only two (5.4%) were annoyed by impact noise from neighbours.

The data were divided according to persons who had bedrooms facing the courtyard (CY) and persons with bedrooms facing a street (ST). Figure 4 shows the proportion of subjects very or extremely annoyed by traffic exhaust, noise from traffic and fan/installations. Annoyance from traffic exhaust and traffic noise was mainly reported by the ST sample, while noise from fan/compressors was reported by 44% among the CY sample and 26% among the ST sample. It can also be noted that the prevalence of annoyance in the ST sample caused by noise from fans/compressors was equivalent to the

Table 3. Proportion of respondents reporting annoyance indoors due to different environmental factors.

Environmental factor	Proportion very or extremely annoyed indoors (95% CI)	Total answers
Noise from fans/compressors	35.9 (20.8 – 51.0)	39
Noise from traffic	12.8 (2.3 –23.3)	39
Exhaust from traffic	18.4 (6.1 - 30.7)	38
Cooking smell from restaurants	20.5 (7.8 – 33.2)	39

Figure 4. Proportion of respondents reporting annoyance indoors due to different environmental factors in their living environment, divided into the ST sample and CY sample. Vertical bars show 95% CI.



reported annoyance from traffic noise, although their apartments had both living rooms and bedrooms facing the street. There was no significant difference in annoyance from fans/compressors between the ST and the CY samples (z=-0.965, p=0.36), while the annoyance caused by traffic noise was significantly higher in the ST sample (z=-4.630, p<0.001).

There was no relationship between floor level and traffic noise annoyance in the ST sample. There was however a significant relationship between noise from fans/compressors and floor

Figure 5. Proportion of respondents reporting disturbed rest/relaxation indoors due to noise from traffic and fan/compressor noise divided into the ST sample and the CY sample. Vertical bars show 95% CI.

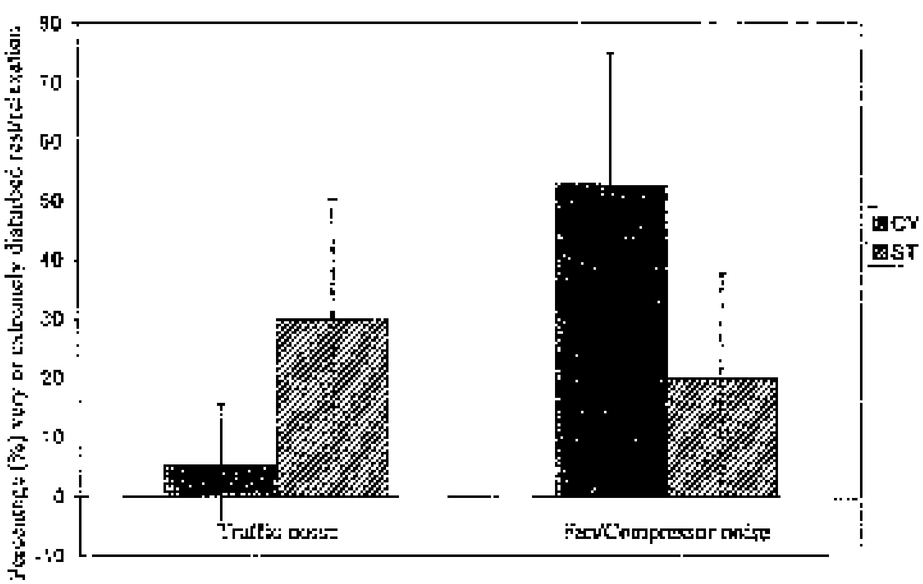


Table 4. Median values and (25th and 75th percentiles) of sleep related questions and proportion and (95% CI) of subjects reporting that sleep was disturbed by noise, for the CY and the ST sample.

	CY	ST
Sleep quality	2.0 (1.0 - 2.0)	2.0 (1.2 – 2.0)
Difficulties in falling asleep	2.0 (1.0 – 3.0)	2.0 (2.0 - 3.0)
Time to fall asleep (min)	20 (11 - 30)	15 (10 – 30)
Tired morning	2.5 (2.0 – 3.2)	3.0 (3.0 – 4.0)
Tensed morning	2.0 (2.0 – 3.0)	3.0 (2.0 - 3.0)
Sleep disturbed by some noise (% reporting yes)	63 % (41.5 – 84.9)	63% (41.5 - 84.9)

level in the CY sample, r=0.57, $p<0.05$. Respondents living on higher floor levels reported a higher degree of annoyance.

The proportions of persons who reported very or extremely disturbed rest/relaxation indoors caused by fan/compressor noise was 37% while 17% reported this disturbance due to traffic noise. Figure 5 shows these data divided into respondents whose bedrooms faced the courtyard and those whose bedrooms faced the street. It can be seen that disturbed rest/relaxation due to traffic noise was reported by 30% in the ST sample and by 5% in the CY sample. This difference was statistically significant (z=-3.655, $p<0.001$). Disturbed rest/relaxation due to fan/compressor noise was reported by 53% in the CY sample and by 20% in the ST sample. This difference was not significantly different (z=-1.420, p=0.166).

With regard to spending time in the courtyard, the proportion of respondents who reported very or extreme annoyance due to fan/compressor noise was 56% while 10% reported annoyance due to traffic noise.

Of the total sample, 37% reported that noise from fans/compressors prevented them from opening the windows as often as they would like "often" or "always", while 34% reported that noise from fans/compressors "never" prevented them from opening windows.

Sleep disturbance

The answers to the most important sleep related questions divided into the ST sample and the CY sample are shown in Table 4. The questions on sleep quality, difficulty in falling asleep and feelings of being tired and irritated in the morning ranged from 1 to 5, where 1 indicates a positive value ("very good sleep quality", "not at all difficult to fall asleep" and "very alert/rested" and "very relaxed" in the morning") and 5 represents a negative value ("very poor sleep quality", "difficult to fall asleep every day" and "very tired" and "very tensed" in the morning).

The table also shows that the ratings of the sleep related parameters were similar among respondents with bedrooms facing the street vs bedrooms facing the courtyard. A significant difference was found for the reports of feeling tired in the morning, however, where more subjects in the ST sample reported being tired (z=-2.316, $p<0.05$). A large percentage of both groups reported that sleep was disturbed by noise. Thirty-nine percent of the comments referred to noise from fans/compressors, 35% referred to traffic noise and 26% referred to other types of noises from people in the street and restaurants. Of the respondents, 46% reported that they did not sleep with the window open during summer. Among respondents with bedrooms facing the street, 60% did not sleep with the window open, while this was reported by 37% of those whose bedroom faced the courtyard. The majority of the reasons given for this had to do with noise.

Discussion

Methods

In epidemiological terms, the study population is very small and does not include a referent group. The results must thus be valued accordingly. The emphasis of the data presentation is therefore descriptive, and special caution must be used in interpreting the statistical analysis of e.g. sleep data, as no adjustment has been made for factors that can influence the sleep parameters.

This study is the first part of a series of studies, which will be followed up by further studies among similar populations in the city of Göteborg and will include referent groups not exposed to low frequency installation noise. In most cases, we will also be able to measure the response after noise abatement programs aimed to reduce the installation noise have been undertaken. At the end of this three-year programme, more valid data will thus be gained.

The subjective responses were obtained by questionnaires masked as a general living environment study. This was done in order not to direct the respondent's attention to noise, which could result in a more prominent annoyance response. Before the study was undertaken, two noise complaints had been reported to the health and environmental authorities, but there were no widespread complaint actions. The answers to the questions on general and specific items dealing with the general living environment and the conditions of the flats indicate that the attempt to mask the real purpose of the questionnaire was successful.

Noise measurements were made in a sample of flats at different locations in the building. A more extensive measurement program would probably have yielded better precision concerning the variation in noise exposure, especially between different floors. The standard deviations were however comparable to previous studies of low frequency ventilation noise involving a more extensive measurement program (Persson Waye and Rylander, 2001).

Results

The results showed that the proportion of respondents who were annoyed by noise from fans/compressors was high. Annoyance caused by installation noise was reported indoors as well as when time was spent in the courtyard. Compared to annoyance caused by traffic noise, the proportion of respondents reporting annoyence caused by installation noise was more than twice as high. Similar differences were reported regarding disturbed rest and relaxation. When the data were subdivided according to residents whose bedrooms faced the courtyard and those whose bedrooms faced the street, the same pattern was found, although it was more pronounced.

The comparatively high annoyance reported for installation noises could be explained by a difference in the perceived necessity of the noise from the different sources. While noise from traffic may be considered as unavoidable in the urban environment, noise from installations that service mainly shops and restaurants may be considered as easier to avoid and hence more unnecessary. The judged unnecessity of neighbourhood noise and street noise has previously been found to be related to annoyance in a survey of 200 subjects living in an urban area (Graeven, 1975). The more unnecessary the noise was perceived to be, the greater noise annoyance was reported. Interestingly, the reverse was found for noise at work, the more necessary the noise was perceived to be, the greater annoyance was reported. However in another occupational study, where subjects were asked to judge their opinion of the possibilities to reduce the noise level at their work place, it was found that persons who thought it was possible to reduce the noise i.e. meaning that they thought it was unnecessary loud, were more annoyed than others (Kjellberg et al., 1996). In further studies, subjects' perception of the necessity of the noise sources should be recorded.

Another explanation of the high occurrence of noise annoyance from installations could be that tenants with traffic on one side of the flat feel that it is very important to be able to open one window without being exposed to exhausts or noise. The finding in this study that respondents with bedrooms facing the street reported about the same extent of annoyance from installation noise as for traffic noise seems to support that theory. The results from this study do however not lend themselves to any conclusions of whether the access to a quiet side would be beneficial from a health point of view, and there is today very little data to support the hypothesis, originally suggested by Kihlman (1993). A recent paper indicates however, that the access to a quiet side resulted in overall lower noise annoyance and also less perceived noise induced sleep disturbances as compared to living in a flat where both sides face a trafficked road (Kihlman et al., 2002). However the authors regard the results as preliminary and hence more data is needed.

The character of the installation noise is another probable explanation for the annoyance response. The noise has a monotonous, continuous character and the low frequency character of the installation noise will penetrate into the flat and increase the annoyance potential. While intermittent noise is usually reported as more annoying and more disturbing of sleep (e.g. Öhrström and Rylander, 1982), less is known of the effects of long term exposure to continuous noise and of noises with a low frequency character. A recently performed experimental sleep study showed that a low frequency ventilation noise at 40 dBA, led to a significant increase of time to fall asleep and an altered cortisol response in the morning (Persson Waye et al., 2003). The results of that study and this field study thus point to the relevance to further study the annoyance potential of installation noises with a large proportion of low frequencies.

The study also points to the importance of obtaining a better basis for effects of low frequency noise at different levels and to consider low frequency noise outdoors as an important factor for indoor effects. The indoor levels with closed windows were at or slightly above the recommended levels for low frequencies indoors (SOSFS 1996:7/E). The high prevalence of annoyance indoors suggest that it is not only the noise levels indoors with closed windows that are of relevance for noise annoyance indoors, but also the noise levels that occur indoors when the windows are open.

The significant relation between greater annoyance and floor level was an unexpected finding. The increase of annoyance is supported by the indication that the noise levels were somewhat higher on the higher floor levels. This is in contrast to traffic noise measurements, where a reduction of the level is found with greater height of the building. The increase in level could be explained by the fact that some of the sources were located on the roof of the buildings but could also be a result of the shape of the enclosed area of the courtyard that probably acts as a resonator for the low frequencies.

Conclusion

The high disturbance of installation noises found in this study indicates the importance of also regulating the noise exposure on the "quiet side" of buildings in order to achieve a reasonable living environment. This is believed to be especially important for residents exposed to high noise levels of traffic noise on the other side of their dwellings. Further studies will give a better base for the extent of annoyance and acceptable levels of installation noises.

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References

Altman D.G. (1991) Practical statistics for medical research. Chapman and Hall, London.

Berglund B., Hassmén P. and Job R. F. S. (1996). Sources and effects of low frequency noise. *J. Acoust. Soc. Am.* 99: 2985-3002.

Bryan M.E. (1976). Low frequency noise annoyance. In Infrasound and Low Frequency Vibration. Tempest W. ed., Academic Press Inc., London LTD, pp65-96.

Challis L.A. and Challis A.M. (1978). Low frequency noise problems from gas turbine power stations. In Proceedings of the International Conference on Noise Control Engineering. Lang W.W. ed., San Francisco, USA. pp475-480.

Chatterton P.F. (1979). A case history of a low frequency noise problem. Noise Control Vibration Isolation, August-September. 295-298

Cocchi A., Fausti P. and Piva S. (1992). Experimental characterization of the low frequency noise annoyance arising from industrial plants. *J. Low Freq. Noise Vibr.* 11: 124-132.

Fields J. M., De Jong R.G., Gjestland T., Flindell I.H., Job R.F.S., Kurra S., Lercher P., Vallet M., Yano T., Guski R., Felscher-Suhr U. and Schumer R.(2001). Standardized general-purpose noise reaction questions for community noise surveys: research and a recommendation. *J. Sound Vib.* 242: 641-679.

Grzeven D. (1975). Necessity, control, and predictability of noise as determinants of noise annoyance. *J. Soc. Psychol.* 95: 85-90.

ISO 389-7:1996. Acoustics. Reference zero for the calibration of audiometric equipment. Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.

Jonasson H. and Nielsen H.L. (1996). Road Traffic Noise - Nordic Prediction Method. ISBN 92 9120 836 1. Tema Nord 1996 25. Nordic Council of Ministers.

Kihlman T. (1993). Action plan against noise. SOU 1993:65. ISBN 91-38-13397-0 (in Swedish).

Kihlman T., Öhrström E. and Skånberg A. Adverse health effects of noise and the value of access to quietness in residential areas. In: Proceedings of Inter Noise 2002. The 2002 International Congress and Exposition on Noise Control Engineering. Dearborn MI USA, August 19-21, 2002. Paper 484

Kjellberg A., Landström U., Tesarz M., Söderberg L. and Åkerlund E. (1996).The effects of nonphysical noise characteristics, ongoing task and noise sensitivity on annoyance and distraction due to noise at work. *J. Environ. Psychol.* 16: 123-136.

Kjellberg A., Muhr P. and Sköldström B. (1998). Fatigue after work in noise - an epidemiological survey study and three quasi-experimental field studies. *Noise and Health* 1: 47-55.

Mirowska M. (1998). An investigation and assessment of annoyance of low frequency noise in dwellings. *J. Low Freq. Noise Vibr.* 17: 119-126.

Persson Waye K. and Rylander R. (2001). The extent of annoyance and long term effects among persons exposed to low frequency noise in the home environment. *J. Sound Vib.* 240: 483-497.

Persson Waye K., Clow A., Edwards S., Hucklebridge F. and Rylander R. (2003). Effects of night-time low frequency noise on the cortisol response to awakening and subjective sleep quality. Life Sciences. 72: 863-875.

SOSFS 1996:7/E. General Guidelines issued by the Swedish National Board of Health and Welfare. Adopted 15th May 1996. Indoor Noise and High Sound Levels.

SP-REPORT 1996:10. Measurement of low frequency sound in rooms. Swedish National Testing and Research Institute, Borås, Sweden.

Vercini A.M., Frassoni C.A. and Skarp A.H.O. (1999). A field research about effects of low frequency noises on man. *Acta Acustica* 85, suppl 1. S16.

Öhrström E. and Rylander R. (1982). Sleep disturbance effects of traffic noise - a laboratory study on after effects. *J. Sound Vib.* 84: 87-103.

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Low frequency noise "pollution" interferes with performance

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To study the possible interference of low frequency noise on performance and annoyance, subjects categorised as having a high- or low sensitivity to noise in general and low frequency noise in particular worked with different performance tasks in a noise environment with predominantly low frequency content or flat frequency content (reference noise), both at a level of 40 dBA. The effects were evaluated in terms of changes in performance and subjective reactions. The results showed that there was a larger improvement of response time over time, during work with a verbal grammatical reasoning task in the reference noise, as compared to the low frequency noise condition. The results further indicated that low frequency noise interfered with a proof-reading task by lowering the number of marks made per line read. The subjects reported a higher degree of annoyance and impaired working capacity when working under conditions of low frequency noise. The effects were more pronounced for subjects rated as high-sensitive to low frequency noise, while partly different results were obtained for subjects rated as high-sensitive to noise in general. The results suggest that the quality of work performance and perceived annoyance may be influenced by a continuous exposure to low frequency noise at commonly occurring noise levels. Subjects categorised as high-sensitive to low frequency noise may be at highest risk.

Keywords: Low frequency noise, performance, annoyance, noise sensitivity

Introduction

The introduction of modern technology and computerised machinery in industry has reduced the occurence of high noise exposure situations but introduced other types of occupational noise of more moderate noise levels. In many cases, the change to moderate noise levels has been achieved by building insulated control rooms from which industrial processes are supervised. The noise in such control rooms is often dominated by noise in the frequency range of 20 to 200 Hz (low frequency noise) caused by ventilation and air conditioning systems as well as by the lower attenuation of the low frequencies by the walls, floors and ceilings. Other occupational environments, such as office areas, house a number of noise sources that generate low frequency noise at moderate levels. Major examples of such sources are network installations, ventilation, heating and air-conditioning systems.

There is a growing body of data showing that low frequency noise has effect characteristics that are different from other environmental noises of comparable levels [Persson Waye 1995; Berglund et al. 1994]. Symptoms that have been reported in connection with annoyance caused by low frequency noise and which may also reduce the working capacity are fatigue, headaches and irritation [Tokita 1980; Nagai et al. 1989; Persson Waye and Rylander 2001]. Although the importance of low frequency noise has been acknowledged in the WHO document on community noise [Berglund et al. 2000], the effects are less well explored compared to noises of higher frequencies and the specific regulations for control in the occupational environment are unsatisfactory.

Many occupational tasks have stringent demands on the employee as concerns knowledge, learning, flexibility, attention, and productivity. Computerised equipment determines the working speed of many employees, and the tasks demand concentration and rapid decisions. Supervising equipment on instrument boards also requires constant attention and, in the case of error messages, rapid remedial actions.

Information on how low frequency noise influences performance in these types of work situations is scarce. An experimental pilot study indicated that low frequency noise from ventilation equipment at a level of 42 dB LAeq could increase the time taken to respond in a verbal grammatical reasoning task, compared to a ventilation noise of equal level but not dominated by low frequencies [Persson Waye et al. 1997]. Similarly, Kjellberg and Wide [1988] found a slower learning rate in this task when it was performed during exposure to simulated ventilation noise. Persson Waye et al. [1997] further showed that the subjects' self-rated performance and mood were affected to a higher degree by the low frequency noise than by noise not containing low frequency components.

It has also been shown that infrasound and low frequencies at 42 Hz may lower the level of wakefulness [Landström 1987; Landström et al. 1985; Landström et al. 1983]. This effect indicates that performance on monotonous, machine-paced tasks such as signal-monitoring tasks may be sensitive to low frequency noise exposure. Performance in these kind of tasks has consistently been found to be most sensitive to changes in wakefulness [Hockey 1986].

Reading comprehension and other verbal tasks have often been found to be more sensitive to noise than other tasks [Jones 1990]. However, it remains to be demonstrated if low frequency noise affects the performance of such tasks.

Generally, the research into the effects of noise on performance presents a rather inconsistent picture [Kjellberg and Landström 1994; Smith and Jones 1992]. One reason for this may be the large individual differences in noise sensitivity in general, and possibly, specifically for low frequency noise. It was previously found that subjects high-sensitive to noise in general, as measured by a sensitivity scale [Weinstein 1978], had the lowest performance accuracy under conditions of exposure to traffic noise [Belojevic et al. 1992]. Similarly, Jelinkova [1988] found that noise sensitive persons had a reduced working ability and attention when exposed to recorded traffic noise at 75 dB LAeq, compared to persons tolerant to noise.

Previous experience recorded from subjects disturbed by low frequency noise in their homes has shown that persons sensitive to low frequency noise are not necessarily sensitive to noise in general as measured by general noise sensitivity scales [Persson Waye 1995]. It is therefore important to categorise subjects not only in terms of sensitivity to noise in general but also with respect specifically to low frequency noise. However, the relation between self-rated sensitivity and performance effects is not clear.

The present study was undertaken to further elucidate the influence of low frequency noise on performance and attempted to answer the following questions:

- Can low frequency noise at a level normally present in control rooms and office areas influence performance and subjective well-being?
- What kind of performance tasks are affected by low frequency noise?
- How is the performance affected by duration of exposure?
- What is the relation between self-rated noise sensitivity and noise effects?

Material and methods

General structure

The subjects performed a series of performance tasks during exposure to a low frequency noise or a reference noise. Based upon responses to questionnaires, the subjects were categorised as having a high- or low sensitivity to noise in general and low frequency noise in particular. Their subjective reactions to the test session were recorded using questionnaires. To assess stress, saliva samples were taken and the amount of cortisol was determined. After each saliva sample, the subjects answered a questionnaire evaluating their perceived stress and energy [Kjellberg et al. 1989]. These latter data will be reported elsewhere [Persson Waye et al. 2001].

Noise exposure

The exposure noises were two ventilation noises, one of a predominantly flat frequency character (reference noise) and the other of a predominantly low frequency character (low frequency noise). The reference noise was recorded from a ventilation installation. To obtain the low frequency noise, sound pressure levels in the frequency region of 31.5 to 125 Hz were increased using a digital sound processor system [Aladdin interactive workbench. Nyvalla DSP Stockholm, Sweden]. Furthermore, the third octave band centred at 31.5 Hz was amplitude-modulated with an amplitude frequency of 2 Hz. Both noises had a level of 40 dBA.

Figure 1 shows the equivalent third octave band sound pressure levels for the two noises, measured at the position of the subjects' head.

Subjects

For the study, 19 female and 13 male (n=32) subjects with an average age of 23.3 (Sd= 2.58) were recruited by advertising. Each person underwent a hearing test [SA 201 II Audiometer, Entomed, Malmö, Sweden] and only persons with normal hearing (<20 dB HL) were allowed to participate. The subjects were given financial compensation for their participation.

Subjective sensitivity to noise

To assess sensitivity to low frequency noise and sensitivity to noise in general, two questionnaires were answered after the last test session. On the basis of the subjects' scores on two of the questions in the questionnaires, subjects were categorised as highly sensitive (high-sensitive) or less sensitive (low-sensitive)

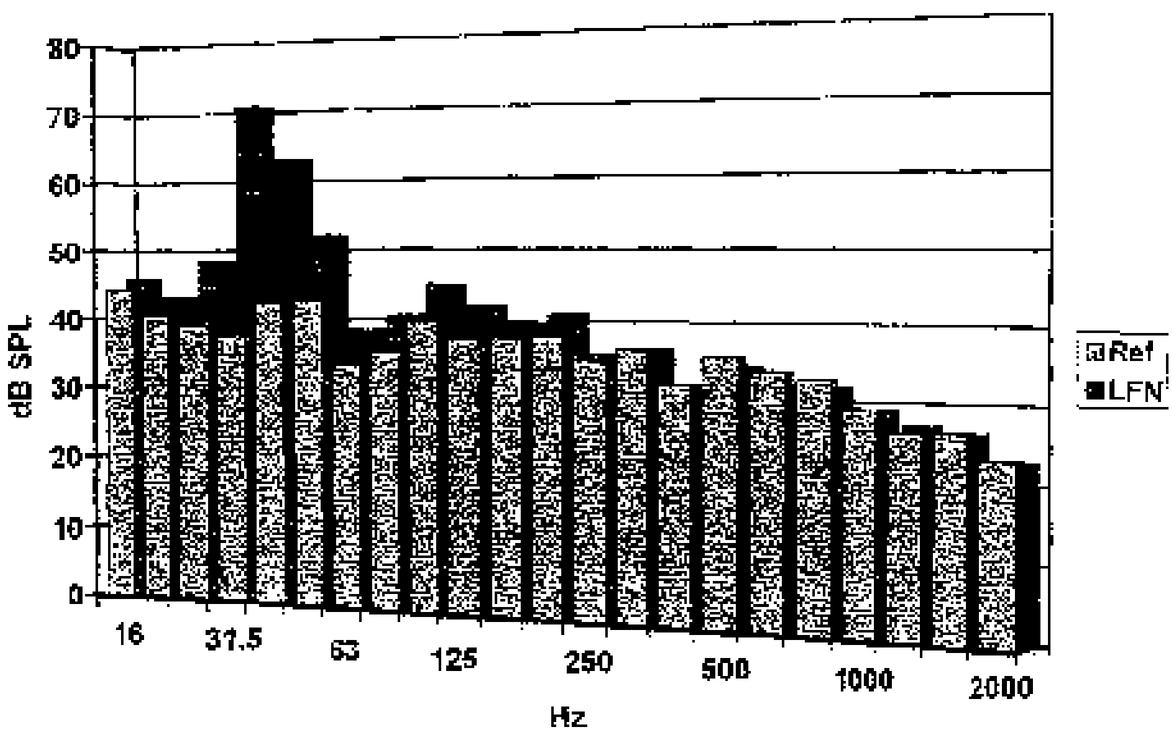

Figure 1. Third octave band sound pressure levels of the reference noise and the low frequency noise (dark coloured bars) used during the test sessions, measured at the position of the subjects head.

to low frequency noise. The first question "are you sensitive to low frequency noise" had five response alternatives ranging from "not at all sensitive" to "extremely sensitive". The second item, "I am sensitive to rumbling noise from ventilation systems", had six response alternatives ranging from "do not agree at all" to "agree completely". The subjects were also categorised as highly sensitive (high-sensitive) or less sensitive (low-sensitive) to noise in general, using the question "are you sensitive to noise in general" (with five response alternatives ranging from "not at all" to "extremely sensitive") and using the total number of points scored in a noise sensitivity evaluation questionnaire [Weinstein, 1978]. The questionnaire had a total of 120 points; the higher the point scores, the higher sensitivity to noise. The subjects' answers ranged between 40 and 114 points, with an average of 70.8.

The categories of sensitivity were elicited through a principal component analysis with direct oblimin rotation of the four sensitivity questions. Two correlating factors, which explained 85% of the variance, were extracted. In the first factor, the two questions on low frequency noise had a loading of 0.9 and the questions on sensitivity to noise in general had a load below 0.5 (see Table 1). The other factor showed the opposite load pattern. The correlation between the two factors was 0.46. Factor scores were calculated for both the two factors, and the four categories (high-sensitive/low-sensitive to low frequency noise and to noise in general) with the medians as cut-off point.

In the group, 15 females and three males were high-sensitive to low frequency noise, and four females and ten males were low-sensitive to low frequency noise. Eleven females and five males were categorised as high-sensitive to noise in general, and eight females and eight males were low-sensitive to noise in general.

The two categorisations were virtually independent (chi^2=0.508, p=0.473). Eight of the 16 subjects categorised as low-sensitive to noise in general, belonged to the group assessed to be high-sensitive to low frequency noise. Six of the subjects in the group high-sensitive to noise in general did not belong to the group assessed to be high-sensitive to low frequency noise.

Test chamber

The experiment was performed in a 24 m^2 room, furnished as an office with a desk, computer and

Table 1. Factor structure matrix for the questions relating to sensitivity to low frequency noise and sensitivity to noise in general.

Factor	Low freq. sensitivity	General noise sensitivity
Sensitive to low frequency noise	0.932	0.385
Sensitive to rumbling noise from ventilation system	0.927	0.498
Sensitive to noise in general	0.570	0.914
Weinstein, total points	0.495	0.899

bookshelf. Behind the subject was a window with a closed Venetian blind so the person could be observed during performance. The sound was produced by four loudspeakers, hidden behind curtains and placed in each corner of the room. To amplify the low frequency noise, there was a subwoofer (ace-bass B2-50) which can reproduce frequencies down to 20 Hz. The background noise from the test chamber ventilation was less than 22 dBA, and the sound pressure levels for frequencies below 160 Hz were below the threshold of normal hearing [ISO 389-7:1996].

Performance tasks

In the experiment, four performance tasks were used. Tasks I, II and IV involved working with a computer and task III involved working with pen and paper. The tasks were chosen in order to involve different levels of mental processing. A high workload was generated by instructing the subjects to work as rapidly and accurately as possible. All performance tasks were carried out twice in each test session, once in phase A and once in phase B (see Table 2).

Task I was a simple reaction-time task and is part of the SPES computer test battery [Gamberale et al. 1989]. The subject was told to press a button as quickly as possible when a red square appeared on a black screen. Mean response times for the five, one-minute periods were recorded.

Task II was a short-term memory task. A set of numbers, e.g. 1 2 5 4, was shown on the computer screen. This set was followed by one number, e.g. 7. The subject was to respond, by yes or no, to whether that number was also present among the set of numbers shown earlier. The total response time and total number of correct and false answers were recorded.

Task II was carried out together with a secondary task, the bulb-task, previously used by Persson Waye et al. [1997]. This task consisted of four differently coloured light bulbs, placed at four different positions on an arch at the periphery of the subject's visual field. Each of the four bulbs was illuminated at random intervals and in random sequence. The subjects' task was to respond only when a yellow bulb was illuminated, after which the subject was instructed to, as quickly as possible, push a response button that matched the colour (red, green or blue) of the light bulb that was illuminated *prior* to the yellow light bulb. The set-up used for task II with a primary and secondary object was designed to require the subject's full attention and concentration. The total response time and number of correct and erroneous responses were recorded.

Task III was a proof-reading task [Landström et al. 1997]. The subject read a text, printed on paper, for exactly ten minutes, and the task was to mark errors in the text. The number of lines read, correct marks, erroneous corrections and the total number of marks were recorded and related to the number of lines read for each subject; correct marks per line, erroneous corrections per line and total number of marks per line.

Task IV was a computerised verbal grammatical reasoning task, translated into Swedish from the original version [Baddeley 1968]. The task is based on grammatical transformation of sentences that have various passive, active, negative and positive structures. The subject was instructed to respond to whether a sentence is false or true in relation to a letter combination following the sentence. For example:

		True	False
A is not followed by B	*BA*	√	
B precedes A	*AB*		√

The set-up used for task IV was designed to impose a high mental workload. In total, the task consisted of eight blocks of 32 sentences. The mean response time for the eight blocks and the number of correct and false answers were recorded.

Questionnaires

Following tasks II, III and IV, a questionnaire was administered to evaluate how much effort the subjects judged had used in order to perform each task. The subject could choose between five response alternatives ranging from "none at all" to "extremely".

A questionnaire evaluating mood [Sjöberg et al. 1979] was completed before and after the test session. The questionnaire consisted of 71 adjectives describing feelings of different kinds, and the adjectives formed the following six mood dimensions: social orientation, pleasantness, activation, extraversion, calmness and control. The subject could choose between four response alternatives: "I agree completely", "I somewhat agree ", "I do not agree" and "I certainly do not agree".

When the test session was completed, the subject completed a questionnaire evaluating self-reported estimates of annoyance due to noise, presence of symptoms experienced during or after the experiment and, also, questions were asked about whether the subject judged that the capacity to work had improved or been impaired due to noise, temperature or light during the tasks. Regarding impaired working capacity, the subject could choose between seven response alternatives ranging from one to seven: "major improvement", "rather much improvement", "some improvement", "neither improvement or impairment", "some impairment", "rather much impairment" and "major impairment". The alternatives for annoyance, ranging from one to five, were "not at all annoyed", "a little annoyed", "rather annoyed", "very annoyed" and "extremely annoyed". For the questions on presence of symptoms experienced during or

Table 2. Experimental set-up.

Min	*Moment*	Min	*Moment*
0	Rest in a relaxing room	98	Short-term memory task and bulb-task
	Questionnaire evaluating mood		Questionnaire evaluating effort
20	Saliva sample	111	Proof-reading task
	Questionnaire evaluating stress		Questionnaire evaluating effort
	Subject to test chamber, noise exposure starts	122	Verbal grammatical reasoning task
24	Simple reaction-time task		Questionnaire evaluating effort
30	Short-term memory task and bulb-task	143	Simple reaction-time task
42	Questionnaire evaluating effort	149	Noise exposure ends, subject to relaxing room
	Saliva sample		Saliva sample
	Questionnaire evaluating stress		Questionnaire evaluating stress
46	Proof-reading task		Questionnaire evaluating mood
56	Questionnaire evaluating effort		Questionnaire evaluating annoyance and
	Saliva sample		presence of symptoms
	Questionnaire evaluating stress		Weinstein questionnaire evaluating attitude to
60	Verbal grammatical reasoning task		noise (after the second test session)
70	Saliva sample		Questionnaire evaluating personal factors
80	Saliva sample		(after the second test session)
	Questionnaire evaluating effort		
	Questionnaire evaluating stress		
95	5 minutes break		

after the experiment, questions were posed concerning headaches, pressure over the cardium or head, occurrence of nausea, lack of concentration, irritation, tiredness, dizziness, irritation in eyes or throat or a sensation of unpleasant taste. The subject could choose between five response alternatives ranging from "not at all" to "extremely".

Experimental design and procedure

The experiment had a 2 (noises) × 2 (phases) × 2 (sensitivity groups) factorial design with repeated measures in the first two factors with independent groups representing the sensitivity factor. In the analyses of the simple reaction-time task and the verbal grammatical reasoning task, a fourth factor, time blocks within the task, was added.

On a separate occasion before the main test session, the subjects learned the procedures and practised on short versions of the performance tasks for about one hour with the reference noise at 35 dBA. Before each task, both written and verbal instructions were given to emphasise the need to "work as rapidly and accurately" as possible. The subjects were also informed that, if needed, they could communicate with the research director through a microphone on the desk.

In the study, each subject took part in two test sessions, on separate days and always in the afternoon. The total exposure time was on average 2 hours and 10 minutes with a variation of ±9 min. The variation was due to the difference in the individuals' performance time carrying out task IV during phase B.

Of the 64 test sessions, 37 started at 12.30, and 27 started at 15.00. The proportion of subjects starting at 12.30 and 15.00 for the two noise conditions was similar, 18/14 for the low frequency noise condition and 19/13 for the reference noise condition. During each test session, the subjects worked with four performance tasks and were exposed to the reference noise or the low frequency noise. A detailed plan of the experimental set-up is found in Table 2. Half of the subjects started with the reference noise and the other half with the low frequency noise. To minimise subjective influence caused by the attitude to noise, motivation and the individual's level of expectations before the test sessions, the written and verbal information about the experiment did not explicitly refer to noise exposure.

Analysis and statistical methods

Analyses of variance, ANOVA, were performed to evaluate the influence of noise exposure, time, subjective sensitivity and their interactions on the different performance tasks and subjective ratings. The p-values are based on degrees of freedom corrected with Greenhouse-Geisser epsilon, when appropriate. To evaluate the difference of means for specific periods, a Student's t-test for dependent data was applied. Correlations between subjective data and performance were done using Pearson's correlation analysis. All tests were two-tailed, and a p-value of <0.05 was considered statistically significant, while a p-value up to 0.10 is reported as a tendency.

The statistical analyses employed SPSS [SPSS base 10.0 for Windows].

Results

No significant interaction of noise and gender was found for the subjective estimations or for any of the performance tasks.

Performance

No significant main effect of noise condition on reaction-time in the *simple reaction-time task* was found ($F(1,29)=1.952$, $p=0.173$).

A tendency to a two-way interaction in reaction-time was found between noise and sensitivity to noise in general ($F(1,29)=4.141$, $p=0.051$). Subjects high-sensitive to noise in general had a somewhat longer reaction-time during the low frequency noise condition compared to the reference noise condition, while the low-sensitive subjects had a similar reaction-time during both noise conditions.

Table 3. Response time in the short-term memory task for the two noise conditions and the two categorisations of noise sensitivity. (NG - Noise in General; LFN - Low Frequency Noise)

Response time (ms)	Reference noise *Phase*			Low frequency noise *Phase*		
	A	*B*	*Diff (A-B)*	*A*	*B*	*Diff (A-B)*
All subjects	**666**	**638**	***28***	**649**	**631**	***18***
High-sensitive to LFN	699	656	*43*	654	648	*6*
Low-sensitive to LFN	625	614	*11*	642	608	*34*
High-sensitive to NG	688	684	*4*	698	670	*28*
Low-sensitive to NG	645	591	*54*	600	591	*9*

Table 4. Response time and percentage correct answers in the bulb-task for the two noise conditions, for all subjects.

	Reference noise *Phase*		Low frequency noise *Phase*	
	A	*B*	*A*	*B*
Response time (ms)	2438	2340	2586	2415
Correct responses (%)	87	89	85	91

The results from the *short-term memory task* and the *bulb-task* are shown in Tables 3 and 4 respectively.

No significant difference in total response time was found between noise exposures for the short-term memory task ($F(1,31)= 0.561$, $p=0.46$) or the bulb-task ($F(1,31)= 0.304$, $p=0.585$). In the short-term memory task, the total number of errors made in phase A and B was small and did not differ between noise exposures.

In the short-term memory task, a significant three-way interaction in response time was found between noise, phase and low frequency noise sensitivity ($F(1,30)= 4.949$, $p<0.05$). As can be seen in Table 3, subjects high-sensitive to low frequency noise decreased their response time considerably from phase A to B during reference noise, while their response time decreased only slightly during the low frequency noise. Subjects low-sensitive to low frequency noise, in contrast, decreased their response time during low frequency noise, while their response time decreased only slightly during the reference noise.

Among subjects categorised according to sensitivity to noise in general, a significant three-way interaction was found between noise, phase and sensitivity to noise in general ($F(1,30)= 6.576$, $p<0.05$). Subjects high-sensitive to noise in general decreased their response time from phase A to B during low frequency noise, but not during reference noise. Subjects low-sensitive to noise in general, on the contrary, only decreased their response time during reference noise.

Table 5. The results from the proof-reading task for the two noise conditions, for all subjects and for the two categorisations of noise sensitivity. (NG - Noise in General; LFN - Low Frequency Noise)

		Reference noise		Low freq. Noise	
		Phase A	*Phase B*	*Phase A*	*Phase B*
Number of lines read	**All subjects**	**134**	**133**	**136**	**137**
	High-sensitive LFN [3]	126	131	132	129
	Low-sensitive LFN [3]	144	136	141	148
	High-sensitive NG [4]	128	135	139	134
	Low-sensitive NG [4]	139	132	133	140
Correct marks/line	**All subjects**	**0.07**	**0.07**	**0.07**	**0.06**
	High-sensitive LFN	0.07	0.063	0.07	0.06
	Low-sensitive LFN	0.08	0.07	0.07	0.07
	High-sensitive NG	0.07	0.07	0.07	0.06
	Low-sensitive NG	0.07	0.06	0.07	0.07
Erroneous corrections/line	**All subjects [1]**	**0.06**	**0.06**	**0.06**	**0.04**
	High-sensitive LFN	0.05	0.05	0.06	0.04
	Low-sensitive LFN	0.06	0.07	0.06	0.04
	High-sensitive NG	0.05	0.05	0.05	0.04
	Low-sensitive NG	0.06	0.07	0.06	0.05
Total marks/line	**All subjects [1,2]**	**0.13**	**0.13**	**0.13**	**0.10**
	High-sensitive LFN	0.13	0.12	0.13	0.10
	Low-sensitive LFN	0.13	0.14	0.13	0.11
	High-sensitive NG	0.12	0.12	0.12	0.09
	Low-sensitive NG	0.13	0.13	0.14	0.11

[1]: A significant two-way interaction between noise and phase.
[2]: A significant difference between the phases.
[3]: A significant three-way interaction between noise, phase and sensitivity to low frequency noise.
[4]: A significant three-way interaction between noise, phase and sensitivity to noise in general.

During the bulb-task, Table 4, subjects high-sensitive to low frequency noise had, regardless of noise exposure, a longer response time than low-sensitive subjects (2674 ms compared with 2150 ms, $F(1,30)=7.545$, $p<0.01$). No significant difference was found for subjects categorised according to general noise sensitivity.

The results of the *proof-reading task* are given in Table 5.

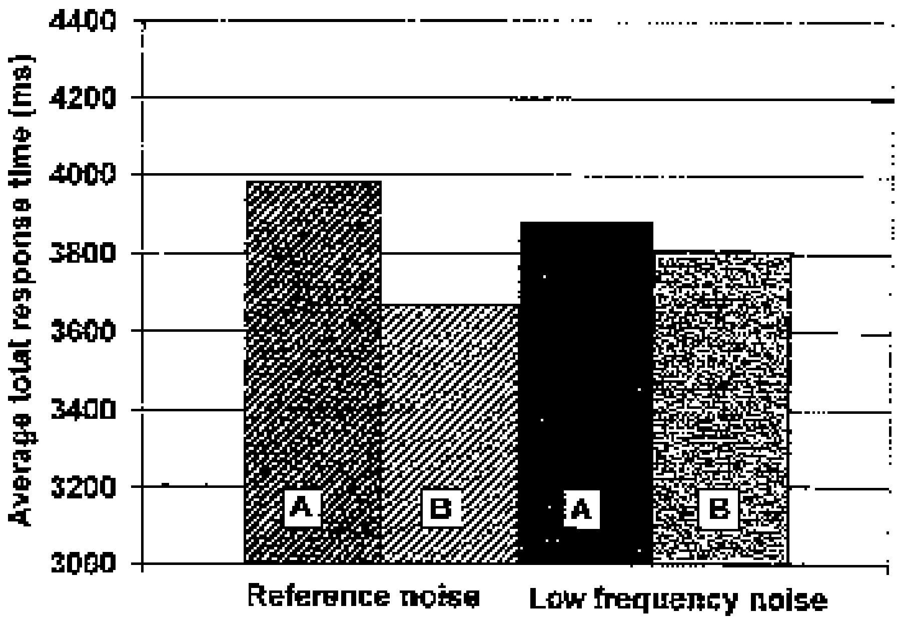

Figure 2. The average total response times (ms) of the verbal grammatical reasoning task in phases A and B, during exposure to reference noise and low frequency noise.

No significant effect of the different noise exposures was found on *number of correct marks per line.*

A significant two-way interaction between noise and phase, ($F(1,31)= 10.069$, $p<0.005$), was found for the *number of erroneous corrections per line.* The number of erroneous corrections was lower during phase B in low frequency noise, but not during reference noise. A two-way interaction between noise and phase was also found for *total marks (correct and erroneous) per line*, ($F(1,31)=7.018$, $p<0.05$).

Regardless of noise exposure, subjects high-sensitive to low frequency noise made slightly fewer total marks per line than low-sensitive subjects. This tendency was the same in both noise conditions. Subjects high-sensitive to low frequency noise also read fewer lines than low-sensitive subjects (on average 129 lines compared with 142 lines). There was a significant three-way interaction between noise phase and low frequency noise sensitivity ($F(1,30)=5.306$, $p<0.05$). Subjects high-sensitive to low frequency noise read a larger number of lines in phase B as compared to phase A during reference noise conditions and a lower number of lines in phase B compared to phase A during low frequency noise conditions. The reverse was seen for low-sensitive subjects.

The same analysis with subjects categorised according to general noise sensitivity showed partly different results. The difference in numbers of lines read, was not present (134 lines for high-sensitive subjects as compared with 136 among low-sensitive). The interaction between noise, phase and sensitivity was significant $F(1,30)=7.976$, $p<0.01$), but the pattern of a lower number of lines read for subjects high-sensitive to low frequency noise was not seen for subjects high-sensitive to noise in general.

The results of the *verbal grammatical reasoning task* are shown in Figures 2 and 3.

The total response times for phases A and B were 3.8 s for the low frequency noise condition and 3.6 s for the reference noise condition. Figure 2 demonstrates that no difference in total response time was found between noise conditions in phase A. The mean response time was shorter during phase B as compared to phase A in both noise conditions (3.7 s versus 3.9 s, $F(1,31)=9.014$, $p<0.01$), but the decrease in response time in phase B was less pronounced during the low frequency noise conditions. This

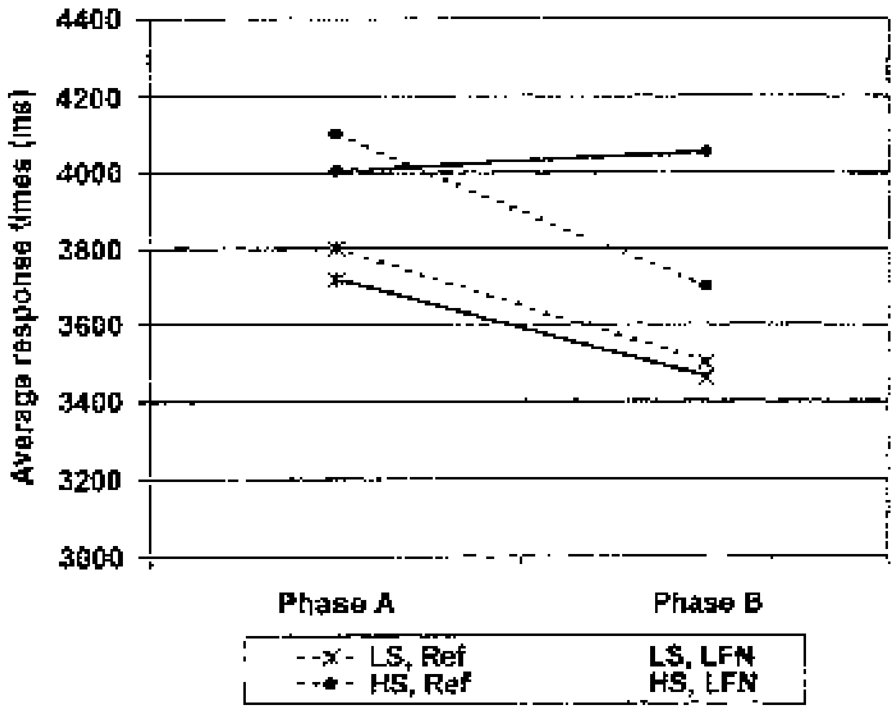

Figure 3. Average response times (ms) of the verbal grammatical reasoning task in phases A and B for subjects high-sensitive (HS) or low-sensitive (LS) to low frequency noise, during exposure to reference noise and low frequency noise.

two-way interaction between noise and phase was significant ($F(1,31)=5.750$, $p<0.05$).

Subjects high-sensitive to low frequency noise had on average a similar response time between noises in phase A. Figure 3 shows that the difference in response time during low frequency noise and reference noise conditions was larger in phase B, and a tendency to a three-way interaction between low frequency noise sensitivity, noise and phase was found ($F(1,30)=3.319$, $p=0.078$). For subjects categorised as high-sensitive to noise in general, no difference between the noise conditions was detected.

In summary, the main results from the performance tasks were that during work with the proof reading task a lower number of erroneous marks as well as total marks were made during low frequency noise. During work with the verbal grammatical task subjects showed a greater improvement over time during reference noise exposure compared to low frequency noise exposure.

Table 6. The average value of rated effort for three of the tasks, for all subjects and for the two different noise conditions.

Noise condition	Short-term memory task	Proof-reading task	Verbal gram. reasoning task
Reference noise	3.2	2.7	3.8
Low freq. noise	3.2	2.9	3.8

Subjective estimations

The average rated effort for the short-term memory task, the proof-reading task and the verbal grammatical reasoning task is given in Table 6.

As can be seen, the rated effort was lowest for the proof-reading task and equivalent to "some effort" to "moderate effort". The highest rating was given for the verbal grammatical reasoning task, which scored closest to the category of "rather much effort". No significant difference was found between the noise conditions on rated effort during the proof-reading task or the verbal grammatical reasoning task. For the short-term memory task, however, a two-way interaction between noise and phase was found ($F(1,31)=4.307$, $p<0.05$). The interaction was due to the task being rated as more effort demanding in phase B as compared to phase A during the reference noise condition, while the subjects rated the same effort in both phases during the low frequency noise.

Subjects high-sensitive to low frequency noise rated, regardless of noise, more effort than low-sensitive subjects on the proof-reading task and the verbal grammatical reasoning task (3.1 versus 2.4; $F(1,30)=4.371$, $p<0.05$ and 4.1 versus 3.4; $F(1,30)=5.886$, $p<0.05$).

The low frequency noise was on average rated as more annoying than the reference noise (2.5 versus 2.0; $F(1,31)=9.922$, $p<0.005$). Furthermore, there was a two-way interaction between low frequency noise sensitivity and noise ($F(1,30)=6.534$, $p<0.05$). Subjects high-sensitive to low frequency noise were more annoyed by the low frequency noise than by the reference noise (3.1 compared to 2.3), while low-sensitive subjects reported on average the same annoyance after both noises (1.6). No significant difference between noises was found when the same analysis was done with subjects categorised according to general noise sensitivity.

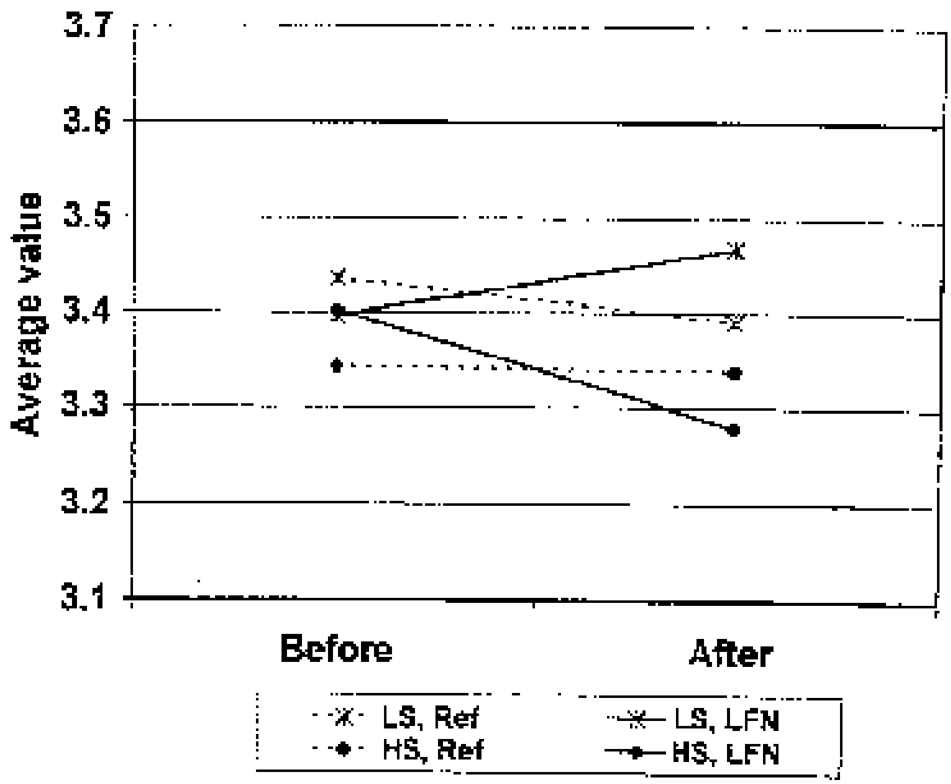

Figure 4. The average values of control before and after the test sessions for reference noise and low frequency noise, related to the two low frequency noise sensitivity groups. Key as Figure 3.

Low frequency noise was on average considered to impair the working capacity more than the reference noise (5.2 versus 4.8; $F(1,31)=6.808$, $p<0.05$). When the data was subdivided into the two noise sensitivity groups, no significant effect due to noise condition could be detected.

No significant main effect of noise condition was found for the mood dimensions. There was, however, a significant three-way interaction between noise, phase and low frequency noise sensitivity ($F(1,29)=4.352$, $p<0.05$) for perception of "being in control" (Figure 4). The figure demonstrates that the high-sensitive subjects' perception of being in control was lower after (3.3), as compared to before (3.4) the exposure to low frequency noise. The opposite results were found for low-sensitive subjects (3.5 after compared to 3.4 before). A tendency to the same three-way interaction, between noise, phase and low frequency noise sensitivity, was present for "activation" ($F(1,29)=3.837$, $p=0.06$). The interaction showed a lower value for perception of activation during both noise conditions for subjects high-sensitive and subjects low-sensitive to low frequency noise, but the decrease was greater for high-sensitive subjects during the low frequency noise condition. However, when the analysis on control and activation was conducted with subjects categorised according to general noise sensitivity, these effects were not present.

No significant main effect of noise condition was found for the different symptoms.

In summary, the main results from the subjective estimations were that the low frequency noise was rated as more annoying and also considered to impair working capacity more than the reference noise. No direct effects of noise condition for symptoms were found.

Relations between performance and subjective estimations

Impaired working capacity due to reference noise exposure was negatively correlated to number of lines read in phase A (r_{xy} -0.495, $p<0.005$).

A significant correlation was also found between rated tiredness and response time in the verbal grammatical reasoning task in phase B during low frequency noise ($r_{xy}=0.524$, $p<0.005$). For the reference noise, there was a correlation between response time in the simple reaction-time task in phase B and headaches ($r_{xy}=0.517$, $p<0.005$).

Impaired working capacity due to low frequency noise exposure was significantly correlated to lack of concentration ($r_{xy}=0.507$, $p<0.005$), nausea ($r_{xy}=0.460$, $p<0.01$), tiredness ($r_{xy}=0.471$, $p<0.01$) and a feeling of pressure on the head ($r_{xy}=0.494$, $p<0.005$). No significant correlation between noise impairment due to reference noise and symptoms was found.

Annoyance due to low frequency noise was correlated to subjective estimation of the following symptoms: a feeling of pressure on the head ($r_{xy}=0.664$, $p<0.001$), tiredness ($r_{xy}=0.519$, $p<0.005$), dizziness ($r_{xy}=0.519$, $p<0.005$), and lack of concentration (r_{xy} = 0.537, $p<0.005$). Reference noise annoyance was correlated only to nausea ($r_{xy}=0.522$, $p<0.005$).

In summary, relationships between annoyance respectively impaired performance and several symptoms were found after work in low frequency noise, while a relationship between annoyance and nausea was found after work in reference noise.

Discussion

The experiment was designed to test the effects of low frequency noise in a situation requiring an increased level of attention and awareness for a fairly prolonged time period. As the experiment was performed under laboratory conditions, the relevance of the results for normal working conditions must be evaluated with care. Alterations in performance found under experimental conditions could incorporate a bias induced by the experimental situation and particularly by the acute exposure conditions (Rylander and Persson Waye 1997). On the other hand, tiredness and decrease in performance induced by a particular environmental stimulus, in this case low frequency noise, would probably have a low level of adaptation and transfer into effects that could be registered in real life after long-term exposure.

The results indicate that low frequency noise, at levels normally occurring in office and control rooms, could negatively influence performance in more demanding verbal tasks, while the effects on the routine tasks were less clear. Decreases in performance on verbal tasks and on tasks that put high demands on information processing have previously been reported in other studies using other types of noise exposures and at higher noise levels [e.g. reviews Smith 1989; Smith and Jones 1992; Kjellberg and Landström 1994]. Importantly, this study used lower noise levels. This was done in order to address the impact of less intense, but more widespread noise. In spite of the comparatively low noise levels, significant differences in performance could be detected and related to the content of low frequencies in the noise. This supports the previous hypothesis [Persson Waye 1995] that different mechanisms mediate the effects on performance under conditions of exposure to low frequency noise as compared to higher frequency noise.

The decrease in response-time over time during work with the verbal grammatical reasoning task was larger in reference noise, indicating a higher learning effect in this noise condition. This together with the results from the proof-reading task, where subjects made fewer total marks over time during exposure to low frequency noise, give some support for the hypothesis that low frequency noise is more difficult to ignore or to habituate to [Benton 1997a; Benton 1997b]. The larger decrease in response time during the verbal grammatical reasoning task in phase B during exposure to reference noise indicates a higher learning effect during the reference noise condition as compared with the low frequency noise condition. Less habituation to low frequency noise may reduce the available information processing resources, and may lead to higher competition between available resources, which would interfere with cognitive processing abilities. The observation that the effects appeared in the second phase of the experiment supports this hypothesis, as the effort to cope in low frequency noise would develop over time and thus be more strenuous over time.

In the proof-reading task, fewer total marks per line read and fewer erroneous corrections per line read were found during the low frequency noise condition in phase B. The tendency to make fewer total marks per line read could be a result of a less thorough treatment of the text material. Such coping strategies for contextual errors per line read have previously been reported by Weinstein [1974; 1977], while he did not find an effect on the number of non-contextual errors as a result of noise exposure. In the study presented here, the total number of marks was rather few and it was thus not meaningful to subdivide the analysis into contextual and non-contextual errors.

The comparatively longer response time over time seen for the verbal grammatical reasoning task during the low frequency noise condition is in agreement with previous findings [Persson Waye et al. 1997]. In that study, a tendency towards longer response time over time was found in the low frequency noise condition, using the same performance task and exposure noises as used in this experiment but involving a smaller number of test subjects. The simple reaction-time task has previously been found to be sensitive to tiredness [Kjellberg et al. 1998]. In this study, a difference between noise conditions for this task was only found for subjects high-sensitive to noise in general. This moderate effect is comprehensible as the design of the study aimed to generate a high and correct work load and the exposure time was limited to two hours. To evaluate tiredness, further studies should be carried out involving subjects working at their own pace and during a longer exposure time.

Few other studies have previously investigated performance after exposure to low frequency noise. Benton and Leventhall [1986] found that exposure to pure tones (centred at 40 Hz and 100 Hz, modulated at 1 Hz and a narrow band centred at 70 Hz at a level of 25 dB above the individual threshold) gave rise to more errors as compared with exposure to traffic noise at 90 dB lin. or silence. The effects were especially pronounced during the last 10 minutes of the total 30-minutes exposure. Some support for impaired performance caused by low frequency noise was also given by Benton and Robinson [1993]. Previous studies are thus in agreement with the findings presented here, but further studies need to be carried out to evaluate more specifically how low frequency noise affects performance and which tasks or situations that are most vulnerable for noise interference.

The results do not give direct support for the hypothesis that low frequency noise would induce different symptoms that could impair performance. No direct effects of noise condition on symptoms, or clear relationships between symptoms and performance effects, were found. However, the relationships between symptoms and annoyance respectively, symptoms and impaired performance, were particularly frequent after work in the low frequency noise condition, while for the reference noise a relationship was found only between annoyance and nausea. Although the study is not able to predict whether symptoms impair performance or whether the strain of performing during the low frequency noise condition could lead to a development of symptoms, the findings support a link between symptoms and the experience of impaired performance.

The reasons for choosing the specific low frequency noise used in this study was to achieve a noise that resembled a realistic ventilation noise, which often includes a tonal component and a modulation characteristic [Broner 1994]. The effects observed after low frequency noise could be related to specific acoustical characteristics such as amplitude modulation and the tonal character at 31.5 Hz. In one study, the presence of modulations was found to lead to increased sleepiness [Persson Waye et al. 1997], but the influence of a tonal character in the low frequency range has been shown to be of little or no importance for annoyance, reduced wakefulness or performance [Landström et al. 1991; Landström et al. 1995; Holmberg et al. 1993]. While the presence of amplitude modulations thus could have increased the effects, the tonal character was of less importance.

Subjects high-sensitive to low frequency noise generally performed less well and also reported the highest annoyance due to low frequency noise. In other studies, subjects high-sensitive to noise in general have been found to have the lowest performance accuracy during exposure to traffic noise [Belojevic et al. 1992]. Interestingly, this study also indicate that the response between the two categorisations of sensitivity to low frequency noise and sensitivity to noise in general were partly different. Some of these differences were found regardless of noise exposure, such as the difference in response time in the simple reaction-time task found using the categorisation of sensitivity to low frequency noise, while this difference was not found using the categorisation of sensitivity to noise in general. Other differences were related to noise exposure, such as the longer response time found in phase B during low frequency noise on the verbal grammatical reasoning task, for subjects high-sensitive to low frequency noise, while no difference between noise conditions was found using the categorisation according to sensitivity to noise in general. Differences related to noise exposure were also found for some of the subjective responses such as a higher rating of annoyance and lower perception of control among subjects high-sensitive to low frequency noise, while this difference was not found using the categorisation according to sensitivity to noise in general.

While the results from the study show that subjects categorised as high-sensitivity to noise in general or to low frequency noise generally gave a higher subjective rating of annoyance and impaired working capacity, the difference caused by noise exposure upon performance and subjective estimations was most obvious among subjects categorised with regard to sensitivity to low frequency noise. This agrees with previous observations that low frequency noise sensitivity is a specific issue. The validity and practical relevance of these characteristics should be further evaluated for effects caused by low frequency noise.

In conclusion, the study supports a hypothesis that low frequency noise at levels normally occurring in office-like environments may influence work performance and subjective perception of annoyance and lead to work impairment. The study also points to the importance of including factors related to individual sensitivity to noise when evaluating effects. According to the results obtained here, subjects categorised as high-sensitive to low frequency noise seem to be at highest risk.

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References

Aladdin interactive work-bench, Nyvalla DSP, Stockholm, Sweden.

Baddeley A.D. (1968) A 3 min reasoning task based on grammatical transformation. Psychon. Sci. 10: 341-342.

Belojevic G., Öhrström E. and Rylander R. (1992) Effects of noise on mental performance with regard to subjective noise sensitivity. Int. Arch. Occup. Environ. Health. 64: 293-301.

Benton S. and Leventhall H.G. (1986) Experiments into the impact of low level, low frequency noise upon human behaviour. J. Low Freq. Noise Vibr. 5: 143-162.

Benton S. and Robinson G. (1993) The effects of noise on text problem solving for the word processor user (WPU). Noise and man 1993. Proceedings of the 6th International Congress on Noise as a Public Health Problem, Nice, France. pp 539-541.

Benton S. (1997a) Measurement challenges in assessing the annoying characteristics of noise. Is low Frequency noise a special case? J. Low Freq. Noise Vibr. 16: 15-24.

Benton S. (1997b) Low frequency noise and the impact upon individual's quality of life: Case study reports. J. Low Freq. Noise Vibr. 16: 203-208.

Berglund B., Hassmén P. and Soames Job R.F. (1994) Health effects induced by low frequency noise: A critical review. Archives of the Center for Sensory Research. 1: 1-28.

Berglund B., Lindvall T., Schwela D. and Goh K-T. (2000) Guidelines for Community Noise. World Health Organization. ISBN: 9971-88-770-3.

Broner N. (1994) Determination of the relationship between low frequency HVAC noise and comfort in occupied spaces – objective phase. ASHRAE 714-RP, Vipac Report 38114.

Gamberale F., Iregren A. and Kjellberg A. (1989) SPES: The computerized Swedish Performance Evaluation System. Background, critical issues, empirical data and users manual. Arbete och Hälsa, National Board of Occupational Safety and Health, Solna, Sweden.

Hockey G.R.J. (1986) Changes in operator efficiency as a function of environmental stress, fatigue, and circadian rhythms. In: Boff KR, Kaufman L & Thomas JP eds. Handbook of perception and performance. Vol. II. Cognitive process and performance, Wiley, New York, chapter 44: pp 1-49.

Holmberg K., Landström U. and Kjellberg A. (1993) Effects of ventilation noise due to frequency characteristics and sound level. J. Low Freq. Noise Vibr. 12: 115-122.

ISO 389-7:1996. Acoustics Reference zero for the calibration of audiometric equipment Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.

Jelinkova Z. (1988) Coping with noise in noise sensitive subjects. Proceedings from the 5th International Congress on Noise as a Public Health problem, Stockholm, Sweden, August 21-25, pp 27-30.

Jones D. (1990) Recent advances in the study of human performance in noise. Environ. Int. 16: 447-458.

Kjellberg A. and Iwanowski S. (1989) The stress/energy questionnaire – Development of a method to evaluate estimations of mood at work. National Institute of Occupational Health. Report 1989:26 (In Swedish).

Kjellberg A. and Landström U. (1994) Noise in the office: Part II - The scientific basis (knowledge base) for the guide. Int. J. Indust. Ergonomics. 14: 93-118.

Kjellberg A. and Wide P. (1988) Effects of simulated ventilation noise on performance of a grammatical reasoning task. Proceedings of the 5th International Congress on Noise as a Public Health Problem, Stockholm, Sweden. August 21-25, pp 31-36.

Kjellberg A., Muhr P. and Sköldström B. (1998) Fatigue after work in noise – an epidemiological survey study and three quasi-experimental field studies. Noise & Health, 1: 47-55.

Landström U., Byström M., Kjellberg A. and Nordström B. (1997) Performance and annoyance during exposure for amplitude-modulated noise at different noise levels. National Institute of Occupational Health. Report 1997:15 (In Swedish).

Landström U. (1987) Laboratory and field studies on infrasound and its effects on humans. J. Low Freq. Noise Vibr. 6: 29–33.

Landström U., Byström M. and Nordström B. (1985) Changes in wakefulness during exposure to noise at 42 Hz, 1000 Hz and individual EEG frequencies. J. Low Freq. Noise Vibr. 4: 27-33.

Landström U., Lundström R. and Byström M. (1983) Exposure to infrasound- perception and changes in wakefulness. J. Low Freq. Noise Vibr. 2: 1-11.

Landström U., Kjellberg A., Söderberg L. and Nordström B. (1991) The effects of broadband, tonal and masked ventilation noise on performance, wakefulness and annoyance. J. Low Freq. Noise Vibr. 10: 112-122.

Landström U., Åkerlund E., Kjellberg A. and Tesarz M. (1995) Exposure levels, tonal components and noise annoyance in working environment. Environment International, 21: 265-275.

Nagai N., Matsumoto M., Yamasumi Y., Shiraishi T., Nishimura K., Matsumoto K., Miyashita K. and Takeda S. (1989) Process and emergence on the effects of infrasonic and low frequency noise on inhabitants. J. Low Freq. Noise Vibr. 8: 87-99.

Persson Waye K. (1995) Doctoral Thesis, Göteborgs University, ISBN 91-628-1516-4. On the effects of environmental low frequency noise.

Persson Waye K. and Rylander R. (2001) The prevalence of annoyance and effects after long term exposure to low frequency noise. J. Sound Vib. 240: 483-497.

Persson Waye K., Rylander R., Benton S. and Leventhall H.G. (1997) Effects on performance and work quality due to low frequency ventilation noise. J. Sound Vib. 205: 467-474.

Persson Waye K., Björkman M., Hellström P-A. and Rylander R. Acute effects of low frequency noise in relation to susceptibility to low frequency noise. (Submitted) J. Sound Vib 1997.

Persson Waye K., Bengtsson J., Rylander R., Hucklebridge F., Evans P. and Clow A. Low frequency noise enhances cortisol among noise sensitive subjects during work performance. (In press) Life Science 2001.

Rylander R. and Persson Waye K. (1997) Human perception of environmental noise in acute and chronic exposure conditions. Proceedings of Inter Noise. Budapest, Hungary 25-27 August. pp 971-976.

Sjöberg L., Svensson E. and Persson L.O. (1979) The measurement of mood. Scand. J. Psychol. 20: 1-18.

Smith AP. (1989) A review of the effects of noise on human performance. Scand. J. Psychol. 30: 185-206.

Smith AP. and Jones D.M. (1992) Noise and performance. In D.M. Jones and AP Smith eds, Handbook of Human Performance, Vol 1: The Physical Environment. Academic Press, London, pp 1-28.

SPSS base 10.0 for Windows.

Tokita Y. (1980) Low frequency noise pollution problems in Japan. Proceedings of the Conference Low frequency noise and hearing, Aalborg, Denmark. pp 189-196.

Weinstein N.D. (1974) Effects of noise on intellectual performance. J. Appl. Psychol. 59: 548-554.

Weinstein N.D. (1977) Noise and intellectual performance: A confirmation and extention. J. Appl. Psychol. 62: 104-107.

Weinstein N.D. (1978) Individual differences in reactions to noise: A longitudinal study in a college dormitory. J. Appl. Psychol. 63: 458-466.

79

STATE OF NEW YORK

SUPREME COURT CLINTON COUNTY

- X

Amy Filion and Dinah Miller,

Petitioners

AFFIDAVIT

-against-

Index No.______

Town of Clinton Town Board,

Respondent

- X

STATE OF NEW YORK,)

) ss.:

COUNTY OF CLINTON)

Nina Pierpont, MD, PhD, being duly sworn, deposes and says:

1. I have become aware of additional important health information related to industrial wind turbines since the submission of the Article 78 lawsuits and wish to add this information to the suits.

2. An international research group centered in Portugal and including physicians from Poland, Russia, and the United States has published extensively on the effects of low-frequency noise on parts of the body other than the ears, particularly on the cardiovascular, pulmonary, and neurological systems.[1] The research includes clinical, pathological, and experimental (animal model) work, and has been ongoing since the late 1980's. The entity these physicians and PhD's describe, called vibroacoustic disease (VAD), includes fibrosis (laying down of additional fibrous thickening in the form of collagen) in the cardiovascular and pulmonary systems, and seizures and cognitive changes in the brain. The disease is caused by long-term exposure to low-frequency noise (less than 500 Hz), most of which cannot be heard.

3. Vibroacoustic disease has been studied mostly in aviation workers (including pilots and flight attendants as well as technicians), but is also found in other industries and community settings. One of the researchers, Mariana Alves-Pereira, PhD, a biomedical engineer, has recently compared the noise spectrum of an environment known to predispose occupants to VAD – the cockpit of a commercial jetliner – to the noise spectrum of other common community settings, finding that a variety of community settings have the low-frequency noise potential for causing VAD. She has examined noise measurements of industrial wind turbines provided to her by Dr. Amanda Harry (a physician) and Dr. Manley (an acoustician) in England and found them to be in the intensity range, at the low frequencies, of noise which can cause VAD. She has also examined graphs of wind turbine sound pressure levels vs. frequency measured by Dr. G.P. van den Berg and considers the noise intensities at the lower frequencies to be concerning with regard to their potential for causing VAD. She is aware of the symptomatology of the D'Entremont family in Pubnico, Nova Scotia, who had to move out of their home 1000 ft. from a wind turbine, and

[1] Papers submitted are a selection from many:

1. Branco M and Alves-Pereira M. 2004. Vibroacoustic disease. Noise and Health 6 (23):3-20.
2. Alves-Pereira M. 1999. Noise-induced extra-aural pathology: a review and commentary. Aviat Space Environ Medication 70 (3 Pt 2):A7-21.
3. Marciniak W et al. 1999. Echocardiographic evaluation of 485 aeronautical workers exposed to different noise environments. 1999. Aviat Space Environ Medication 70 (3 Pt 2):A46-53.

notes the similarity of their symptoms to those of people with proven VAD. We are working to provide her with noise measurements from additional wind turbine installations.

4. Dr. Alves-Pereira's papers are very instructive with regard to how neighbors and town governments should be handling the issues of noise and noise measurements related to wind turbines. An A-weighted decibel measurement misses all the low-frequency noise, since A weighting is specifically designed to mimic the frequency response pattern of the human ear. The frequencies which are harmful to other parts of the body, for example the heart, lungs, and brain, generally cannot be heard. Just as we cannot detect X rays (because our eyes are not sensitive to this frequency), yet can be harmed by them, so we can be harmed by non-audible noise (pressure waves in the air), though our ears are not sensitive to them. The mechanism of this harm is the differing resonance frequencies of different parts of the human body, especially the chest and skull. Air pressure (sound) waves of certain wavelengths resonate inside these walled spaces, setting up vibrations to which the body responds by reinforcing its softer tissues with extra collagen, causing such problems as thickening of the pericardium (membrane inside which the heart beats) and cardiac valves, fibrosis of the lungs, and proliferation of glial (supporting) cells in the brain.

5. The Ellenburg and Clinton wind turbine ordinances are inadequate to protect the citizenry from the potential ill health effects of low-frequency noise from wind turbines. The ordinances do not place any restriction on the production of low-frequency noise, since they restrict only the A-weighted decibel level, which excludes low-frequency noise. Rather than a single decibel level the noise environment needs to be characterized by measurement of linear (unweighted) decibel levels across the sound frequency spectrum. Measurements should be taken inside homes, since the lower frequency, longer wavelengths also resonate within rooms, magnifying their loudness relative to the outside. Low frequency noise also comes through walls with less attenuation than the 15 dB decrease assumed for higher frequency audible noise.

6. The ordinances also allow for an averaged noise level reading (Leq), not recognizing that it is the peaks of noise, not the average, which will be most annoying and most harmful.

7. In short, the sections of the Clinton and Ellenburg wind turbine ordinances need to be revised in order to protect their citizens against the risk of serious, long-term pathology due to the low-frequency component of wind turbine noise.

Nina Pierpont, MD, PhD
19 Clay Street
Malone, New York 12953
(518) 483-6481

Sworn to before me this
day of April, 2006

Notary Public

Table 1. Data from a group of 140 aircraft technicians (selected from an initial group of 306 workers), occupationally exposed to LFN (Low Frequency Noise)(8 hrs/day, 5 days/week). Exposure time (in years) refers to the amount of time it took for 70 individuals (50%) to develop the corresponding sign or symptom (Castelo Branco, 1999b).

Clinical Stage	Sign/Symptom
Stage I-Mild (1 -4 years)	Slight mood swings, Indigestion and heart-burn, Mouth/throat infections, Bronchitis
Stage II-Moderate (4- 10 years)	Chest pain, Definite mood swings, Back pain, Fatigue, Fungal, viral and parasitic skin infections, Inflammation of stomach lining, Pain and blood in urine, Conjunctivitis, Allergies
Stage III-Severe (> 10 years)	Psychiatric disturbances, Haemorrhages of nasal, digestive and conjunctive mucosa, Varicose veins and haemorrhoids, Duodenal ulcers, Spastic colitis, Decrease in visual acuity, Headaches, Severe joint pain, Intense muscular pain, Neurological disturbances [include seizures & decreased cognition]

*Note: Where there is nighttime as well as daytime exposure to low frequency noise (LFN), the symptoms and pathology progress more rapidly, according to Dr. Mariana Alves-Pereira.

Source: N. Branco & M. Alves-Pereira, "Vibroacoustic disease," Noise & Health, vol. 6, no. 23 (April-June 2004):3-20.

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Sources and effects of low-frequency noise

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The sources of human exposure to low-frequency noise and its effects are reviewed. Low-frequency noise is common as background noise in urban environments, and as an emission from many artificial sources: road vehicles, aircraft, industrial machinery, artillery and mining explosions, and air movement machinery including wind turbines, compressors, and ventilation or air-conditioning units. The effects of low-frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficacy of many structures (dwellings, walls, and hearing protection) in attenuating low-frequency noise compared with other noise. Intense low-frequency noise appears to produce clear symptoms including respiratory impairment and aural pain. Although the effects of lower intensities of low-frequency noise are difficult to establish for methodological reasons, evidence suggests that a number of adverse effects of noise in general arise from exposure to low-frequency noise: Loudness judgments and annoyance reactions are sometimes reported to be greater for low-frequency noise than other noises for equal sound-pressure level; annoyance is exacerbated by rattle or vibration induced by low-frequency noise; speech intelligibility may be reduced more by low-frequency noise than other noises except those in the frequency range of speech itself, because of the upward spread of masking. On the other hand, it is also possible that low-frequency noise provides some protection against the effects of simultaneous higher frequency noise on hearing. Research needs and policy decisions, based on what is currently known, are considered. © *1996 Acoustical Society of America.*

PACS numbers: 43.50.Qp, 43.28.Dm

SOURCES AND EFFECTS OF LOW-FREQUENCY NOISE

The industrialization and mobilization of human endeavor have led to increased noise production across the full range of noise frequencies, leading to a global problem of reduced human well-being due to noise (see, e.g., Hede and Bullen, 1982; Kihlman, 1993; Schultz, 1978; WHO, 1980). The effects of noise on humans have been extensively reviewed, but apart from hearing loss (King *et al.*, 1992; Kryter, 1985, 1994; Ward, 1993) and annoyance (Fidell *et al.*, 1991; Job, 1988) are not uniformly agreed upon (Andersson and Lindvall, 1988; Berglund *et al.*, 1986; Berglund *et al.*, 1990). Low-frequency noise is a common component of occupational and residential noise which has received less attention. However, low-frequency noise has features not shared with noises of higher pitch. Low-frequency noise (infrasound included) is the superpower of the frequency range: It is attenuated less by walls and other structures; it can rattle walls and objects; it masks higher frequencies more than it is masked by them; it crosses great distances with little energy loss due to atmospheric and ground attenuation; ear protection devices are much less effective against it; it is able to produce resonance in the human body; and it causes great subjective reactions (in the laboratory and in the community studies) and to some extent physiological reactions in humans than mid- and high frequencies. These features dictate that the effects of low-frequency noise deserve independent attention. The present review considers low-frequency noise exposures and their physical, physiological, and psychological effects on humans.

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I. DEFINITION OF LOW-FREQUENCY NOISE

The range of human hearing is generally considered to be 20–20 000 Hz for young individuals, the upper limit declining with increasing age. Frequencies above 20 kHz (ultrasound) are generally considered to be inaudible by convention (see Kryter, 1985, p. 456), even though frequencies up to 30 kHz have been "heard" through bone conduction (as cited by Yeowart, 1976). The focus of the present review is on the lower end of the frequency spectrum. In selecting the frequency range, we decided to treat low-frequency noise as including what is normally taken to be infrasound (see Fig. 1).

There are three reasons for this decision. First, sound below 20 Hz is generally termed infrasound and not included in low-frequency noise on the grounds that it is inaudible (see, e.g., Backteman *et al.*, 1983a). However, sound below 20 Hz can be perceived by humans, reflecting interindividual differences in hearing threshold. This is shown in Fig. 2,

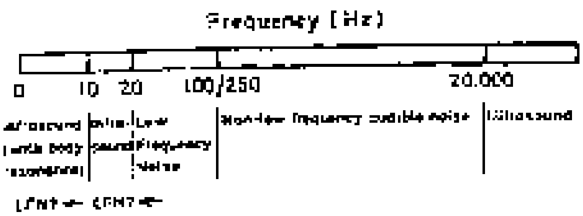

FIG. 1. The frequency spectrum of sound and its nomenclature.

which presents a compilation of hearing thresholds as a function of signal frequency.

The setting of the arbitrary lower limit of human hearing determines the lower limit of low-frequency noise and the upper bound of infrasound. Such a setting is not a matter of absolutes. The threshold of hearing for tones and frequency bands depends on the loudness as well as the frequency and duration. In this sense, logically, human hearing capacity extends well below the 20-Hz range if one considers a signal that is sufficiently loud (see Fig. 2). Thus the threshold of absolute hearing extends well into the nominal infrasound range. It has been suggested that at very low frequencies human detection does not occur through hearing in the normal sense. Rather, detection results from nonlinearities of conduction in the middle and inner ear which generate harmonic distortion in the higher, more easily audible frequency range (von Gierke and Nixon, 1976). This account does not dictate that the noise is not heard, but rather that the method of hearing is indirect, as indeed is the mechanical method of all hearing (i.e., the relevant nerves are fired by changes in other biological structures in the ear, not directly by noise itself).

Second, regardless of the process by which a sound wave is detected, it is critical to consider waves which are detected through skeletal bones, the ear, harmonics, tactile senses, or resonance in body organs. Detection raises the possibility of subjective reactions such as annoyance, and annoyance may contribute in complex ways to other biological and psychological effects of the signal (Job, 1993; Stansfeld, 1992).

Third, determination of health and other effects of low-frequency noise must consider field data. Real occurrences of low-frequency noise will often include considerable energy below 20 Hz as well as energy in what is usually considered the low-frequency noise range. Thus the arbitrary setting of a cutoff at 20 Hz is not conducive to analysis of such data.

The determination of precisely what constitutes *low-frequency* sound is also not perfectly clear in terms of its upper limit. Sound up to 250 Hz are sometimes referred to as low-frequency sound although others have set the upper limit of the range to 100 Hz (e.g., Backteman *et al.*, 1983a). Inevitably, the same problems of setting an arbitrary limit on a continuum apply to the upper limit of low-frequency noise as to the lower limit. However, given that there is no suggestion that the upper limit is in fact marked by a qualitative shift such as audibility to inaudibility, this cut point is not as critical. In the present review noise below 250 Hz is considered to constitute low-frequency noise.

As implied by the word "noise," low-frequency noise is defined as an unwanted sound containing major components within a specified frequency range. Thus it depends, among other things, upon the complex temporal pattern and intensity of the sound, which determine whether the sound will be labeled as noise or as "meaningful" sound such as music or speech. Such classification also depends on cultural factors (Kawano *et al.*, 1991), the individual (what one person hears as music another may consider unwanted sound), and on time and circumstances (a Mozart symphony may be music at dinner time but noise in the middle of the night when one is awakened from sleep; see Job, 1993).

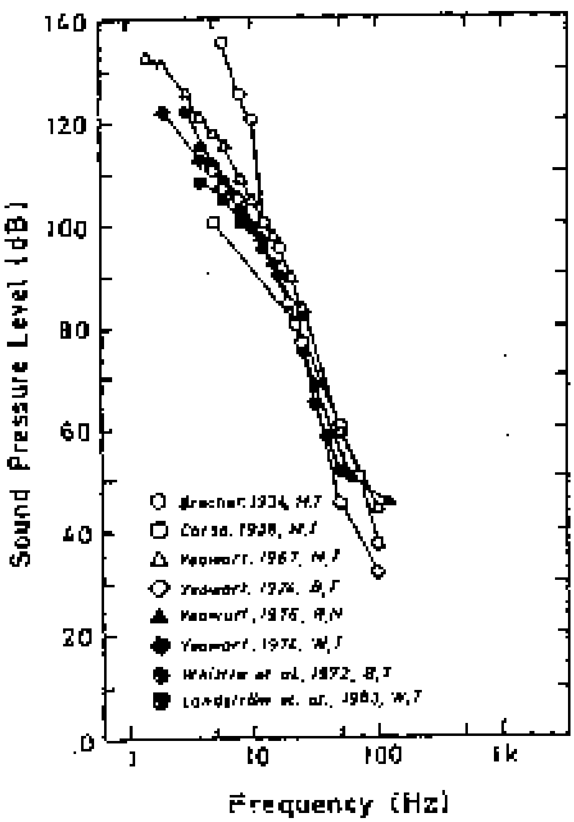

FIG. 2. Hearing thresholds as a function of signal frequency in various studies (M=monaural; B=binaural; W=whole body, T=tone; N=noise band).

II. SOURCES AND TRANSMISSION OF PROPERTIES

Sources for low-frequency noise are either of a natural origin, such as air turbulence (wind), thunder, ocean waves, volcanic eruptions, and earthquakes (von Gierke and Parker, 1976; Backteman *et al.*, 1983a), or of human origin such as heating, ventilation, air-conditioning systems, machinery, cars, trucks, airplanes, and loudspeaker systems (Blazier, 1981; Backteman *et al.*, 1983a, 1983b). In terms of effects on humans, artificial noises are more important because people react more to them (von Gierke and Parker, 1976), probably because of their attitude to the source (Job, 1988). The extent of exposure to low-frequency noise from trans-

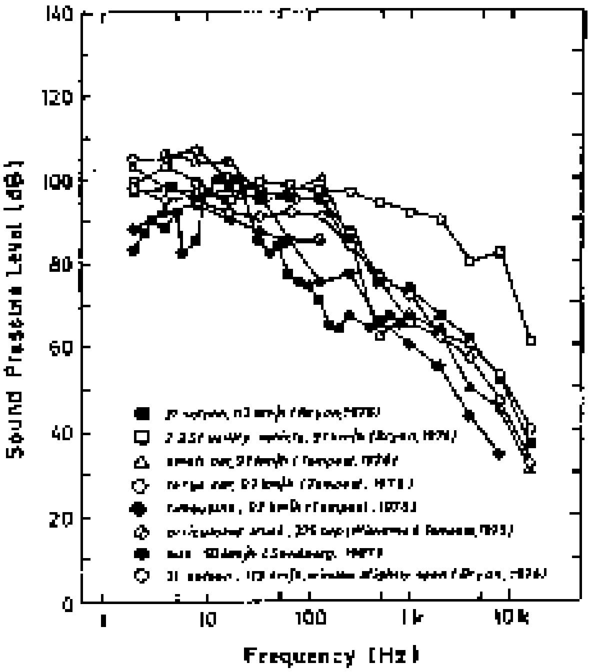

FIG. 3. Passenger noise exposure in road transportation vehicles as a function of frequency.

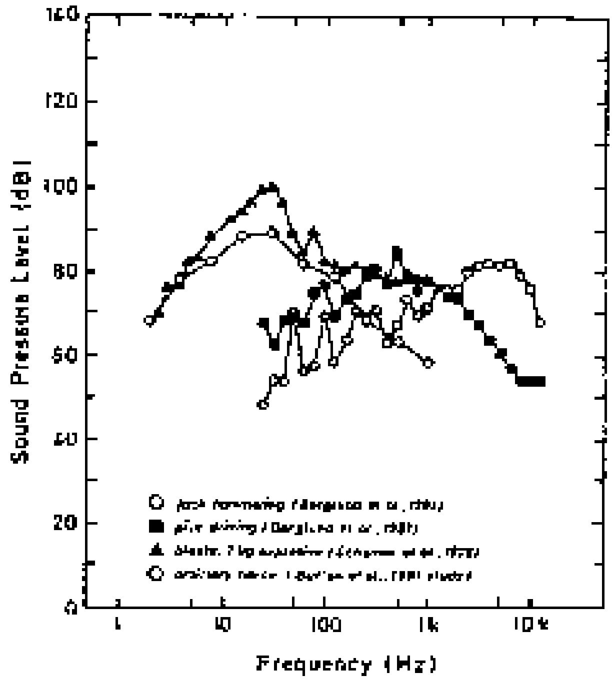

FIG. 4. Community noise exposure for impulsive sources as a function of frequency.

portation vehicles is shown in Fig. 3. The data presented in this figure indicate the extensive production of low-frequency noise by machinery, and especially transport machinery to which much of the population is exposed both inside the vehicles and while in proximity to the transportation corridor.

The data on impulsive noise sources are noteworthy because impulsive noise generates greater levels of subjective reactions such as annoyance and dissatisfaction than does nonimpulsive noise of the same energy level (Bullen *et al.*, 1991; Job, 1988; Schomer, 1981; Vos and Smoorenburg, 1985). The impulsive noise sources typically studied include quarry blasting (Fidell *et al.*, 1983; Murray and Avery, 1984), sonic booms (Kamperman, 1980; McKennel, 1978), explosions (Peploe *et al.*, 1995), and artillery (Bullen *et al.*, 1991, Schomer, 1981). Low-frequency noise exposures from various impulsive sources are presented in Fig. 4.

These data show that impulsive noise sources tend to differ from other community noise sources studied not only in their impulsiveness but also in their greater proportion of low-frequency noise. For example, the profiles of blast noise or artillery noise in Fig. 4 may be compared with the corresponding profile for road traffic noise (a commonly studied community noise) in Fig. 3.

A great proportion of low-frequency components of impulsive noises may, in part, account for a greater community reaction to some impulsive sources. The greater impact of impulsive noises with major components of low frequencies seems paradoxical, in that low frequencies themselves cannot be truly impulsive due to their long wavelengths. However, impulsive noise is a complex noise for which the time window for spectrum analysis is critical, and in addition, many impulsive sounds are fluctuating over time. Thus the present data analysis identifies a coincidence of impulsiveness and low-frequency noise in community sources rather than a physical necessity. Finally, the data on wind turbines indicate that the predominance of low-frequency noise is of particular concern for communities living close to wind turbines (Fig. 5). However, at distances of a few hundred meters the low-frequency noise is theoretically below hearing threshold.

The pervasive extent of low-frequency noise originating from machinery may result in it being experienced as a constant background noise (or so-called ambient noise), often at least partly masked by noise of higher frequencies. Figure 6 presents data on the spectrum of ambient noise in residential areas, in particular showing the magnitude of low-frequency noise in residential areas of Sydney, Australia.

Again, much but not all of the low-frequency energy is below hearing threshold (cf. Fig. 2). At times when the masking effect is reduced, due to, for example, the damping effect of walls in a building, which predominantly affects the higher frequencies, or during night time when surrounding noise is reduced, low frequencies will dominate the spectrum of perceived noise (Persson and Björkman, 1988). This is of particular concern because of the high proportion of the population who sleep at such times, and because of the evidence that sleep disturbance is of particular concern as an effect on human wellbeing (Berglund *et al.*, 1984).

Aircraft noise, a major source of community noise, also contains significant amounts of energy in the low-frequency range, as shown in Fig. 7. These data indicate that much of

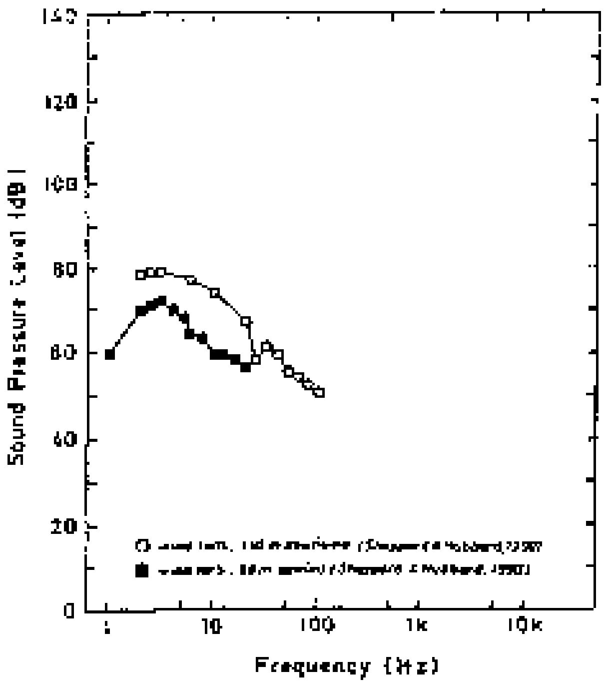

FIG. 5. Community noise exposure from wind turbines as a function of frequency.

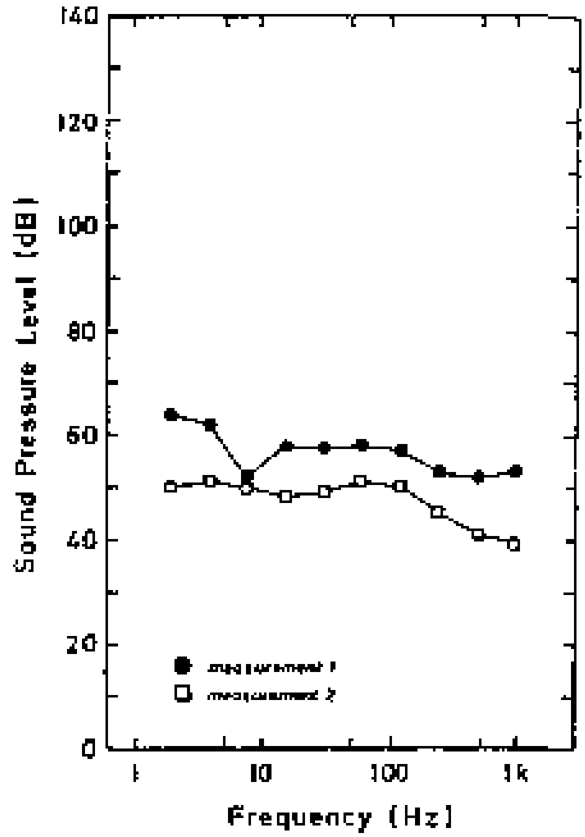

FIG. 6. Ambient noise levels as a function of frequency. The data were collected in residential areas (outdoors) around Sydney, as part of a study reported by Berglund et al. (1991). The two curves represent the background levels averaged over different measurement times at two different sites.

the low-frequency noise emanating from each of the aircraft-types recorded is audible.

In addition to general exposure to low-frequency noise (in the community and for passengers in many vehicles), substantial low-frequency noise exposure may occur at work. Figure 8 illustrates the noise spectra of air movement plants in various work environments, and identifies a predominance of low-frequency noise. Such machinery is common in many work environments other than those of heavy industry which are generally recognized to produce occupational noise problems. Thus occupational exposure to low-frequency noise may be more ubiquitous than first thought.

Transmission of low-frequency noise is noteworthy for several features which arise from its extremely long wavelengths. Low-frequency noise travels extended distances with very little energy loss. Dramatic examples attest to this claim: the sonic booms of supersonic aircraft flying between Europe and New York produce low-frequency noise levels as strong as 75 dB (Lin) as far away as the North of Sweden (Liszka, 1978); noise at 2 Hz apparently emanating from oil rigs in the North Sea also has been detected in Sweden (Liszka, 1974); low-frequency sound waves were recorded to travel around the earth several times after the volcanic eruption of Mt. Krakatoa; and a soundwave of 0.1 Hz will loose only 5% of its energy in traveling around the earth (see Backteman et al., 1983a). The consequence of this feature is that even sources which produce noise energy evenly distributed across the frequency spectrum will result in relatively more and more of the energy of the noise occurring in the lower frequency range as the distance from the source increases. For example, Bryan (1976) recorded factory boiler noise at 18 and 46 m from the source. Noise in the 31-, 63-, and 125-Hz ranges in oct suffered no detectable loss of energy between these two distances while noise in the 2-, 4-, and 8-kHz ranges each lost between 6 and 7 dB in propagation over the same distance.

The mismatch between the acoustical impedance of air and most objects, including the human body, prevents much of the sound energy from entering the ear. As the frequency of the wave is lowered, more of the energy enters the ear, the body, and other objects (von Gierke and Nixon, 1976). Thus low-frequency noise transmission extends into many objects allowing it to set up resonant vibration in our dwellings and our possessions as well as our chest cavities, sinuses, and throat.

II. PERCEPTION OF LOW-FREQUENCY NOISE AND VIBRATION

The relationship between frequency and sound-pressure level (SPL) is such that a sound with a frequency of 20 Hz has to exceed an SPL of approximately 84 dB (re: 20 μPa, i.e., relative to the international standard reference quantity, ISO R131, 1959; ISO 131, 1979) to be detected. For lower frequencies the SPL for detection must be higher. Figure 2 presented the results of a number of studies of hearing

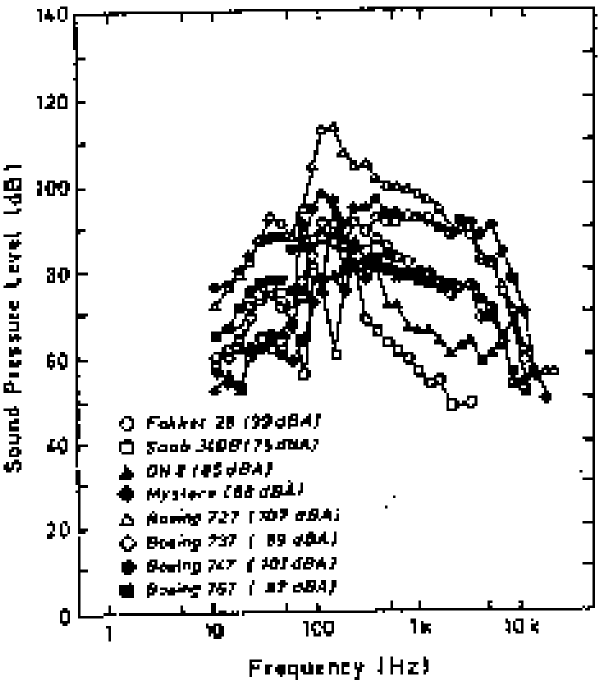

FIG. 7. Noise exposure as a function of frequency, for various aircraft types. These data are from recordings of aircraft movements taken outside, on the ground directly underneath the flight path, at Sydney Airport, Australia.

threshold for low-frequency noise and other noises. These research data show good agreement in supporting the following conclusions. First, low-frequency noise, including infrasound, is clearly detectable by the human auditory apparatus.

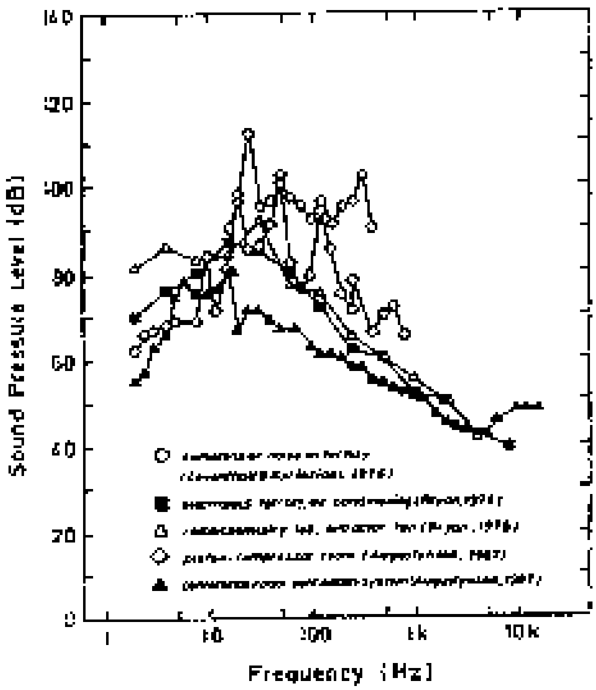

FIG. 8. Occupational exposure to noise from air movement plants.

Second, considerably more energy is required for detection in the low-frequency ranges. Finally, it should be noted that the absence of conscious (auditory) detection does not automatically mean that the noise has no other effects on the human body.

A. Vibration

Humans are sensitive to vibration from a region below 0.5 Hz to at least 100 kHz, even though it is the region between 0.5 and 200 Hz that seems to cause most concern (Rao and Ashley, 1976). While most noise within the low-frequency range is perceived by the normal hearing system, vibration of the body also results from low-frequency noise and the surrounding area. This is an important source of stimulation which influences the human perception of, and reaction to, low-frequency noise. The consequences of these effects are considered further in relation to annoyance, below.

IV. MEASUREMENT OF LOW-FREQUENCY NOISE

A. Instrumentation

The physical means by which low-frequency noise is detected and calibrated have advanced considerably over the course of research interest in low-frequency noise, with the consequence that many of the earlier studies may be suspected of failing to control for a variety of confounding effects on the data reported. In particular, insufficient measurement and control of the frequency range and harmonics may be identified as potential problems in both field recordings and experimental generation of low-frequency noise. The digital technique that has revolutionized acoustic recordings of complex sound and their reproductions has contributed to the resolution of these difficulties.

B. Units of measurement

Sound-pressure levels are usually measured on a decibel scale (dB). Due to the complex function of the human auditory system, and the need to be able to assess sound-pressure level (the physical correlate of loudness) objectively and rapidly, different filters are therefore often used to weight sound-pressure values as a function of frequency. The filters were developed to approximate the supraliminal response characteristics of the human auditory system as determined from psychophysical experiments. The frequency weighting filters of sound-level meters are not based on the curve for the hearing threshold, but on equal-loudness or equal-annoyance contours. Such filters are standardized but it should be kept in mind that they are approximating the contours, and particularly so for low frequencies. Hence, the forms of the contours are uncertain due to lack of agreement in empirical data (e.g., Møller, 1987; Møller and Andresen, 1984). Thus in these filters, typically the midfrequencies are amplified in contrast to the low and high frequencies which are deemphasized. The presently used A, B, and C filters in sound-level meters were aimed at mimicking isoloudness curves over frequency under different conditions of sound intensities (Fletcher and Munson, 1933), that is, for sounds of low, medium, and high loudness level, respectively.

The reason for this is that the shape of these isoloudness contours varies with loudness level. An approximation of the Fletcher–Munson pure-tone pressure-field equal-loudness contour at 40 Phon is used in the A filter, at 70 Phon in the B filter, and at 100 Phon in the C filter. The measurement unit Phon is an equal-loudness metric that corresponds to dB SPL units for a pure tone centered at 1 kHz. The reason for introducing this unit is that the exponent of the underlying psychophysical power function relating (perceived) loudness to sound pressure varies with frequency. Unfortunately, most of the equal loudness contours covering the low-frequency range (<70 Hz) are based either on nonempirical theoretical extrapolations and/or on sparse data that rely on uncertain methodology for comparisons over frequencies (Goldstein, 1994). As a special condition, the D filter was developed to account for aircraft noise (IEC 537, 1976). It is based on a new 40-Noy diffuse free-field contour obtained only for the frequency band range 50–11 200 Hz. At low frequencies it weights sound pressure similar to the B filter but amplifies it at high frequencies. The unit Noy was assigned to the perceived noisiness of a white noise band from 0.9 to 1.09 kHz at 40 dB SPL (Kryter, 1985, 1994). Within "normal" frequencies, the A filter appears to provide acceptable correlations between physical measures of noise and their corresponding subjective evaluations (e.g., Goldstein, 1994; Scharf and Hellman, 1980).

One major drawback with the scale of A-weighted SPL is, however, that it in fact underestimates the importance of frequencies below approximately 100 Hz (Kjellberg *et al.*, 1984; Kjellberg and Goldstein, 1985; Kuwano *et al.*, 1989). For example, loudness of noise which contains a substantial low-frequency component is underestimated by as much as the equivalent of 9 dB within the range 52–70 dB(A) (Gamberale *et al.*, 1982) or 6 Phon for 63 Hz and below (Berglund, 1990; Berglund and Berglund, 1986). In fact, for sounds exceeding an SPL of 60 dB, regardless of frequency, the reliability of the A-weighting diminishes (Berglund, 1990). Vercammen (1992) has suggested that an additional limit be set to the lower frequency part of the A-weighted spectrum (10–160 Hz) which lies 5–10 dB lower than the present one. The inability of A weightings to handle low-frequency noise is perhaps not surprising given that the isoloudness functions employed in the weighting were hand extrapolations into the lower frequencies rather than being based on empirical low-frequency data (see Goldstein, 1994). For example, in the absence of empirical data, both Stevens (1975) and Kryter (1985, 1994) chose to extrapolate the equal-loudness and equal-noisiness contours into the low-frequency range.

Different procedures developed for predicting (perceived) loudness or annoyance of complex sounds from frequency weightings, or from various calculation procedures (e.g., Kryter, 1985, 1994; Zwicker and Fastl, 1990; Stevens, 1975), have been less successful for low-frequency noise. Bryan (1976) in his "slope hypothesis" suggested that spectrum shape, especially in the low-frequency range, should be considered. However, this hypothesis was later firmly refuted (Goldstein and Kjellberg, 1985).

In psychophysical terms, the perceived loudness of a pure tone at 1 kHz grows as a power function with sound pressure with an exponent of about 0.6 (Stevens, 1975). Exponents of the same magnitude have also been established for pure tones above 300–400 Hz (Marks, 1978). However, for a low-frequency tone of 20 Hz, the exponent is approximately twice as high, i.e., 1.2 (Goldstein, 1994). This indicates that a doubling in perceived loudness is achieved with only an increase of 4–5 dB for a low-frequency tone whereas a tone with higher frequency needs to be increased by 9–10 dB to elicit the same perception of a doubling in loudness (see Stevens, 1972; Whittle *et al.*, 1972).

An alternative approach to the determination of the appropriate measure of noise exposure is to examine the ability of various measures of noise to predict community reactions (dissatisfaction, and other factors in addition to annoyance; Job, 1993). Such different measures or indices take into account not only the frequency weighting but also special weighting for the event with maximum SPL, the number of noise events, time of the day, etc. (e.g., Goldstein, 1994). For example, Bullen *et al.* (1985; Job *et al.*, 1991) examined 88 different indices of aircraft noise exposure. Such studies of noise with a substantial low-frequency component have produced conflicting results. C weighting is recommended and commonly employed for artillery noise (e.g., Schomer, 1981) whereas Bullen *et al.* (1991) found that the unweighted level [24 h Leq dB(Lin)] provided slightly better prediction of reaction that did C weighting. The value of Zwicker's method of loudness calculation for noises of various spectral composition has been empirically confirmed (e.g., Berglund, 1990). In predicting reaction to blast noise from mining, Fidell *et al.* (1983) suggested that a complex measure based on centiles of the probability of ground vibration plus 10 Log (number of events) was a better predictor of reaction that equal energy units. However, subsequent reanalysis supported an equal energy unit as an effective predictor (Bullen and Job, 1985). While equal energy units have often proven the most effective predictor of community reaction (Bullen *et al.*, 1985; Bullen *et al.*, 1991; Job *et al.*, 1991), among presently available predictors, the issue of the best noise index for predicting reaction remains to be settled.

V. EFFECTS OF LOW-FREQUENCY NOISE ON HUMANS

The lack of attenuation of low-frequency noise by walls and other structures and its pervasive ambient levels make low-frequency noise a factor of critical importance to health (Møller, 1984). Because low-frequency noise is a major component of many occupational and community noises the effects of such noises may be viewed as, in part, the effects of low-frequency noise. The pervasively wide frequency mixture of real world noises renders the determination of pure low-frequency noise effects tenuous. The task is complicated by the more effective propagation of low-frequency noise which results in a changing mix of frequencies with distance from the source, and the more effective masking of higher frequency noises by low-frequency noise than vice versa (Wegel and Lane, 1924; Zwicker, 1963). Nonetheless, relevant data exist from two basic methodologies: laboratory studies of the effects of explicitly controlled noise exposures

TABLE I. Exposure parameters and results of TTS studies after exposure to low-frequency noise.

Reference	Exposure	TTS	Recovery
Alford *et al.* (1966; in Backteman *et al.*, 1983a)	119–133 dB 2–12 Hz 3 min	11 of 21 Ss had TTS (3–8 kHz) >10 dB (11–22 dB)	
Englund *et al.* (1978)	125 dB 14 and 16 Hz 2 h	TTS in 16-Hz condition for freq. between 125 and 1k Hz TTS max. 10 dB (250 Hz) No sign. TTS in 14-Hz cond.	
Jerger *et al.* (1966)	119–144 dB 7–12 Hz 3 min	11 of 19 Ss had TTS (3–6 kHz), TTS 10–22 dB	Within 30 min
Johnson (1973; in von Gierke and Parker, 1976)	126–171 dB 1.6–12 Hz 2 s–30 min	TTS in 140 dB: 4, 7, 12 Hz: 30-min condition (1 subject) TTS 14–17 dB	Within 30 min
		TTS for 1 of 8 Ss in 140 dB; 4, 7, 12 Hz; 5-min condition TTS 8 dB	Within 30 min
Mills *et al.* (1983)	octave band noise 84 and 90 dB 63, 125, 250 Hz 24 and 8 h	TTS in 84 dB; 63, 125, 250 Hz: 24-h condition TTS 7–15 dB TTS in 90 dB; 63, 125, 250 Hz: 8-h condition TTS 13–18 dB	Up to 48 h 12–24 h
Mohr *et al.* (1965)	discrete tones narrow-band noise 150–154 dB 10–20 Hz 2 min	No TTS after 1 h	
Nixon, 1973 (in von Gierke and Parker, 1976)	135 dB 18 Hz 5-min exposure in rapid succession	Average TTS of 0–15 after 30-min exposure	Within 30 min
Nixon (1973)	140 dB 14 Hz 5–30 min	TTS in 1 of 3 Ss. TTS 20–25 dB	Within 30 min
Tonndorf (in von Gierke and Parker, 1976)	Submarine diesel room 10–20 Hz no level given	Depression of upper limits of hearing as measured by number of seconds a tuning fork was heard	In few hours outside of diesel room

and field studies of the effects of naturally occurring noise events. In addition, some studies have employed a combination of these methods, for example, by combining the home situation with controlled noise exposures (Peploe *et al.*, 1993).

Reviews of the health effects of noise in general exist (e.g., WHO, 1993), and are not repeated here. The review which follows is focused on laboratory studies which employ low-frequency noise, and on field studies of noise sources with a large low-frequency noise component.

A. Effects on hearing

Effects of low-frequency noise on hearing have been examined in terms of permanent loss of auditory acuity (permanent threshold shifts, PTS) and in terms of temporary threshold shift (TTS). While TTS is of less importance in itself (except for immediate performance which requires good auditory acuity), TTS may be viewed as the best average predictor of PTS (Ward, 1993). TTS is effective in predicting what noise sources will produce more PTS although it is not especially useful in predicting individual listener's losses (Ward, 1993). Thus, in considering losses induced by a source, such as low-frequency noise, TTS is of value. This predictor is a critical research tool because of the obvious problems involved in inducing PTS in research involving human beings.

1. Temporary threshold shifts (TTS)

A number of studies have examined TTS as a function of frequency of tones or narrow bands of noise. A compilation of results and exposure parameters of such studies concerned with low-frequency noise are summarized in Table I. These studies consistently show that TTS does occur with exposure to low-frequency noise, and the recovery period may be longer for sounds of higher pitch (Nixon and Johnson, 1973). However, the clinical significance of TTS is not clear since the exposure parameters employed are more extreme than those likely to actually be experienced in community noise. Nonetheless, these empirical data suggest the possibility of PTS resulting from occupational exposures, and leave open the possibility of PTS from sufficiently long durations of exposure in community settings.

B. Permanent threshold shifts (PTS)

For obvious reasons, data on PTS come from field studies of occupational exposure. Whereas such data focused on low-frequency noise are rare, a few studies of occupational noise sources with a large component of low-frequency noise exist. In addition, some early laboratory studies have employed exposures which would be unlikely to pass today's ethics committee's screenings of research; e.g., Mohr *et al.* (1965). Noise exposure in a submarine diesel room with a dominant frequency around 10–20 Hz produced TTS with recovery in a few hours (von Gierke and Nixon, 1976). Exposure to sonic booms resulted in no adverse effects on hearing even when exposure levels were intense (up to 6.9×10^3 N/m^2) or when continued for as much as 30 booms per day for two 30-day periods (for a review see von Gierke and Nixon, 1976). At extreme pressure (4.15×10^4 N/m^2) produced by very low-frequency noise, tympanic membrane damage may occur along with some other ear damage (von Gierke and Nixon, 1976).

Given the common mix of frequencies in real world noises, the influence of low-frequency noise on the effects of energy in higher frequency bands should be considered. Consistent with the evidence that low-frequency noise is particularly effective in masking noise at higher frequencies, low-frequency noise may also ameliorate the hearing damage of higher frequency noise. Evidence for such an effect comes from Nixon's study of vehicle air bag inflation, in which reduced TTS occurred when low-frequency noise was added to a noise burst (see von Gierke and Nixon, 1976, pp. 130–131).

1. *Aural pain*

The threshold of aural pain is approximately 135 dB for sound energy around 50 Hz with a steady increase in threshold to around 155 dB at 5 Hz (von Békésy, 1960; von Gierke and Nixon, 1976).

C. Balance and the vestibular system

Intense energy in the very low-frequency ranges may affect the vestibular system. Because of ethical considerations and invasive measurement techniques much of the research on low-frequency noise and the vestibular system has been carried out on animal models, mainly monkeys and guinea pigs. Both species show evidence of vestibular effects of low-frequency noise in perilymph pressure (Parker, 1976). However, the behavioral significance of these responses is small given the absence of eye movement response associated with vestibular stimulation (nystagmus or counter-rolling) to intense low-frequency noise (below 20 Hz) in both guinea pigs and monkeys (Parker, 1976). Parker's observations were made under exposure to intense stimulation (up to 172 dB). Overall the threshold of nystagmus was lower for higher frequencies, but still required intensities of 140 dB and above. This relationship between vestibular effects and frequency is consistent with the pattern for human subjects, and the absence of nystagmus in response to intense (up to 155 dB) low-frequency noise (0.6–12 Hz: see further von Gierke and Nixon, 1976). Thus vestibular effects appear to be greater for noise in the frequency range above 250 Hz.

D. Respiratory effects

Respiratory effects (suspended or reduced respiration, gagging, and coughing) of low-frequency noise have been documented in laboratory animals and human beings (von Gierke and Nixon, 1976). However, the intensity of stimulation required to produce such effects (150–154 dB) suggests that these effects are unlikely to be of practical importance except in extreme occupational exposure, such as might occur in rocket launches. Human accident data and animal data suggest a more extreme pressure limit for lung damage (1.03×10^5 N/m^2, according to von Gierke and Nixon, 1976).

E. Annoyance, loudness, and noisiness

The primary, and most frequently reported, perceived effect of low-frequency noise is not that of loudness or noisiness, but that of annoyance (Broner, 1978). The concept of annoyance is operationalized in various ways. It may refer to human response to noise events measured in laboratories, community studies of self-reported annoyance reactions, or the confusion of annoyance with disturbance of various activities such as conversation or sleep. The concept of noisiness has been used sometimes synonymously with annoyance (Kryter, 1985, 1994) and sometimes as a quality characteristic of sounds (Berglund *et al.*, 1975).

The degree of annoyance or disturbance generated by a specific noise, regardless of frequency, is difficult to predict accurately for individuals (Haslegrave, 1990; Job, 1988). The same noise may for different people result in totally different responses depending on cultural factors (Kuwano *et al.*, 1991), activity at the time of exposure (Borsky, 1980), attitude to the noise source (Fields, 1992, 1993; Job, 1988), noise sensitivity (Job, 1988; Stansfeld, 1992), controllability of the stressor (Evans, 1982), and other individual differences (see Job, 1993). Prediction of individual reactions is also slightly limited by the reliability of the reaction and noise measures (Job, 1991). Nonetheless, prediction of the averaged reactions of groups of subjects in socioacoustic surveys is good (Job, 1988).

Scales of the perceived loudness, noisiness, and annoyance of noises generally show strong correlations (Berglund *et al.*, 1986; Peploe *et al.*, 1993; Stevens, 1961, 1972), although the three scales do dissociate with more complex sounds or examination of stimuli which differ on a number of characteristics such as rise time, sharpness, spectral content, information content (Berglund *et al.*, 1975, 1976; Berglund *et al.*, 1994a; Berglund *et al.*, 1994b; Hellman, 1984;

Preis and Berglund, 1993), or contextual effects such as the task being undertaken at the time (Lindvall and Radford, 1973).

Low-frequency noise differentiates itself from noise that consists of a broader frequency spectrum in that it seems more difficult to predict both loudness and annoyance accurately. Even though the A filter has proven itself useful as an approximate estimation of annoyance for mid- to high-frequency stationary noise, it severely underestimates annoyance as well as (perceived) loudness when the noise contains low-frequency components. Bryan (1971, 1976), for example, found that noise containing high levels of low-frequency noise, and low levels of high-frequency noise, gave rise to vigorous complaints even though the exposure level was only around 55 dB(A). Tempest (1973), investigating low-frequency noise present in a car, a diesel train, from traffic noise indoors, an oil furnace, and from a ventilation installation, found that the number of complaints were far larger than could be predicted from the sound-pressure levels of the noises as judged by the dB(A) level. Similarly, Persson and Björkman (1988) compared four broadband fan noises centered at 80, 250, 500, and 1000 Hz and found that the 80-Hz band was perceived to be significantly more annoying than the other noises at equal A-weighted levels. A considerable body of research has produced similar findings (e.g., Broner and Leventhall, 1978, 1982; Gamberale *et al.*, 1982; Goldstein and Kjellberg, 1985; Kjellberg *et al.*, 1984; Persson *et al.*, 1985, 1990, Persson and Rylander, 1988; Scharf *et al.*, 1977; Vasudevan and Leventhall, 1982, 1989; Åkerlund *et al.*, 1990).

Comparison of socioacoustic survey results from different noise sources also supports a greater reaction (for equal loudness) to sources with more low-frequency components. Reaction to aircraft noise is generally higher than reaction to road noise, and this difference has been identified in direct comparison within a single study (Hall *et al.*, 1981).

Low-frequency noise also differs from other noise in producing vibrations of the human body and other objects. This is of practical significance to human reactions to the noise. For example, the extremely intense low-frequency noise produced by aircraft during takeoff (see Fig. 7) may rattle doors, windows, and other household objects, thereby causing discomfort and annoyance reactions. Rattle and vibration magnify reaction to the noise (Berglund *et al.*, 1975; Bullen *et al.*, 1991; Howarth and Griffin, 1991; Schomer and Neathammer, 1987; WHO, 1993). This effect is of significant size. Schomer and Averbuch (1989), investigating noise from helicopters and artillery which produce blast sounds containing little energy above 200 Hz, found that no commonly used environmental noise measure could adequately describe the indoor environment in cases when the blast excited rattles. Even though extremely small (under 1 dB) changes in both A- and C-weighted SPL were registered, subjective response changes equal to noise of up to 13 dB occurred when the blast excited rattles. Finally, in a multiple regression application to predict overall reaction (dissatisfaction) to artillery noise, reaction to the shaking and vibration was found to be a better predictor than all the disturbances of activities (conversation, watching television, reading, relaxing, etc.) combined (Bullen *et al.*, 1991). The effects of vibration of the human body on reaction are complicated by tendency to confuse vibration emission with noise alone, whereby people "hear" more noise than is actually present (e.g., Griffin, 1990; Howarth and Griffin, 1990; Kastka and Paulsen, 1991; Kryter, 1985, 1994). The opposite is also possible: Motion sickness has been linked to low-frequency noise even without accompanying vibration (Yamada *et al.*, 1991).

Another particular feature of low-frequency noise is that it is often accompanied by a throbbing characteristic which may increase the annoyance reactions (Broner and Leventhall, 1983; Vasudevan and Gordon, 1977; Vasudevan and Leventhall, 1982, 1989).

F. Nonauditory physiological effects

1. Cardiovascular effects

Laboratory studies of noise at various frequencies show noise-induced changes in blood pressure with vasoconstriction or vasodilation, and heart rate change (e.g., Andrén, 1982; Andrén *et al.*, 1988; Andrén and Hansson, 1983; Carter and Beh, 1989; Osada *et al.*, 1972; Parrot *et al.*, 1992, Rovekamp, 1983; Vallet *et al.*, 1983). However, these effects interact with task demands (Tafalla and Evans, 1993); they are not uniformly observed (Etholm and Engenberg, 1964) and are of unclear clinical significance. Nonetheless, the observation that those with a family history of hypertension show more pronounced cardiac reaction to noise is indicative of concern (von Eiff *et al.*, 1981). The finding that men show more reaction than women (Loeb *et al.*, 1982; Yamada *et al.*, 1986) also adds weight to the clinical relevance of the reactions given that men, on average, suffer cardiac infarction earlier than women.

Studies of low-frequency noise specifically have shown changes in heart rate in subjects who suffer from low-frequency noise, but not in other subjects (e.g., Yamada *et al.*, 1986). This pattern of results suggests that reactions to low-frequency noise may not have habituated in these subjects or that the habituation is specific to the environment in which the noise exposure occurs, consistent with a classical conditioning theory of habituation (Hall and Honey, 1989; Lovibond *et al.*, 1984). Extending the lack of habituation, Michalak *et al.* (1990) showed a sensitization effect in response to aircraft noise.

Long-term exposure appears to produce peripheral vasoconstriction with occupational (Zhao *et al.*, 1991) or other exposure (Neus *et al.*, 1983). Children living under the flight paths in Los Angeles also show elevated blood pressure (Cohen *et al.*, 1986). Adults living in highly exposed road noise areas showed slight increases in heart disease risk (Babisch *et al.*, 1993) while those in highly exposed aircraft noise areas showed elevated blood pressure, greater use of blood pressure medication and greater prevalence of cardiovascular disease (Knipschild, 1977a, 1977b, 1980; Knipschild and Oudshoorn, 1977). The latter studies included tracking across time to show that with a change in the aircraft operations blood pressure medication changed accordingly. The latter result suggests that these effects may be attributed to the noise rather than self-selection of the relevant populations or other differences between the areas under comparison. Clearly, long-term high blood pressure may be of clinical significance (Jansen, 1969; Harris *et al.*, 1980).

Although health effects of noise have been extensively researched (see, e.g., Berglund and Lindvall, 1990; Berglund *et al.*, 1990; Vallet, 1993), no study has specifically compared complex low frequency noise with other complex noises to determine if there is differential reaction. However, circulatory system effects of low-frequency noise have been identified in the laboratory and the studies of aircraft noise are of particular relevance by virtue of their high proportion of low-frequency noise. For this reason, particular health concern should be given low-level military aircraft which will produce intense exposure. It would appear on balance of probability that low-frequency noise produce cardiovascular effects.

2. Endocrine effects

Laboratory studies show increased catecholamines and cortisol in response to noise (e.g., Cantrell, 1974; Cavatorta *et al.*, 1987; Welch and Welch, 1970). As with other stressors, the effects of controllability may affect endocrine reactions to noise (Averill, 1973; Job, 1993; Lundberg and Frankenhaeuser, 1978). These hormonal changes, if prolonged, may produce significant health-related effects (decreased immunity, increased heart rate and blood pressure, and cardiac arrhythmias). A review by Bly *et al.* (1993) suggested that there is evidence of immunomodulation by noise stress. The effects of frequency spectrum of the sound are not known.

G. Effects on performance and cognition

Effects of noise on performance have been intensively investigated and reviewed (Abel, 1990; Broadbent, 1957; Davies and Jones, 1985; Jones, 1984; Loeb, 1981). While noise clearly affects performance on a variety of tasks, especially divided attention tasks, the effects often interact in complex and inconsistent ways with time of day, arousal, and gender (Frankenhaeuser and Lundberg, 1977; Hamilton and Hockey, 1970; Holding *et al.*, 1983; Salamé, 1988), and with task speed and accuracy (Broadbent, 1954; Carter and Beh, 1987). Importantly, the learning of children is also affected by noise (Evans, 1990; Hygge, 1993).

Despite this extensive and sophisticated research literature, studies of the effects of low-frequency noise are surprisingly rare and inferences can only be drawn from predominantly low-frequency noise. For example, drivers of heavy lorries experience a reduction in wakefulness which can be attributed to low-frequency noise (Landström *et al.*, 1988). Thus, to date, there is no clear evidence to suggest that low-frequency noise has differential effects on performance or cognition.

H. Sleep disturbance

Sleep disturbances and poorer performance due to sleep loss have been reported when either continuous or intermittent noises were present (Eberhardt *et al.*, 1987; Thiessen, 1970, 1978). This has been verified by questionnaires (e.g., Langdon and Buller, 1977) and through laboratory studies in which noise of various SPLs have been alternated with quiet nights (Carter *et al.*, 1993a; Jurriens *et al.*, 1983; Thiessen and Lapointe, 1978, 1983; Wilkinson *et al.*, 1980; Öhrström and Rylander, 1982). It should be noted that sleep disturbance is also an effect of ongoing concern in daytime noise, because of shift workers (see Carter *et al.*, 1993b; Knauth and Rutenfranz, 1975).

Noise produces cardiovascular effects during sleep (Muzet and Ehrhardt, 1978; Muzet *et al.*, 1981); changes in sleep pattern (e.g., Wilkinson and Campbell, 1984) and sleep loss appear to cause compromised immunity (Brown, 1991; Brown *et al.*, 1989; Palmblad *et al.*, 1976; Palmblad *et al.*, 1979). Thus it is of significance not only because of the disturbance at the time but also because of health-related changes.

Although the effects of noise on sleep are well documented (see Öhrström, 1993a), studies of low-frequency noise are again rare. A relevant exceptional study is that by Nagai *et al.* (1989). They described how inhabitants living along a superhighway initially complained of the shaking and rattling of windows, then became chronically insomniac and excessively tired from the continuing low-frequency noise reaching levels between 72 and 85 dB(A). It is apparent that low-frequency noise disturbs sleep, and when it produces rattle it is likely to be more disturbing than higher frequency noise.

I. Effects on communication and psychosocial effects

There can be no doubt that noise can mask speech. However, the degree depends on a number of factors of the speech and the masking noise. In principle, noises around the same frequency as speech (mainly between 0.1 and 6 kHz) will mask more effectively than noise at higher frequencies. However, given the upward spread of masking which makes low-frequency noise an efficient masker of noises of higher frequency, low-frequency noise can be expected to mask speech rather well. In support of this supposition, intense noise of frequencies as low as 20 Hz has been found to affect speech intelligibility adversely (Pickett, 1959). This effect appears to be ignored in the development of methods utilized to predict speech intelligibility. For example, the articulation index (French and Steinberg, 1947; Kryter, 1962), the speech interference level (Beranek, 1947; see also ANSI, 1969), the rapid speech transmission index (see Houtgast and Steeneken, 1983), and direct measurements of SPL, in dB(A) (Klump and Webster, 1963; Kryter, 1985, 1994; Loeb, 1986), have been used to predict speech interference level. These measures cover the region between 250 and 7000 Hz which, admittedly, covers the range for the human voice. Common to all these methods is that they do not consider the upward spread of masking by low-frequency noise.

The factors of annoyance with speech interference are more complex than those of the interference itself, and encompass cognitive factors apparently unrelated to low-frequency noise (see Bergman, 1980; Miller and Licklider, 1950; Preis and Terhardt, 1989). However, noise may under certain exposure conditions result in better speech intelligibility due to the process of auditory inclusion and thus also reduce its effect on annoyance reaction (Berglund *et al.*, 1994a).

A number of nondesirable social effects have been found in connection with living in noisy neighborhoods, such as an increased crime rate and decreased casual social interaction (Appleyard and Lintell, 1972). The latter effect may, however, be more a result of impaired speech communication due to masking than from noise *per se*. Noise may also affect the act of helping. Specifically, subjects have been shown to offer less help with various tasks in the presence of noise as compared to the same situation without the noise (Boles and Hayward, 1978; Page, 1977). Generally, broadband community noise, including low-frequency noise, may even at low levels constitute a risk for certain groups such as the elderly, the hearing impaired, and children at the stage when they acquire language (WHO, 1993).

J. Mental health

Like so many outcomes, the effects of noise on mental health are difficult to establish because of confounding differences between populations exposed or not exposed to noise. For example, studies of populations near versus not near Los Angeles Airport were confounded by differences in racial composition among other factors (Meecham and Shaw, 1979; Meecham and Smith, 1977). However, long-term studies suggest a complex relationship between mental health effects such as depression, noise sensitivity, and noise exposure (Stansfeld, 1992; Stansfeld *et al.*, 1985). Other long-term studies have identified the possible effects of noise on psychosocial well-being (Öhrström, 1993b). Furthermore, Kryter's (1990) reanalysis of psychiatric-hospital admission rates identified an effect of aircraft noise independent of confounding factors which were statistically or selectively controlled.

Examination of mental health effects of pure low-frequency noise is not feasible since pure sources occur rarely in the real world. However, the effects of aircraft noise (which contains much low-frequency energy; see Fig. 7) outlined above are consistent with a role of low-frequency noise in mental health effects. The possibility that mental health effects grow in part from annoyance and feelings of helplessness (Job, 1993; Job and Barnes, 1995; Overmier and Hellhamer, 1988; Seligman, 1991) and the greater annoyance occasioned by low-frequency noise are suggestive of greater effects from low-frequency noise than from other noises.

VI. METHODOLOGICAL ISSUES

In determining the effects of low-frequency noise on human well-being a myriad of methodological issues arise. Because the problems differ between the various basic research methods, these are listed below separately for the laboratory and field studies.

A. Laboratory studies

(1) The standard methodological issues to do with selection of subjects, experimenter bias and all the complex effects of context (including stimulus range, regression, and sequential order effects) are relevant to laboratory studies of noise in general and of low-frequency noise in particular. These effects have been critically reviewed elsewhere (Goldstein, 1994; Poulton, 1989). The impact of these effects may be reduced by master scaling which is a procedure by which individual differences in perceptual scaling are utilized for obtaining calibrated scales, independent of exposure context (Berglund, 1991).

(2) Examination of low-frequency noise in the laboratory requires its generation or reproduction and presentation to the subjects. Problems have, for example, included impure signal, insufficient air space in headphones, and the generation of harmonics (see von Békésy, 1960; Yeowart, 1976). These problems have been steadily reduced with advances in technology and knowledge.

(3) Measurement of low-frequency noise has also proven difficult. Tolerances in sound-level meters have been much more lenient for low-frequency noise (e.g., Brüel & Kjær, type 2209.3; IEC, 1979). Technical concerns with the capture of low-frequency noise have been reviewed (Goldstein, 1994) and measurement unit problems were considered earlier.

(4) Doubts about the generalizability of laboratory findings to real world situations apply particularly to research on low-frequency noise. For example, the effects of the unfamiliar laboratory environment on noise-induced sleep loss are difficult to establish. Even studies which allow some nights of familiarization to the sleeping laboratory may not replicate the effects of years of sleeping in the same room. The observations may also involve classic Hawthorne effects (cf. Dickson and Roethlisberger, 1966). Similarly, studies of annoyance in the laboratory may overlook the effects of ameliorating actions in one's home, such as turning up the volume of the television or radio sets. Another reaction of importance here is habituation which may be specific to the environment in which the noise is heard (Hall and Honey, 1989; Lovibond *et al.*, 1984), which will result in an absence of habituation in the laboratory. Related research on the creation of positive sound environments may provide answers here. Studies which combine the experimental and field methods in examining, for example, sleep disturbance in the home and annoyance from controlled exposures in the home (Peploe *et al.*, 1993) are helpful in this regard.

(5) Generalization from temporary effects to clinical significance is uncertain for many effects, although in the cases of TTS, mental illness, and blood pressure, there is somewhat more reason for confidence.

(6) The earliest studies employed exposure levels which would almost certainly not be allowed today. While these data are therefore of value, these studies apparently employed inadequate data collection via insufficient self-report (Mohr *et al.*, 1965).

(7) The early experiments were often conducted on military subjects who had participated in many experiments and so received much noise exposure. The effects of this prior experience are unknown.

B. Field studies

(1) Field studies of the effects of noise including low-frequency noise run the same risks in methodology as field studies in general (e.g., Last, 1988). These include problems with drawing causal inferences from correlational data obtained in cross-sectional studies or from one aggregate level to another (ecological fallacy), the use of self-report data from respondents who may be motivated to exaggerate their reactions, confounding differences between populations exposed or not exposed to noise, biases from certain types of people agreeing to participate versus those who refuse or are not home when the study is done, interviewer bias, and question wording bias. Some of these problems are relieved in studies of noise by multiple calls back to residences producing high response rates (e.g., Hede and Bullen, 1982), or by group questionnaire administration (e.g., Job and Bullen, 1987), or by other means [see Job and Bullen, 1985]. Nonetheless, problems remain to be resolved.

(2) The extrapolation from observed effects to clinical significance is not as critical a problem as in laboratory studies, but remains a problem nonetheless for some measures. Although of significance in itself, it is not clear whether annoyance created by low-frequency noise leads to other mental health problems, nor whether reduced psychosocial well-being in high noise areas is a predictor of more serious mental disorders.

(3) Respondents may have difficulty identifying the source of low-frequency noise and so may misattribute the noise to another source in reporting their reactions (cf. Berglund, 1991; Berglund *et al.*, 1980).

(4) Perhaps the most serious problem specific to field studies of low-frequency noise is that pure low-frequency noise is rare. Thus most such studies are of broadband noise with a predominant or significant low-frequency component. Thus the effects of low-frequency noise *per se* are difficult to identify. Comparison of different noise sources with differing components of low-frequency noise is only a partial solution to this problem. The different noise sources differ on many variables in addition to their low frequency components. For example, attitudes to the noise source, time of day of noise, proximity, and visibility of the source may all vary and may all affect reaction.

VII. ABATEMENT OF LOW-FREQUENCY NOISE

With the automation of technological processes in industry, an increasing number of workers are moved from the immediate vicinity of the machinery to control cabins of some sort. These cabins offer the opportunity to reduce noise hazards, vibration, and other harmful agents in the working environment. The sound insulation ability of "soundproof" cabins averages typically 30–50 dB for frequencies above 500 Hz, but only 0–19 dB for frequencies below 500 Hz (Kaczmarska and Augustynska, 1992). Thus their ability to reduce low-frequency noise is less than adequate. Likewise, the use of personal hearing protectors is less effective in the low-frequency range. For example, Harris (1979) has shown that the use of earplugs alone may reduce the noise level by as much as 40 dB within the frequency range 800–8000 Hz. If earplugs are used in combination with earmuffs, a reduction of up to 60 dB can be obtained. The same protectors may, however, only reduce the low-frequency noise (within the range 20–100 Hz) by about 5–25 dB (Harris, 1979). This form of local protection also fails to address effects of low-frequency noise on other parts of the body. Thus personal hearing protectors are not the ideal solution for low-frequency noise.

Transmission loss through walls and windows are lower within the low frequency region than for noise of higher frequencies, especially if the room resonances coincide with the low-frequency noise (Leventhall, 1988). However, with double glazing, attenuation can be achieved, as shown in the middle panel of Fig. 9. The general difficulty of insulating against low-frequency noise highlights the value of attenuation of the noise at the source, as suggested, for example, by Backteman *et al.* (1983a, 1983b), rather than allowing the noise to spread.

Figure 9 shows the results of three sound abatement studies which considered a range of frequencies of noise including low-frequency noise. The left panel shows a successful source reduction. Another successful case is described by Ellison (1991) in which a large rope-making machine together with a number of smaller machines were found to cause what the complainant described as a "throbbing noise." However, in this case, the disturbing noise was propagated through ground-borne vibrations in the range 8–15 Hz. The solution was to improve the maintenance of the machines which led to a reduction of vibrations and noise in the range 15–20 dB. This reduction satisfied the complainant, and as a side effect improved the serviceability of the machines in question.

Active noise control is a viable alternative to passive attenuation especially with respect to ventilation and exhaust fan noise (Wise *et al.*, 1992). Active attenuation preserves the unobstructed airflow by injecting canceling noise into the duct. The technique is particularly efficient for low-frequency noise which may be reduced by 3–18 dB depending on frequency composition (Leventhall *et al.*, 1994). Additional advantages of active control are that external lagging of ducts is not necessary, a thinner sound absorptive lining may be used inside for attenuation of high-frequency noise, and the running costs of the active system may be as low as 1% of the energy saved by reduced airflow resistance compared to a corresponding passive attenuation system.

VIII. RECOMMENDATIONS

A. Research needs

Further research is needed in relation to a number of features and outcomes of low-frequency noise. These needs include the following.

(1) In general, there has been too little research on the role of different frequency spectra of noise in the production of effects on humans. Greater consideration of this factor in many studies of noise is desirable.

(2) Most of the research of adverse effects of low-frequency noise in humans has used short durations of exposure. It is of great importance to research prolonged expo-

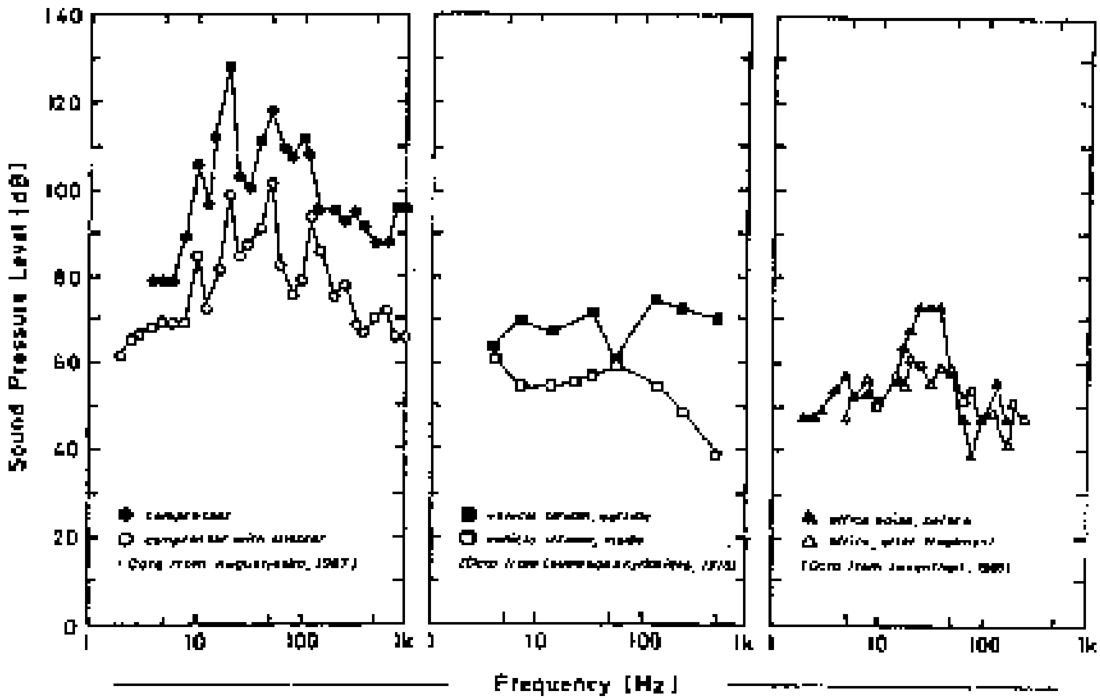

FIG. 9. The results of three low-frequency noise abatement studies.

sures, extending at least over 15–30 min, so that the effects may be generalized from laboratory studies to field situations.

(3) Longitudinal studies of the effects of low-frequency noise sources are needed in order to examine the long-term pattern of effects (see also Berglund *et al.*, 1984). At this stage the pattern of development of and possible predictors of problems of clinical significance are unclear. Predictors of later problems would be of value in providing prophylactic interventions instead of treatment after the problem is established.

(4) Noise sources sometimes change substantially, such as in changes to road traffic with openings of new freeways or aircraft traffic with new airports or runways. Such occasions provide relatively rare opportunities to assess the effects of noise to a large extent independent of the effects of population differences arising from selection of living location in quiet or noisy areas. Such opportunities should not be missed, and in such studies the frequency spectrum of the noise should be assessed.

(5) Given the impure examples of low-frequency noise which exist for field studies, comparison of different sources is necessary to provide a guide as to the contribution of low-frequency noise to the reactions observed. However, such comparisons are confounded by other differences between the sources. These differences could largely be handled by measurement of these factors and statistical control of them.

(6) The mechanisms of individual differences in the effects of noise are of critical concern. Examination of which individuals are most affected and what features they share is needed. Knowledge of the mechanisms of these effects may be invaluable in intervening to prevent the adverse effects of low-frequency noise.

(7) The impact of environmental noise with low-frequency components should be researched for various risk groups such as persons with impaired hearing, noise sensitive individuals, children who develop learning disabilities, the elderly (with presbyacusis), etc. Knowledge of effects on such populations is of particular concern because of the prevalence of low-frequency noise in indoor sources such as ventilation systems.

(8) The development of standardized techniques to measure low-frequency noise in the laboratory, in housing, and at work sites is desirable. The inadequacy of weighting filters in sound-level meters has been identified.

(9) Laboratory studies of the effects of the various features of (real and artificial) noise signals are needed.

(10) The relative contributions of low-frequency and impulsiveness and tonal aspects of noise require further examination in laboratory and field studies.

(11) Detailed assessment is needed of the relative importance of vibration and rattle versus the low-frequency noise itself in producing reactions. This would involve both laboratory and field research.

(12) Continued development of methods for low-frequency noise attenuation and control measurement technology are needed.

B. Action on the basis of current knowledge

The effects of low-frequency noise (and many other environmental pollutants) on human beings are difficult to establish for various methodological reasons outlined above. Definitive solutions to these problems would require unethical exposures to low-frequency noise. Thus the effects must be judged on balance. The balance of probability would appear to favour the conclusion that low-frequency noise has a variety of adverse effects on humans, both physiological and psychological. These latter effects are often more serious than those produced by higher frequency noise, partly due to the pervasiveness of low-frequency noise, its efficient propagation, and reduced efficacy of many structures in attenuating low-frequency noise. The evidence provided in this review warrants concerned action without the potentially extremely lengthy delay that may be occasioned by waiting for definitive proof which may never arise.

In industrial and community settings more emphasis should be placed on determining the frequency spectrum of a noise rather than the current focus on sound-pressure level alone. Some standards for industry allow greater exposure to low-frequency noise, possibly on the basis that much of it cannot be heard. For example, the Polish standards allow more noise in the range below 20 Hz than in higher frequencies (see Kaczmarska and Augustynska, 1992). Such standards should consider the option of allowing less noise in the low-frequency range since the possibility exists that a stimulus may have an effect even without conscious (auditory) detection.

Low-frequency noise emission can often be reduced through insulation of the source, better maintenance of relevant machinery (e.g., ventilation ducts) or active sound absorption (see Gan, 1987; Leventhall *et al.*, 1994). Such measures should be actively encouraged.

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Abel, S. M. (1990). "The extra-auditory effects of noise and annoyance: An overview of research," J. Otolaryngol. 19, 1–13.

Åkerlund, E., Löfstedt, P., Landström, U., and Kjellberg, A. (1990). "Low frequency noise and annoyance in working environments," J. Low Frequency Noise Vib. 9, 61–65.

Andersson, K., and Lindvall, T. (Eds.) (1988). Health Effects of Community Noise. Evaluation of the Nordic Project on "The Health Effects of Community Noise," Copenhagen, Denmark: Nordic Council of Ministers, Miljörapport No. 6.

Andrén, L. (1982). "Cardiovascular effects of noise," Acta Med. Scand. Suppl. 657, 1–45.

Andrén, L., and Hansson, L. (1983). Regulation of arterial blood pressure during stress. J. Hypertension 1, 249–250.

Andrén, L., Eggertsen, R., and Svensson, A. (1988). "Noise and essential hypertension," in *Noise as a Public Health Problem. Vol. 1: Abstract Guide*, edited by B. Berglund, U. Berglund, J. Karlsson, and T. Lindvall (Swedish Council for Building Research, Stockholm, D15:1988), pp. 83–84.

ANSI (1969). American National Standard for Calculation of the Articulation Index, ANSI S3.5 (American National Standards Institute, New York).

Appleyard, D., and Lintell, M. (1972). "Environmental quality of city streets: The residents' viewpoint," J. Am. Inst. Planners 38, 84–101.

Augustyńska, D. (1987). "Infrasonic noise emitted by flow machines, its sources and reduction methods," in *Proceedings of the 4th International Meeting on Low Frequency Noise and Vibration*, edited by L. Lundh (University of Umeå, Umeå, Sweden), pp. 1-1-1–1-1-10.

Averill, J. R. (1973). "Personal control over aversive stimuli and its relationship to stress," Psychol. Bull. 80, 286–303.

Babisch, W., Elwood, P. C., and Ising, H. (1993). "Road traffic noise and heart disease risk: Results of the epidemiological studies in Caerphilly, Speedwell and Berlin," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 3, pp. 260–273.

Backteman, O., Köhler, J., and Sjöberg, L. (1983a). "Infrasound–tutorial review: Part 1," J. Low Frequency Noise Vib. 2, 1–31.

Backteman, O., Köhler, J., and Sjöberg, L. (1983b). "Infrasound–tutorial review: Part 2," J. Low Frequency Noise Vib. 2, 176–210.

Békésy, G. von (1960). *Experiments in Hearing* (McGraw-Hill, London).

Beranek, L. L. (1947). "The design of speech communication systems," Proc. Inst. Radio Eng. 35, 880–890.

Berglund, B. (1990). "Loudness scaling in environmental psychoacoustics," in E. Ozimek (Ed.), *Subjective and Objective Evaluation of Sound* (World Scientific, Singapore), pp. 3–14.

Berglund, B. (1991). "Quality assurance in environmental psychophysics," in *Ratio Scaling of Psychological Magnitude—In Honor of the Memory of S. S. Stevens*, edited by S. J. Bolanowski Jr. and G. A. Gescheider (Erlbaum, Hillsdale, NJ), pp. 140–162.

Berglund, B., and Berglund, U. (1986). *Hörstyrkan hos ljud från högspänningsledningar (The loudness of power line noises)*. Stockholm: Naturvårdsverket (Swedish Environmental Protection Board), Report No. 3015 (in Swedish).

Berglund, B., and Lindvall, T. (Eds.) (1990). "Special Issue on Public Health Implications of Environmental Noise," Environ. Int. 16 (4–6), 313–601.

Berglund, B., Berglund, U., and Lindvall, T. (1975). "Scaling loudness, noisiness and annoyance of aircraft noise," J. Acoust. Soc. Am. 57, 930–934.

Berglund, B., Berglund, U., and Lindvall, T. (1976). "Scaling loudness, noisiness and annoyance of community noise," J. Acoust. Soc. Am. 60, 1119–1125.

Berglund, B., Berglund, U., and Lindvall, T. (1980). "Loudness separation of community noises," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen, and W. D. Ward (ASHA Reports, Rockville, MD) No. 10, pp. 349–354.

Berglund, B., Berglund, U., Goldstein, M., and Lindvall, T. (1981). "Loudness (or annoyance) summation of combined community noises," J. Acoust. Soc. Am. 70, 1628–1634.

Berglund, B., Berglund, U., and Lindvall, T. (Eds.) (1984). *Adverse Effects of Community Noise—Research Needs* (Nordic Council of Ministers, Oslo, Norway).

Berglund, B., Berglund, U., and Lindvall, T. (1986). "On the meaning of annoyance," Trans. Acoust. Soc. Jpn. No. N86-10-5.

Berglund, B., Lindvall, T., and Nordin, S. (Eds.) (1990). "Adverse effects of aircraft noise," Environ. Int. 16, 315–338.

Berglund, B., Harder, K., and Preis, A. (1994a). "Annoyance perception of sound and information extraction," J. Acoust. Soc. Am. 95, 1501–1509.

Berglund, B., Hassmén, P., and Preis, A. (1994b). "On perceived unclarity of complex sounds," in L. M. Ward (Ed.), *Fechner Day '94* (The International Society for Psychophysics, Vancouver, B. C., Canada), pp. 85–90.

Bergman, M. (1980). *Aging and the Perception of Speech* (University Park, Baltimore).

Blazier Jr., W. E. (1981). "Revised noise criteria for application in the acoustical design and rating of HVAC systems," Noise Control Eng. J. 16, 64–73.

Bly, S. H. P., Goddard, M., and McLean, J. (1993). "A review of the effects of noise on the immune system," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France: INRETS), Vol. 2, pp. 509–512.

Boles, W. E., and Hayward, S. C. (1978). "Effects of urban noise and

sidewalk density upon pedestrian cooperation and tempo," J. Soc. Psychol. 104, 29–35.
Borsky, P. N. (1980). "Review of community response to noise," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen and W. D. Ward (ASHA Reports, Rockville, MD), no. 10, pp. 453–474.
Brecher, G. A. (1934). "Die untere Hör- und Tongrenze," Pflügers Archiv Gesamte Physiol. 234, 380–393.
Broadbent, D. E. (1954). "Some effects of noise on visual performance," Q. J. Exp. Psychol. 6, 1–5.
Broadbent, D. E. (1957). "Effects of noise on behavior," in *Handbook of Noise Control*, edited by C. M. Harris (McGraw-Hill, New York), pp. 10.1–10.34.
Broner, N. (1978). "The effects of low-frequency noise on people—a review," J. Sound Vib. 58, 483–500.
Broner, N., and Leventhall, H. G. (1978). "Low frequency noise annoyance and the dB(A)," Acoust. Lett. 2, 16–21.
Broner, N., and Leventhall, H. G. (1982). "A criterion for predicting the annoyance due to higher level, low frequency noise," J. Low Frequency Noise Vib. 1, 20–28.
Broner, N., and Leventhall, H. G. (1983). "Low-frequency noise annoyance assessment by low-frequency noise rating (LFNR) curves," J. Low Frequency Noise Vib. 2, 20–27.
Brown, R. (1991). "Sleep and resistance to infection." Paper presented at the Inaugural Australian Psychophysiology Conference, Sydney, Australia.
Brown, R., Pang, G., Husband, A. J., and King, M. G. (1989). "Suppression of immunity to influenza virus infection in the respiratory tract following sleep disturbance," Reg. Immunol. 2, 321–325.
Bryan, M. E. (1971). "Annoyance effects due to low frequency sounds," Br. Acoust. Soc. Meeting Infrasound (University of Salford, Lancashire).
Bryan, M. E. (1976). "Low frequency noise annoyance," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 65–96.
Bullen, R. B., and Job, R. F. S. (1985). "Re-analysis of data presented in 'Community Response to Blasting' by Fidell et al. [J. Acoust. Soc. Am. 74, 888–893 (1983)]," J. Acoust. Soc. Am. 78, 799–800.
Bullen, R. B., Job, R. F. S., and Burgess, D. H. (1985). "Reaction to Aircraft Noise on RAAF Bases," National Acoustic Laboratories, Commissioned Report 3, Canberra, Australian Government Publishing Service.
Bullen, R. B., Hede, A. J., and Job, R. F. S. (1991). "Community reaction to noise from an artillery range," Noise Control Eng. J. 37, 115–128.
Cantrell, R. W. (1974). "Prolonged exposure to intermittent noise: Audiometric, biochemical, motor, psychological and sleep effects," Laryngoscope, Suppl. 1, 84, 1–55.
Carter, N. L., and Beh, H. C. (1987). "The effect of intermittent noise on vigilance performance," J. Acoust. Soc. Am. 82, 1334–1341.
Carter, N. L., and Beh, H. C. (1989). "The effect of intermittent noise on cardiovascular functioning during vigilance task performance," Psychophysiology 26, 548–559.
Carter, N. L., Crawford, G., Kelly, D., and Hunyor, S. (1993a). "Environmental noise during sleep and sympathetic arousal assessed by urinary catecholamines," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 3, pp. 388–392.
Carter, N. L., Taylor, R., Job, R. F. S., Peploe, P., Jenkins, A., and Morrell, S. (1993b). "Proposals for studies of aircraft noise and health, Sydney airport," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 2, pp. 469–472.
Cavatorta, A., Falzoi, M., Romanelli, A., Cigala, F., Riccò, M., Bruschi, G., Franchini, I., and Borghetti, A. (1987). "Adrenal response in the pathogenesis of arterial hypertension in workers exposed to high noise levels," J. Hypertension 5, 463–466.
Cohen, S., Evans, G. W., Stokols, D., and Krantz, D. S. (1986). *Behavior, Health, and Environmental Stress* (Plenum, New York).
Corso, J. F. (1958). "Absolute thresholds for tones of low frequency," Am. J. Psychol. 71, 367–374.
Davies, D. R., and Jones, D. M. (1985). "Noise and efficiency," in *The Noise Handbook*, edited by W. Tempest (Academic, New York), pp. 87–141.
Dickson, W. J., and Roethlisberger, F. J. (1966). *Counselling in an Organization: A Sequel to the Hawthorne Studies* (Harvard University, Boston).
Eberhardt, J. L., Stråle, L. O., and Berlin, M. H. (1987). "The influence of continuous and intermittent traffic noise on sleep," J. Sound Vib. 116, 445–464.
Eiff, A. W. von, Friedrich, G., Langewitz, W., Neus, H., Rüddel, H., Schirmer, G., and Schulte, W. (1981). "Traffic noise and hypertension risk. A hypothalamic theory of essential hypertension. Second Communication," Münch. Med. Wochenschr. 123, 420–424.
Ellison, L. F. (1992). "Low frequency noise and vibration annoyance due to low speed rotating machinery," J. Low Frequency Noise Vib. 10, 63–71.
Englund, K., Hagelthorn, G., Hörnqvist, S., Lidström, I. M., Lindqvist, M., Liszka, L., and Söderberg, L. (1978). *Infraljuds effekter på människan.* [The effects of infrasound on man]. Stockholm: Arbetarskyddsstyrelsen, Undersökningsrapport 33. (In Swedish).
Ericson, B., and Engström, K. E. (1964). "The influence of noise on some circulatory functions," Acta Oto-Laryngol. 58, 208–213.
Evans, G. W. (Ed.) (1982). *Environmental Stress* (Cambridge U.P., New York).
Evans, G. W. (1990). "The nonauditory effects of noise on child development," in *Noise as a Public Health Problem*, edited by B. Berglund, U. Berglund, J. Karlsson, and T. Lindvall (Swedish Council for Building Research, Stockholm, D2: 1990), Vol. 5, pp. 425–453.
Fields, J. M. (1992). "Effects of Personal and Situational Variables on Noise Annoyance with Special Implications for en Route Noise," Washington, DC: Federal Aviation Administration and NASA Report No FAA-AEE-92-03.
Fields, J. M. (1993). "Effects of personal and situational variables on noise annoyance in residential areas," J. Acoust. Soc. Am. 93, 2753–2763.
Fidell, S. A., Horonjeff, R., Schultz, T. J., and Teffeteller, S. (1983). "Community response to blasting," J. Acoust. Soc. Am. 74, 888–893.
Fidell, S. A., Barber, D. S., and Schultz, T. J. (1991). "Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise," J. Acoust. Soc. Am. 89, 221–233.
Fletcher, H., and Munson, W. A. (1933). "Loudness, its definition, measurement and calculation," J. Acoust. Soc. Am. 5, 82–108.
Frankenhaeuser, M., and Lundberg, U. (1977). "The influence of cognitive set on performance and arousal under different noise loads," Motivation Emotion 1, 139–149.
French, N. R., and Steinberg, J. C. (1947). "Factors governing the intelligibility of speech sounds," J. Acoust. Soc. Am. 19, 90–119.
Garberale, F., Goldstein, M., Kjellberg, A., Liszka, L., and Löfstedt, P. (1982). Upplevd hörstyrka och störningsgrad hos lågfrekvent ljud. [Perceived loudness and annoyance of low frequency noise] Arbete & Hälsa 1982:2. (National Board of Occupational Safety and Health, Solna, Sweden) (in Swedish).
Gan, W. S. (1987). "Active noise absorption in infrasonics using adaptive digital signal processing," in *Proceedings of the 4th International Meeting on Low Frequency Noise and Vibration*, edited by L. Liszka (University of Umeå, Umeå, Sweden), pp. 1-2-1–1-2-8.
Gierke, H. E. von, and Nixon, C. W. (1976). "Effects of intense infrasound on man," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 115–150.
Gierke, H. E. von, and Parker, D. E. (1976). "Infrasound," in *The Handbook of Sensory Physiology*, edited by W. D. Keidel and W. D. Neff (Springer-Verlag, Berlin), Vol. V/3, pp. 585–624.
Goldstein, M. (1994). "Low-Frequency Components in Complex Noise and Their Perceived Loudness and Annoyance," Doctoral Dissertation, Department of Psychology, Stockholm University. Arbete & Hälsa 1994: 2 (Solna, Sweden: National Board of Occupational Safety and Health).
Goldstein, M., and Kjellberg, A. (1985). "Annoyance and low frequency noise with different slopes of the frequency spectrum," J. Low Frequency Noise Vib. 4, 43–51.
Griffin, M. J. (1990). *Handbook of Human Vibration* (Academic, London).
Hall, F., Birnie, S., Taylor, S. M., and Palmer, J. (1981). "Direct comparison of community response to road traffic noise and to aircraft noise," J. Acoust. Soc. Am. 70, 1690–1698.
Hall, G., and Honey, R. C. (1989). "Contextual effects in conditioning, latent inhibition and habituation: Associative and retrieval functions of contextual cues," J. Exp. Psychol. 15, 232–241.
Hamilton, P., and Hockey, G. R. J. (1970). "Arousal and information selection in short-term memory," Nature 226, 866–867.
Harris, C. M. (ed.) (1979). *Handbook of Noise Control* (McGraw-Hill, New York), 2nd ed.
Haslegrave, C. M. (1990). "Auditory environment and noise assessment," in *Evaluation of Human Work*, edited by J. R. Wilson and N. Corlett (Taylor & Francis, London), pp. 406–439.
Harris, D., Richardson, B., and Ashford, N. A. (1980). "Noise, General Stress Responses and Cardiovascular Disease Processes. Review and Re-

assessment of Hypothesized Relationship," Washington, D.C., EPA Report 550/9-80-101.
Hede, A. J., and Bullen, R. B. (1982). "Aircraft Noise in Australia: A Survey of Community Response," National Acoustic Laboratories, Report No. 88, Commonwealth Department of Health, Canberra, Australia: Australian Government Publishing Service.
Hellman, R. P. (1984). "Growth rate of loudness, annoyance, and noisiness as a function of tone location within the noise spectrum," J. Acoust. Soc. Am. 75, 209–218.
Hockey, G. R., Loeb, M., and Baker, M. A. (1983). "Effects and aftereffects of continuous noise and computation work on risk and effort choices," Motivation Emotion 7, 331–344.
Houtgast, T., and Steeneken, H. J. M. (1983). "Experimental verification of the STI: A valid basis for setting indoor noise level criteria," in *Noise as a Public Health Problem*, edited by G. Rossi (Centro Ricerche e Studi Amplifon, Milan, Italy), Vol. 1, pp. 477–488.
Howarth, H. V. C., and Griffin, M. J. (1990). "Subjective response to combined noise and vibration: Summation and interaction effects," J. Sound Vib. 143, 443–454.
Howarth, H. V. C., and Griffin, M. J. (1991). "The annoyance caused by simultaneous noise and vibration from railways," J. Acoust. Soc. Am. 89, 2317–2323.
Hygge, S. (1993). "Classroom experiments on the effects of aircraft, traffic, train and verbal noise on long-term recall and recognition in children aged 12–14 years," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 2, pp. 531–534.
IEC (1976). *Frequency Weighting for the Measurement of Aircraft Noise (D-weighting)* (Geneva, Switzerland: International Electrotechnical Commission, IEC Publication), pp. 537–1976. [Publication now withdrawn by IEC.]
IEC (1979). *Sound Level Meters* (Geneva, Switzerland: International Electrotechnical Commission, IEC Publication), pp. 651–1979.
ISO (1959). "Expression of the Physical and Subjective Magnitudes of Sound and Noise," Geneva, Switzerland: International Organization for Standardization, ISO Recommendation R 131-1959.
ISO (1979). "Acoustics—Expression of physical and subjective magnitudes of sound or noise in air," Geneva, Switzerland: International Organization for Standardization, International Standard ISO 131-1979(E). (Replaces ISO R131-1959.)
Jansen, G. (1969). "Effects of noise on physiological state," in *Noise as a Public Health Hazard*, edited by W. D. Ward and J. Fricke (American Speech Hearing Association, Washington, DC), pp. 89–98.
Jerger, J., Alford, B., Coats, A., and French, B. (1966). "Effects of very low frequency tones on auditory thresholds," J. Speech Hear. Res. 9, 150–160.
Job, R. F. S. (1988). "Community response to noise: A review of factors influencing the relationship between noise exposure and reaction," J. Acoust. Soc. Am. 83, 991–1001.
Job, R. F. S. (1991). "Reliability and stability of noise reaction scales," Transp. Res. Record 1312, 101–108.
Job, R. F. S. (1993). "Psychological factors of community reaction to noise," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France: INRETS), Vol. 3, pp. 48–70.
Job, R. F. S., and Barnes, B. W. (1995). "Stress and consumption: Inescapable shock, neophobia and finickiness about drinking quinine-adulterated water," Behav. Neurosci. 109, 106–116.
Job, R. F. S., and Bullen, R. B. (1986). "Social Survey Methodology: A Review of the Assessment of Community Noise Reaction in Dose/Response Studies," National Acoustic Laboratories Report 106, Canberra, Australia Government Publishing Service.
Job, R. F. S., and Bullen, R. B. (1987). "The effects of a face to face interview versus a group administered questionnaire in determining reaction to noise," J. Sound Vib. 116, 161–168.
Job, R. F. S., Bullen, R. B., and Burgess, D. H. (1991). "Noise-induced reaction in a work community adjacent to aircraft runways: The Royal Australian Airforce," in *Inter-Noise '91: The Cost of Noise*, edited by A. Lawrence (Noise Control Foundation, Poughkeepsie, NY), Vol. 2, pp. 985–898.
Johnson, D. L. (1973). "Various aspects of infrasound," *Proceedings of Colloquium on Infrasound* (The National Centre for Scientific Research, Paris, France) (38–40 rue de General Leclerc, Paris), pp. 337–358.
Jones, D. M. (1984). "Performance effects," in *Noise and Society*, edited by D. M. Jones and A. J. Chapman (Wiley, Chichester, UK), pp. 155–184.
Jurriens, A. A., Griefahn, B., Kumar, A., Vallet, M., and Wilkinson, R. T. (1983). "An essay in European research collaboration. Common results from the project on traffic noise and sleep in the home," in *Noise as a Public Health Problem*, edited by G. Rossi (Centro Richerche e Studio Amplifon, Milan), Vol. 2, pp. 929–937.
Karczmarska, A., and Augustynska, D. (1992). "Study of sound insulation of control cabins in industry in the low frequency range," J. Low Frequency Noise Vib. 11, 42–46.
Kamperman, G. W. (1980). "Human response to blasting noise and vibration," in *Inter-Noise '80* (Public Noise Control Foundation, New York), pp. 979–984.
Kastka, J., and Paulsen, R. (1991). "Felduntersuchung zur Wirkung von Lärm und Erschütterung für Verschiedene Quellen," in *Deutsche Physicalische Gesellschaft: Fortschritte der Akustik-DAGA '91* (Bad Honnef, DPG GmbH), pp. 441–444.
Kihlman, T. (1993). *Handlingsplan mot buller* [Action Plan Against Noise] (SOU, Stockholm, Liber), p. 6 (in Swedish).
King, P. F., Coles, R. R. A., Lutman, M. E., and Robinson, D. W. (1992). "Assessment of Hearing Disability," *Guidelines for Medicolegal Practice* (Whurr, London).
Kjellberg, A., and Goldstein, M. (1985). "Loudness assessment of band noise of varying bandwidth and spectral shape. An evaluation of various frequency weighting networks," J. Low Frequency Noise Vib. 4, 12–26.
Kjellberg, A., Goldstein, M., and Gamberale, F. (1984). "An assessment of dB(A) for predicting loudness and annoyance of noise containing low frequency components," J. Low Frequency Vib. 3, 10–16.
Klumpp, R. G., and Webster, J. C. (1963). "Physical measurements of equally speech-interfering Navy noises," J. Acoust. Soc. Am. 35, 1328–1338.
Knauth, P., and Rutenfranz, J. (1975). "The effects of noise on sleep of nightworkers," in *Experimental Studies of Shiftwork*, edited by P. Colquhoun, S. Folkard, P. Knauth, and J. Rutenfranz (Westdeutscher Verlag, Opladen).
Knipschild, P. (1977a). "Medical effects of aircraft noise: Community cardiovascular survey," Int. Arch. Occup. Environ. Health 40, 185–190.
Knipschild, P. (1977b). "Medical effects of aircraft noise: General practice survey," Int. Arch. Occup. Environ. Health 40, 197–200.
Knipschild, P. (1980). "Aircraft noise and hypertension," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen, and W. D. Ward (ASHA Reports, Rockville, MD), No. 10, pp. 5–83.
Knipschild, P., and Oudshoorn, N. (1977). "Medical effects of aircraft noise: Drug survey," Int. Arch. Occup. Environ. Health 40, 191–196.
Kryter, K. D. (1962). "Methods for the calculation and use of the articulation index," J. Acoust. Soc. Am. 34, 1689–1697.
Kryter, K. D. (1985). *The Effects of Noise on Man* (Academic, London), 2nd ed.
Kryter, K. D. (1990). "Aircraft noise and social factors in psychiatric hospital admission rates: A reexamination of some data," Psychol. Med. 20, 395–411.
Kryter, K. D. (1994). *The Handbook of Hearing and the Effects of Noise. Physiology, Psychology, and Public Health* (Academic, New York).
Kuwano, S., Namba, S., and Miura, H. (1989). "Advantages and disadvantages of A-weighted sound pressure level in relation to subjective impression of environmental noises," Noise Control Eng. J. 33, 107–115.
Kuwano, S., Namba, S., Hashimoto, T., Berglund, B., Zhen, D. A., Schick, A., Hoege, H., and Florentine, M. (1991). "Emotional expression of noise: A cross-cultural study," J. Sound Vib. 151, 421–428.
Landström, U., Lundström, R., and Byström, M. (1983). "Exposure to infrasound-perception and changes in wakefulness," J. Low Frequency Noise Vib. 2, 1–11.
Landström, U., Lindblom-Häggqvist, S., and Löfstedt, P. (1988). "Low frequency noise in lorries and correlated effects on drivers," J. Low Frequency Noise Vib. 7, 104–109.
Langdon, F. J., and Buller, I. B. (1977). "Road traffic noise and disturbance to sleep," J. Sound Vib. 50, 13–28.
Last, J. M. (1988). *A Dictionary of Epidemiology* (Oxford U.P., Oxford, UK), 2nd ed.
Leventhall, H. G. (1988). "Low frequency noise in buildings—internal and external sources," J. Low Frequency Noise Vib. 7, 74–85.
Leventhall, H. G., and Kyriakides, K. (1976). "Environmental infrasound: Its occurrence and measurement," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 1–18.
Leventhall, H. G., Wise, S. S., and Dineen, S. (1994). An energy efficient method for controlling noise in HVAC systems. Poster paper at CIBSE National Conference, 3–4 October, 1994.

ton, DC Environmental Protection Agency, Rep. EPA550/9-77-101.
Schomer, P. D. (1981). "Community Reaction to Impulse Noise: Initial Army Survey," Champaign, IL, U.S. Army Construction Engineering Research Laboratory, Tech. Rep. N-100.
Schomer, P. D., and Averbuch, A. (1989). "Indoor human response to blast sounds that generate rattles," J. Acoust. Soc. Am. 86, 665–673.
Schomer, P. D., and Neathammer, R. D. (1987). "The role of helicopter noise induced vibration and rattle in human response," J. Acoust. Soc. Am. 81, 966–976.
Schomer, P. D., Goff, R. J., and Little, L. M. (1978). "Statistics of amplitude and spectrum of blasts propagated in the atmosphere," J. Acoust. Soc. Am. 63, 1431–1443.
Schultz, T. J. (1978). "Synthesis of social surveys on noise annoyance," J. Acoust. Soc. Am. 64, 377–405.
Seligman, M. E. P. (1991). *Learned Optimism* (Random House, Milson's Point, NSW Australia).
Shepherd, K. P., and Hubbard, H. H. (1991). "Physical characteristics and perception of low frequency noise from wind turbines," Noise Control Eng. J. 36, 5–15.
Stansfeld, S. A. (1992). "Noise, noise sensitivity and psychiatric disorder: Epidemiological and psychophysiological studies," Psychol. Med. Monograph Suppl. 22.
Stansfeld, S. A., Clark, C. R., Jenkins, L. M., and Tarnopolsky, A. (1985). "Sensitivity to noise in a community sample: I. The measurement of psychiatric disorder and personality," Psychol. Med. 15, 243–254.
Stevens, S. S. (1961). "Procedure for calculating loudness: MARK VI," J. Acoust. Soc. Am. 33, 1577–1585.
Stevens, S. S. (1972). "Perceived level of noise by MARK VII and decibels (E)," J. Acoust. Soc. Am. 51, 575–601.
Stevens, S. S. (1975). *Psychophysics: Introduction to its Perceptual, Neural and Social Prospects* (Wiley, New York).
Tafalla, R. J., and Evans, G. (1993). "Noise, physiology and human performance: The potential role of effort," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France: INRETS), Vol. 2, pp. 515–518.
Tempest, W. (1973). "Loudness and annoyance due to low frequency sound," Acustica 29, 200–205.
Tempest, W. (1976). "Infrasound in transportation," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 19–36.
Thiessen, G. J. (1970). "Effects of noise during sleep," in *Psychological Effects of Noise*, edited by B. L. Welch and A. S. Welch (Plenum, New York), pp. 271–275.
Thiessen, G. J. (1978). "Disturbance of sleep by noise," J. Acoust. Soc. Am. 64, 216–222.
Thiessen, G. J., and Lapointe, A. C. (1978). "Effect of intermittent truck noise on percentage of deep sleep," J. Acoust. Soc. Am. 64, 1078–1080.
Thiessen, G. J., and Lapointe, A. C. (1983). "Effect of continuous truck noise on percentage of deep sleep waking, and sleep latency," J. Acoust. Soc. Am. 73, 225–229.
Vallet, M. (Ed.) (1993). *Noise as a Public Health Problem* (Arcueil Cedex, France, INRETS), Vol. 3.
Vallet, M., Gagneux, J., Clairet, J. M., Laurens, J. F., and Letisserand, D. (1983). "Heart rate reactivity to aircraft noise after a long-term exposure," in *Noise as a Public Health Problem*, edited by G. Rossi (Centro Ricerche e Studio Amplifon, Milan), pp. 965–975.
Vasudevan, R. N., and Gordon, C. G. (1977). "Experimental study of annoyance due to low-frequency environmental noise," Appl. Acoust. 10, 57–69.
Vasudevan, R. N., and Leventhall, H. G. (1982). "A study of annoyance due to low frequency noise in the home," J. Low Frequency Noise Vib. 1, 157–164.
Vasudevan, R. N., and Leventhall, H. G. (1989). "Annoyance due to environmental low frequency noise and source location—a case study," J. Low Frequency Noise Vib. 8, 30–39.
Vercammen, M. L. S. (1992). "Low-frequency noise limits," J. Low Frequency Noise Vib. 11, 7–13.
Vos, J., and Smoorenburg, G. F. (1985). "Penalty for impulse noise, derived from annoyance ratings for impulse and road-traffic sounds," J. Acoust. Soc. Am. 77, 193–201.
Ward, W. D. (1993). "Developments in noise induced hearing loss during the last 25 years," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 3, pp. 37–41.
Wegel, R. L., and Lane, C. E. (1924). "The auditory masking of one pure tone by another and its probable relation to the dynamics of the inner ear," Physiol. Rev. 23, 266–285.
Welch, B. L., and Welch, A. S. (Eds.) (1970). *Physiological Effects of Noise* (Plenum, New York).
Whittle, L. S., Collins, S. J., and Robinson, D. W. (1972). "The audibility of low frequency sounds," J. Sound Vib. 21, 431–448.
WHO (1980). "Noise. Environmental Health Criteria Document, 12," Geneva, Switzerland, World Health Organization.
WHO (1993). "Community Noise. Environmental Health Criteria Document" (External Review Draft, June 28, 1993, edited by rapporteurs B. Berglund and T. Lindvall), Stockholm, Stockholm University and Karolinska Institute.
Wilkinson, R. T., and Campbell, K. B. (1984). "Effects of traffic noise on quality of sleep: Assessment by EEG, subjective report and performance the next day," J. Acoust. Soc. Am. 75, 468–475.
Wilkinson, R. T., Campbell, K. C., and Roberts, L. D. (1980). "Effects of noise at night upon performance during the day," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen, and W. D. Ward (ASHA Reports, Rockville, MD), No. 10, pp. 406–412.
Williams, D., and Tempest, W. (1975). "Goods vehicle noise," J. Sound Vib.
Wise, S. S., Depies, C. R., and Dineen, S. E. (1992). "Case histories of active noise control on industrial fans and air handlers used for heating, ventilating, and air conditioning," in *Inter-Noise '92. The Cost of Noise*, edited by A. Lawrence (Noise Control Foundation, Poughkeepsie, NY), pp. 307–312. 43, 97–107.
Yamada, S., Watanabe, T., Kosaka, T., Negishi, H., and Watanabe, H. (1986). "Physiological effects of low frequency noise," J. Low Frequency Noise Vib. 5, 14–25.
Yamada, S., Sucki, M., Hagiwara, S., Watanabe, T., and Kosaka, T. (1991). "Psychological combined effects of low frequency noise and vibration," J. Low Frequency Noise Vib. 10, 130–136.
Yeowart, N. S. (1976). "Thresholds of hearing and loudness for very low frequencies," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 37–64.
Yeowart, N. S., and Evans, M. J. (1974). "Thresholds of audibility for very low frequency pure tones," J. Acoust. Soc. Am. 55, 814–818.
Yeowart, N. S., Bryan, M. E., and Tempest, W. (1967). "The monaural MAP threshold of hearing at frequencies from 1.5 to 100 c/s," J. Sound Vib. 6, 335–342.
Zhao, Y., Zhang, S., Selvin, S., and Spear, R. C. A. (1991). "A dose response relation for noise induced hypertension," Br. J. Ind. Med. 48, 179–184.
Zwicker, E. (1963). "Über die Lautheit von ungedrosselten und gedrosselten Schallen," Acustica 13, 194–211.
Zwicker, E., and Fastl, H. (1990). *Psychoacoustics. Facts and Models* (Springer-Verlag, Berlin).

STATE OF NEW YORK

SUPREME COURT CLINTON COUNTY

- X

Amy Filion and Dinah Miller,

Petitioners

AFFIDAVIT

-against-

Index No._____

Town of Clinton Town Board,

Respondent

- X

STATE OF NEW YORK,)

) ss.:

COUNTY OF CLINTON)

Nina Pierpont, MD, PhD, being duly sworn, deposes and says:

1. I have become aware of additional important health information related to industrial wind turbines since the submission of the Article 78 lawsuits and wish to add this information to the suits.

2. An international research group centered in Portugal and including physicians from Poland, Russia, and the United States has published extensively on the effects of low-frequency noise on parts of the body other than the ears, particularly on the cardiovascular, pulmonary, and neurological systems.[1] The research includes clinical, pathological, and experimental (animal model) work, and has been ongoing since the late 1980's. The entity these physicians and PhD's describe, called vibroacoustic disease (VAD), includes fibrosis (laying down of additional fibrous thickening in the form of collagen) in the cardiovascular and pulmonary systems, and seizures and cognitive changes in the brain. The disease is caused by long-term exposure to low-frequency noise (less than 500 Hz), most of which cannot be heard.

3. Vibroacoustic disease has been studied mostly in aviation workers (including pilots and flight attendants as well as technicians), but is also found in other industries and community settings. One of the researchers, Mariana Alves-Pereira, PhD, a biomedical engineer, has recently compared the noise spectrum of an environment known to predispose occupants to VAD – the cockpit of a commercial jetliner – to the noise spectrum of other common community settings, finding that a variety of community settings have the low-frequency noise potential for causing VAD. She has examined noise measurements of industrial wind turbines provided to her by Dr. Amanda Harry (a physician) and Dr. Manley (an acoustician) in England and found them to be in the intensity range, at the low frequencies, of noise which can cause VAD. She has also examined graphs of wind turbine sound pressure levels vs. frequency measured by Dr. G.P. van den Berg and considers the noise intensities at the lower frequencies to be concerning with regard to their potential for causing VAD. She is aware of the symptomatology of the D'Entremont family in Pubnico, Nova Scotia, who had to move out of their home 1000 ft. from a wind turbine, and

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[1] Papers submitted are a selection from many:

1. Branco M and Alves-Pereira M. 2004. Vibroacoustic disease. Noise and Health 6 (23):3-20.
2. Alves-Pereira M. 1999. Noise-induced extra-aural pathology: a review and commentary. Aviat Space Environ Medication 70 (3 Pt 2):A7-21.
3. Marciniak W et al. 1999. Echocardiographic evaluation of 485 aeronautical workers exposed to different noise environments. 1999. Aviat Space Environ Medication 70 (3 Pt 2):A46-53.

notes the similarity of their symptoms to those of people with proven VAD. We are working to provide her with noise measurements from additional wind turbine installations.

4. Dr. Alves-Pereira's papers are very instructive with regard to how neighbors and town governments should be handling the issues of noise and noise measurements related to wind turbines. An A-weighted decibel measurement misses all the low-frequency noise, since A weighting is specifically designed to mimic the frequency response pattern of the human ear. The frequencies which are harmful to other parts of the body, for example the heart, lungs, and brain, generally cannot be heard. Just as we cannot detect X rays (because our eyes are not sensitive to this frequency), yet can be harmed by them, so we can be harmed by non-audible noise (pressure waves in the air), though our ears are not sensitive to them. The mechanism of this harm is the differing resonance frequencies of different parts of the human body, especially the chest and skull. Air pressure (sound) waves of certain wavelengths resonate inside these walled spaces, setting up vibrations to which the body responds by reinforcing its softer tissues with extra collagen, causing such problems as thickening of the pericardium (membrane inside which the heart beats) and cardiac valves, fibrosis of the lungs, and proliferation of glial (supporting) cells in the brain.

5. The Ellenburg and Clinton wind turbine ordinances are inadequate to protect the citizenry from the potential ill health effects of low-frequency noise from wind turbines. The ordinances do not place any restriction on the production of low-frequency noise, since they restrict only the A-weighted decibel level, which excludes low-frequency noise. Rather than a single decibel level the noise environment needs to be characterized by measurement of linear (unweighted) decibel levels across the sound frequency spectrum. Measurements should be taken inside homes, since the lower frequency, longer wavelengths also resonate within rooms, magnifying their loudness relative to the outside. Low frequency noise also comes through walls with less attenuation than the 15 dB decrease assumed for higher frequency audible noise.

6. The ordinances also allow for an averaged noise level reading (Leq), not recognizing that it is the peaks of noise, not the average, which will be most annoying and most harmful.

7. In short, the sections of the Clinton and Ellenburg wind turbine ordinances need to be revised in order to protect their citizens against the risk of serious, long-term pathology due to the low-frequency component of wind turbine noise.

Nina Pierpont, MD, PhD
19 Clay Street
Malone, New York 12953
(518) 483-6481

Sworn to before me this
day of April, 2006

Notary Public

Table 1. Data from a group of 140 aircraft technicians (selected from an initial group of 306 workers), occupationally exposed to LFN (Low Frequency Noise)(8 hrs/day, 5 days/week). Exposure time (in years) refers to the amount of time it took for 70 individuals (50%) to develop the corresponding sign or symptom (Castelo Branco, 1999b).

Clinical Stage	Sign/Symptom
Stage I-Mild (1 -4 years)	Slight mood swings, Indigestion and heart-burn, Mouth/throat infections, Bronchitis
Stage II-Moderate (4- 10 years)	Chest pain, Definite mood swings, Back pain, Fatigue, Fungal, viral and parasitic skin infections, Inflammation of stomach lining, Pain and blood in urine, Conjunctivitis, Allergies
Stage III-Severe (> 10 years)	Psychiatric disturbances, Haemorrhages of nasal, digestive and conjunctive mucosa, Varicose veins and haemorrhoids, Duodenal ulcers, Spastic colitis, Decrease in visual acuity, Headaches, Severe joint pain, Intense muscular pain, Neurological disturbances [include seizures & decreased cognition]

*Note: Where there is nighttime as well as daytime exposure to low frequency noise (LFN), the symptoms and pathology progress more rapidly, according to Dr. Mariana Alves-Pereira.

Source: N. Branco & M. Alves-Pereira, "Vibroacoustic disease," Noise & Health, vol. 6, no. 23 (April-June 2004):3-20.

Lindvall, T., and Radford, E. P. (Eds.) (1973). "Measurement of annoyance due to exposure to environmental factors," Environ. Res. 6, 1–36.

Liszka, L. (1974). "Long-distance propagation of infrasound from artificial sources," J. Acoust. Soc. Am. 56, 1383–1388.

Liszka, L. (1978). "Long distance focusing of Concorde sonic boom," J. Acoust. Soc. Am. 64, 631–635.

Loeb, M. (1981). "The present state of research on the effects of noise: Are we asking the right questions?," J. Audiol. Res. 21, 93–104.

Loeb, M. (1986). *Noise and Human Efficiency* (Wiley, Chichester).

Loeb, M., Holding, D. H., and Baker, M. A. (1982). "Noise stress and circadian arousal in self-paced computation," Motiv. Emotion 6, 43–48.

Lombard, P. F., Preston, G. C., and Mackintosh, N. J. (1984). "Context specificity of conditioning and latent inhibition," J. Exp. Psychol. Animal Behav. Process. 10, 360–375.

Lundberg, U., and Frankenhaeuser, M. (1978). "Psychophysiological reactions to noise as modified by personal control over noise intensity," Biolog. Psychol. 6, 51–59.

Marks, L. E. (1978). "PHONION: Translation and annotations concerning loudness scales and the processing of auditory intensity," in *Cognitive Theory*, edited by N. J. Castellan and F. Restle (Erlbaum, Hillsdale, NJ), Vol. 3, pp. 7–31.

McKennell, A. C. (1978). "Annoyance from Concorde flights around Heathrow," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen, and W. D. Ward (ASHA Reports, Rockville, MD), No. 10, pp. 562–566.

Meecham, W. C., and Shaw, N. (1979). "Effects of jet noise on mortality rates," Br. J. Audiol. 13, 77–80.

Meecham, W. C., and Smith, H. G. (1977). "Effects of jet aircraft noise on mental hospital admissions," Br. J. Audiol. 11, 81–85.

Michalak, R., Ising, H., and Rebentisch, E. (1990). "Acute circulatory effects of military low altitude flight noise," Int. Arch. Occup. Environ. Health 62, 365–372.

Miller, G. A., and Licklider, J. C. R. (1950). "The intelligibility of interrupted speech," J. Acoust. Soc. Am. 22, 167–173.

Mills, J. H., Osguthorpe, D., Burdick, C. K., Patterson, J. H., and Mozo, B. (1983). "Temporary threshold shifts produced by exposure to low-frequency noises," J. Acoust. Soc. Am. 73, 918–923.

Mohr, G. C., Cole, J. N., Guild, E., and von Gierke, H. E. (1965). "Effects of low frequency and infrasonic noise on man," Aerosp. Med. 36, 817–824.

Møller, H. (1984). "Physiological and psychological effects of infrasound on humans," J. Low Frequency Noise Vib. 3, 1–17.

Møller, H. (1987). "Annoyance of audible infrasound," J. Low Frequency Noise Vib. 6, 1–17.

Møller, H., and Andresen, J. (1984). "Loudness of pure tones at low infrasonic frequencies," J. Low Frequency Noise Vib. 3, 78–87.

Murray, B. J., and Avery, G. (1984). "Survey of community reaction to overpressure from blasting," Wilkinson-Murray Report No. W4244, Lindfield, Australia.

Muzet, A., and Ehrhardt, J. (1978). "Habituation of heart rate and finger pulse responses to noise in sleep," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen and W. D. Ward (ASHA Reports, Rockville, MD), No. 10, pp. 401–404.

Muzet, A., Ehrhardt, J., Eschenlauer, R., and Lienhard, M. P. (1981). "Habituation and age differences of cardiovascular responses to noise during sleep," *Sleep 1980. Fifth European Congress on Sleep Research* (Karger, Basil, Amsterdam), pp. 212–215.

Nagai, N., Matsumoto, M., Yamasumi, Y., Shiraishi, T., Nishimura, K., Matsumoto, K., Miyashita, K., and Takeda, S. (1989). "Process and emergence on the effects of infrasonic and low frequency noise on inhabitants," J. Low Frequency Noise Vibration 8, 87–99.

Neus, H., Ruddel, H., Schulte, W., and von Eiff, A.-W. (1983). "The long-term effect of noise on blood pressure," J. Hypertension 1, 251–253.

Nixon, C. W. (1973). "Human auditory response to intense infrasound," *Proceedings of Colloquium on Infrasound* (The National Centre for Scientific Research, Paris, France), 15B 40 rue de General Leclerc, Paris.

Nixon, C. W., and Johnson, D. L. (1973). "Infrasound in hearing," in *Noise as a Public Health Problem*, edited by W. D. Ward (Environmental Protection Agency, Washington D.C.), pp. 329–348.

Öhrström, E. (1993a). "Research on noise and sleep since 1988: Present state," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 3, pp. 331–338.

Öhrström, E. (1993b). "Long-term effects in terms of psycho-social wellbeing, annoyance and sleep disturbance in areas exposed to high levels of road traffic noise," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil Cedex, France, INRETS), Vol. 3, pp. 357–366.

Öhrström, E., and Rylander, R. (1982). "Sleep disturbance effects of traffic noise—a laboratory study on after-effects," J. Sound Vib. 84, 87–103.

Osada, Y., Yoshida, K., Tsunashima, S., Ogawa, S., Hirokawa, A., Nakamura, K., Obokata, C., and Harada, K. (1972). "Influence of sex and age on the physiological response to intermittent noise," Bull. Inst. Public Health (Tokyo) 21, 14–19 (in Japanese).

Overmier, J. B., and Hellhammer, D. H. (1988). "The learned helplessness model of depression," Anim. Models Psych. Disord. 2, 177–202.

Page, R. A. (1977). "Noise and helping behavior," Environ. Behav. 9, 311–334.

Palmblad, J., Karlsson, K., Strander, H., Fröberg, J., Karlsson, C.-G., Levi, L., Granström, M., and Unger, P. (1976). "Stressor exposure and immunological response in man; Interferon-producing capacity and phagocytosis," J. Psychosom. Res. 20, 193–199.

Palmblad, J., Petrini, B., Wasserman, J., and Åkerstedt, T. (1979). "Lymphocyte and granulocyte reactions during sleep deprivation," Psychosom. Med. 41, 273–278.

Parker, D. E. (1976). "Effects of sound on the vestibular system," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 151–185.

Parrot, J., Petiot, J. C., Lobreau, J. P., and Smolik, H. J. (1992). "Cardiovascular effects of impulse noise, road traffic noise, and intermittent pink noise at Leq=75 dB, as a function of sex, age and level of anxiety. A comparative study. I. Heart rate data," Int. Arch. Occup. Environ. Health 63, 477–484.

Peploe, P., Cook, R., and Job, R. F. S. (1993). "Evaluation of the APL criterion for community annoyance caused by noise," National Acoustic Laboratories Commissioned Report No. 79, Chatswood, NSW, Australian Hearing Services.

Persson, K., and Björkman, M. (1988). "Annoyance due to low frequency noise and the use of the dB(A) scale," J. Sound Vib. 127, 491–497.

Persson, K., and Rylander, R. (1988). "Disturbance from low-frequency noise in the environment: A survey among the local environmental health authorities in Sweden," J. Sound Vib. 121, 339–345.

Persson, K., Björkman, M., and Rylander, R. (1985). "An experimental evaluation of annoyance due to low frequency noise," J. Low Frequency Noise Vib. 4, 145–153.

Persson, K., Björkman, M., and Rylander, R. (1990). "Loudness, annoyance and dBA in evaluating low frequency sounds," J. Low Frequency Noise Vib. 9, 32–45.

Pickett, J. M. (1959). "Low frequency noise and methods for calculating speech intelligibility," J. Acoust. Soc. Am. 31, 1259–1263.

Poulton, E. C. (1989). *Bias in Quantifying Judgments* (Erlbaum, Hillsdale, NJ).

Preis, A., and Berglund, B. (1993). "Perceived annoyance of intermittent environmental sounds," in *Noise as a Public Health Problem*, edited by M. Vallet (Arcueil, Cedex, France, INRETS), Vol. 2, pp. 343–346.

Preis, A., and Terhardt, E. (1989). "Annoyance of distortions of speech: Experiments on the influence of interruptions and random-noise impulses," Acustica 68, 263–267.

Rao, B. K. N., and Ashley, C. (1976). "Subjective effects of vibration," in *Infrasound and Low Frequency Vibration*, edited by W. Tempest (Academic, London), pp. 187–234.

Rovekamp, A. J. M. (1983). "Physiological effects of environmental noise on normal and more sound-sensitive human beings," in *Noise as a Public Health Problem*, edited by G. Rossi (Centro Ricerche E Studi Amplifon, Milan), Vol. 1, pp. 605–614.

Salamé, P. (1988). "Exploring the irrelevant speech effect: Music, speech-like noises and visual immediate memory," in *Noise as a Public Health Problem Vol. 1: Abstract Guide*, edited by B. Berglund, U. Berglund, J. Karlsson, and T. Lindvall (Swedish Council for Building Research, Stockholm), D25:1988, p. 102.

Sandberg, U. (1987). "Identification of infrasound generation mechanisms in a bus," in *Proceedings of the 4th International Meeting on Low Frequency Noise and Vibration*, edited by L. Liszka (University of Umeå, Umeå, Sweden), pp. 8-7-1–8-7-11.

Scharf, B., and Hellman, R. (1980). "How best to predict human response to noise on the basis of acoustic variables," in *Noise as a Public Health Problem*, edited by J. V. Tobias, G. Jansen, and W. D. Ward (ASHA Reports, Rockville, MD), No. 10, pp. 475–487.

Scharf, B., Hellman, R., and Bauer, J. (1977). "Comparison of Various Methods for Predicting Loudness and Acceptability of Noise," Washing-

Vibroacoustic Disease

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Vibroacoustic disease (VAD) is a whole-body, systemic pathology, characterized by the abnormal proliferation of extra-cellular matrices, and caused by excessive exposure to low frequency noise (LFN). VAD has been observed in LFN-exposed professionals, such as, aircraft technicians, commercial and military pilots and cabin crewmembers, ship machinists, restaurant workers, and disk-jockeys. VAD has also been observed in several populations exposed to environmental LFN. This report summarizes what is known to date on VAD, LFN-induced pathology, and related issues.

In 1987, the first autopsy of a deceased VAD patient was performed. The extent of LFN-induced damage was overwhelming, and the information obtained is, still today, guiding many of the associated and ongoing research projects. In 1992, LFN-exposed animal models began to be studied in order to gain a deeper knowledge of how tissues respond to this acoustic stressor.

In both human and animal models, LFN exposure causes thickening of cardiovascular structures. Indeed, pericardial thickening with no inflammatory process, and in the absence of diastolic dysfunction, is the hallmark of VAD. Depressions, increased irritability and aggressiveness, a tendency for isolation, and decreased cognitive skills are all part of the clinical picture of VAD. LFN is a demonstrated genotoxic agent, inducing an increased frequency of sister chromatid exchanges in both human and animal models. The occurrence of malignancies among LFN-exposed humans, and of metaplastic and displastic appearances in LFN-exposed animals, clearly corroborates the mutagenic outcome of LFN exposure.

The inadequacy of currently established legislation regarding noise assessments is a powerful hindrance to scientific advancement. VAD can never be fully recognized as an occupational and environmental pathology unless the agent of disease - LFN - is acknowledged and properly evaluated. The worldwide suffering of LFN-exposed individuals is staggering and it is unethical to maintain this status quo.

Keywords: cardiovascular thickening, echocardiography, respiratory drive, tumours, extra-cellular matrix, low frequency noise

Introduction

For the past two millennia, acoustic events have been associated with hearing impairment. Within the past 200 years, human civilization has been an ever-increasing source of acoustic energy, on par only with the amount of light that is produced on our planet. However, unlike electromagnetic radiation, where different frequencies are known to produce different health hazards, with acoustic energy no such information is available. Despite the substantial body of evidence indicating that acoustic phenomena impinges on more than just the ear, "noise" continues to be assessed based on the assumption that only what the individual *hears* is harmful (Alves-Pereira and Castelo Branco, 1999). The implication that an agent of disease has to be perceived to be harmful is ludicrous: x-rays, for example, are not perceived by humans, but are, nevertheless, a fully recognized health hazard.

In 1928, Laird published one of the first studies on the physiological effects of noise on typists (Laird, 1928), and since then, vast amounts of medical and biomedical studies have appeared in the literature (Alves-Pereira, 1999). In 1946, E. Dart, employed as a physician at the Ford aircraft engine manufacturing plant, in Detroit, MI, USA, described a set of symptoms observed in aircraft technicians (Dart, 1946). Rumancev, in 1961, describes the same collection of symptoms that he observed in a population of workers employed by a reinforced concrete factory, in the Soviet Union (Rumancev, 1961). Cohen, in the USA in 1971, reported on the medical complaints of boiler-plant workers, before and after the implementation of a hearing conservation program, and listed similar symptoms as Dart and Rumancev before him (Cohen, 1971). Grechkovskaia *et al.* speak of a "vibronoise pathology" in workers employed at an aircraft industry in Kiev, Ukraine (Grechkovskaia *et al.* 1997). Balunov *et al.* studied workers engaged in ferro-concrete production in St. Petersburg, Russia, under combined vibration, infrasound and noise, and concluded that this group had an increased morbidity (Balunov *et al.*, 1998). In 86 female textile workers, Magomedov *et al.* identified disturbances of the autonomic and central nervous systems that preceded hypoacousis, such as asthenovegetative and neurotic syndromes (Magomedov *et al*, 1997). Also in 1997, Izmerov *et al.* suggested the existence of a whole body response to infrasound (Izmerov *et al.*, 1997).

In 1979, the health of workers employed by the Portuguese Air Force, at an aircraft maintenance, repair and manufacturing plant (OGMA), was placed under the care of author Castelo Branco. While visiting all work-stations, he witnessed an aircraft run-up procedure and observed a technician walking about aimlessly, in what appeared to be an epileptic-like episode (Castelo Branco and Rodriguez, 1999). This prompted an investigation into the medical records of all aircraft technicians to determine how many had been previously diagnosed with late-onset epilepsy. The astounding number of 10%, versus the expected 0.2% found among the Portuguese population, was the basis for the in-depth neurological evaluation that ensued (Castelo Branco and Rodriguez, 1999).

Until 1987, aircraft technicians employed by OGMA received a series of medical tests that included brainstem auditory evoked potentials, brain MRI, cognitive tests and neurological examinations. All subjects were fully-informed volunteers. A large amount of neurological changes were identified in this group of aircraft technicians (Martinho Pimenta and Castelo Branco, 1999a) that included brain lesions and increased latencies in nerve conduction (Pimenta *et al.*, 1999), decreased cognition (Gomes *et al.*, 1999) and the appearance of archaic reflexes (Martinho Pimenta *et al.*, 1999a).

The First Autopsy

In 1983, the first patient in this group died suddenly, and an autopsy was not possible. This irritated Mr. Felipe Pedro, another aircraft technician, who had taken an academic interest in his health problems. The event prompted him to draw up a legal will, demanding that, upon his death, an autopsy be performed by Castelo Branco. Mr. Felipe Pedro worked as a ship machinist in the Portuguese Navy for 10 years prior to being hired by OGMA, in 1959, as an aircraft technician. A detailed description of the course of his medical evolution is given elsewhere (Castelo Branco, 1999a).

One early September morning in 1987, Castelo Branco received a phone call from Mr. Felipe Pedro who told him that he was very ill and was going to die. He asked Castelo Branco to meet him at the hospital so the autopsy could be performed. When Castelo Branco reached the hospital, Mr. Felipe Pedro was deceased. And the autopsy was performed. The findings so graciously provided to us by Mr. Felipe Pedro have been the basis for much of the subsequent research into noise-exposed workers.

Diagnosed with late-onset epilepsy in 1981, this man died at age of 58, of cardiac tamponade caused by a small infarct. His heart disclosed 11 small scars of previous silent ischemic events. Cardiac valves seemed swollen, and the pericardium surrounding the heart was greatly thickened. Coronary arteries were thickened, but not by the usual, and expected, artherosclerotic plaques. Instead, a continuous thickening of the

Table 1. Data from a group of 140 aircraft technicians (selected from an initial group of 306 workers), occupationally exposed to LFN (8 hrs/day, 5 days/week). Exposure time (in years) refers to the amount of time it took for 70 individuals (50%) to develop the corresponding sign or symptom (Castelo Branco, 1999b).

Clinical Stage	Sign/Symptom
Stage I-Mild (1-4 years)	Slight mood swings, Indigestion and heart -burn, Mouth/throat infections, Bronchitis
Stage II-Moderate (4-10 years)	Chest pain, Definite mood swings, Back pain, Fatigue, Fungal, viral and parasitic skin infections, Inflammation of stomach lining, Pain and blood in urine, Conjunctivitis, Allergies
Stage III–Severe (> 10 years)	Psychiatric disturbances, Haemorrhages of nasal, digestive and conjunctive mucosa, Varicose veins and haemorrhoids, Duodenal ulcers, Spastic colitis, Decrease in visual acuity, Headaches, Severe joint pain, Intense muscular pain, Neurological disturbances

intima lined all vessel walls. Microscopic studies later revealed that much of the thickening was due to abnormal proliferation of collagen fibres. Two tumours were found, a Grawitz in the kidney, and a grade I, microcystic astrocytoma in the right parietal region of the brain.

Echocardiography

The autopsy findings of thickened cardiac structures led to the echocardiographic study of the population of aircraft technicians. All had thickened pericardia, and many also exhibited thickened cardiac valves (Marciniak *et al.*, 1999). A literature review revealed that Prof. Matoba, in Japan, had already identified pericardial thickening in some chainsaw workers (Matoba, 1983). Today, pericardial thickening in the absence of an inflammatory process, and with no diastolic dysfunction, is the hallmark of VAD (Holt, 2000). Pericardial thickening among LFN-exposed individuals has been anatomically confirmed through light and electron microscopy studies of VAD patient pericardial fragments (collected with patients' informed consent, during cardiac bypass surgery received for other reasons) (Castelo Branco *et al.*, 1999a, 2001, 2003a,b).

Echo-imaging equipment for cardiac structures has many manufacturers and many different models. Enhancing the view of pericardial thickening is not an established procedure. Thus, technician-dependent subjectivity is still inherent to this diagnostic method for VAD. Nevertheless, echocardiography is still the standard test for diagnosing VAD. Thickened cardiac structures have been observed in aircraft technicians (Marciniak *et al.*, 1999), commercial airline pilots and flight attendants (Araujo *et al.*, 2001), and in an islander population exposed to environmental LFN (Torres *et al.*, 2001). Thickening of cardiovascular structures has also been observed in LFN-exposed animal models (Castelo Branco *et al.*, 2003c).

The Clinical Stages of Vibroacoustic Disease

The evolution of VAD, as per years of occupational exposure, was defined in 1999 (see Table 1) (Castelo Branco,1999b). Establishing the evolution of VAD was not an easy task given the insidious nature of this pathology. In an initial group of 306 male aircraft technicians, all employed by OGMA for more than 10 years, rigorous selection criteria were applied as per Table 2. A group of 140 technicians (average age of 42 years, SD=10.4) remained after the application of selection criteria, i.e., 166 individuals were excluded.

OGMA, founded in 1918, possessed an on-site medical unit where all employees were seen when hired, and an individual medical file was

Table 2. Conditions for study population exclusion.

Conditions	Comments
Streptococcal Infections	Due to their propensity to induce extracellular matrix changes.
Diabetes mellitus	Same as above
Pre-existing Cardiovascular Disease	But not labile hypertensives, because it is suspected that this might be a measure of individual susceptibility, and because lesions are distinct from those caused by established hypertension.
Tobacco Abuse	Smokers of more than 20 cigarettes a day.
Alcohol Abuse	Drinkers with more than a litre of wine per day (10-12% alcohol content)
Drug Use	Users of any recreational or psychotropic drug.

opened. Subsequently, all annual examinations and medical complaints were recorded in the employee's medical file. The on-site medical unit offered employees a variety of medical specialties free of charge, such as internal medicine, cardiology, endocrinology, psychiatry, neurology, clinical and social psychology, dentistry, orthopaedics, general surgery, ophthalmology and otorhinolaryngology. An employee who required a specialist not available in the on-site medical unit, and wanted to make use of the National Health Care System, had to be referred to that specialist by one of the on-site general physicians. All medical information was thus recorded in all employee medical files.

The medical files of the 140 technicians were comprehensively and chronologically reviewed. Simultaneously, a sociologist and a social worker interviewed family and friends to obtain additional information on the individual's behaviour outside his professional activity. The methodology to obtain a correspondence between sign/symptom and years of occupational exposure was the 50% cut-off, i.e., the sign/symptom was included in the list if it was identified in 50% (N=70) of the study population. Thus, referring to Table 1, after 1-4 years of occupational exposure, at least 70 of these 140 individuals developed bronchitis, in smokers and non-smokers alike (smokers in study group: N=45). Or, after 10 years of occupational activity, at least 70 exhibited headaches and nose bleeds. It should be emphasized that these signs and symptoms are not mutually exclusive, and most VAD patients suffer from more than one or two of these clinical situations, simultaneously (Castelo Branco, 1999b).

Table 1 refers to the signs and symptoms developed specifically by aircraft technicians working the standard 8 hrs/day, 5 days/week. Not all LFN-exposed workers have this exposure schedule. For example, ship machinists can spend 3 weeks onboard ship (i.e., exposed to substantial LFN-rich environments) and 2 weeks at home (i.e., presumably not in LFN-rich environments) (Arnot, 2003). Other professional activities exist where the LFN-exposure time pattern is not the standard 8-hr/day exposure, such as with submarine and oil rig operators, and astronauts. In these cases, the evolution of signs and symptoms could be greatly accelerated. Moreover, since different LFN environments have unique frequency distributions, the fact that some frequency bands may be more predominant than others (i.e., concentrate more acoustical energy) can lead to the development of slightly different pathology. If the LFN exposure is environmental and/or leisurely, the standard 8hr/day model is also not applicable.

Associated Pathology

Other important pathologies were identified among these 140 aircraft technicians, but since they were not identified in 50% of the population, they were not included in Table 1. Nevertheless, their incidence is clinically important.

Some kind of respiratory insufficiency was found in 24 of the 140 professionals, 11 were smokers. In 10 of the 24 cases, a mere light physical effort was necessary to produce symptoms. Notably, only 45 of the 140 individuals were smokers, 38 of which had over 20 years of occupational LFN exposure.

Late-onset epilepsy was diagnosed in 22 individuals, some of whom saw their seizures subside when away from their workstation. Reflex epilepsy due to vibratory stimulus (Martinho Pimenta and Castelo Branco, 1999b) and visual stimulus was observed in two individuals. Auditory stimuli did not trigger seizures but, in some cases, triggered rage reactions and movement disorders (Martinho Pimenta and Castelo Branco, 1999c).

Balance disturbances were also a common complaint, identified in 80 individuals, although the severity of the balance disturbance ranged from dizziness to severe vertigo (Martinho Pimenta *et al.*, 1999b). Unique and sudden episodes of non-convulsive neurological deficit occurred in 11 individuals. These were diagnosed as cerebral ischemic vascular accidents, which was compatible with imaging studies. EEG and multi-modal evoked potentials showed considerable power changes that were in agreement with clinical psychological and neurological evidences. Delays in multi-modal evoked potentials (including endogenous), observed in all 140 patients, are a sign of progressive neurological deterioration and early aging process, as is the appearance of the archaic palmo-mental reflex, that affects about 40% of these 140 patients.

Other important pathologies observed among these 140 individuals were endocrine disorders, the most common being thyroid dysfunction (18 cases). The overall national Portuguese rate for adult thyroid dysfunction is 0.97% vs. the 12.8% identified in our group of 140 technicians. Similarly, diabetes was seen in 16 individuals (average age 39 years, SD=7.8) (11.4%), while the overall national rate for a similar age-group is 4.6% (Castelo Branco, 1999b).

Among the 140 professionals, 28 had malignant tumours. Five of these 28 individuals exhibited simultaneous tumours of different types. All CNS tumours (N=5) were malignant gliomas, and all respiratory system tumours were squamous cell carcinomas (5 in lung, 1 in larynx). Other tumours were found in the stomach (N=10), colon and rectum (N=9), soft tissue (N=1), and bladder (N=1) (Castelo Branco, 1999b). All digestive system tumours were low-differentiated adenocarcinomas. These data led to the investigation of the genotoxicity of LFN. In both human (Silva *et al.*, 1999a,b) and animal (Silva *et al.*, 2002) models, LFN induced an increased frequency of sister chromatid exchanges, effectively demonstrating that LFN is a genotoxic agent.

More recently, in 2003, a new pathological sign was identified among VAD patients: decreased respiratory drive (Reis Ferreira *et al.*, 2003a; Castelo Branco *et al.*, 2003d). To date, pulmonary function tests are normal in VAD patients, with the singular exception of the $P_{0.1}(CO_2)$ index, which is a measure of the inspiratory pressure (or suction) developed at the mouth, 0.1 seconds after the start of inspiration. This initial respiratory drive originates in the autonomic (or involuntary) pathway of the neural control of the respiratory function. By rebreathing CO_2, normal individuals would present a minimum six-fold increase of the $P_{0.1}(CO_2)$ index when compared to normal $P_{0.1}$. If the neural control of respiration is compromised, then a less-than six-fold increase would be expected in the $P_{0.1}(CO_2)$ index (Calverly, 1999; Cotes, 1993; Gibson, 1996). In VAD patients, all $P_{0.1}(CO_2)$ index values are

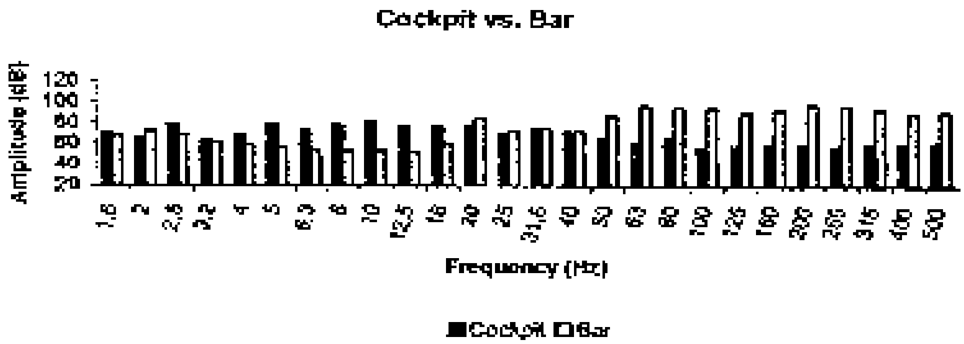

Figure 1. Frequency distributions, within the 1.6 – 500 Hz range, of the Airbus-340 cockpit in cruise flight and of a popular Lisbon Bar.

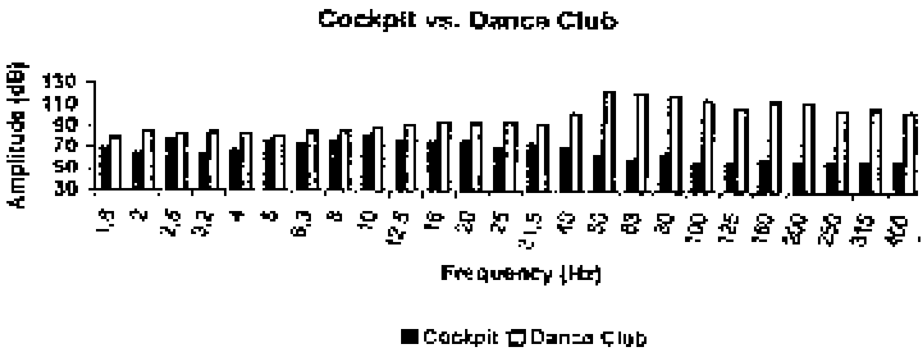

Figure 2. Frequency distributions, within the 1.6 – 500 Hz range, of the Airbus-340 cockpit in cruise flight and of a popular Lisbon Dance Club.

below 50%, when normal values would be above 60%.

Lastly, the issue of auto-immune diseases in LFN-exposed individuals. In the electron microscopy studies of VAD-patient pericardial fragments, non-apoptotic cellular death was frequently observed (Castelo Branco *et al.*, 2003a). Instead, biomechanical forces seemed to be responsible for the images of burst cells, with live organelles and no surrounding plasma membrane. Under these circumstances, the appearance of auto-immune diseases in these patients is not unreasonable. Indeed, previous studies have shown that LFN exposure induces an accelerated onset of lupus in lupus-prone mice (Águas *et al.*, 1999a). Lupus has also been identified in flight attendants (Araújo *et al.*, 2001), and in entire families of islanders exposed to environmental LFN (Torres *et al.*, 2001). Vitiligo is another common finding, especially in the LFN-exposed islander population. Vitiligo is associated with immune changes of CD8 and CD4 lymphocyte populations. These immune changes have also been observed in LFN-exposed workers (Castro *et al.*, 1999) and animal models (Águas *et al.*, 1999b). Other authors have also corroborated the existence of auto-immune processes in noise-exposed workers (Matsumoto *et al.*, 1992, 1989; Jones *et al.*, 1976; Soutar *et al.*, 1974; Lippmann *et al.*, 1973).

Control Populations

One of the most difficult tasks of conducting studies related to LFN-induced pathology is the lack of viable control populations. By definition, in LFN-related studies, control populations are individuals who *are not exposed* to LFN.

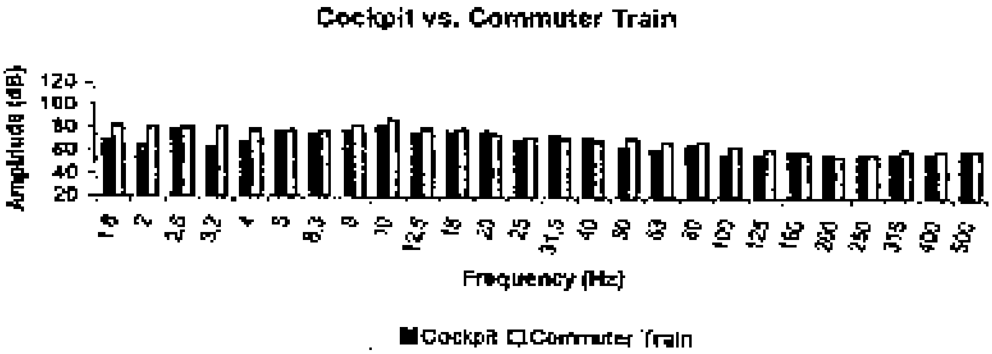

Figure 3. Frequency distributions, within the 1.6 – 500 Hz range, of the Airbus-340 cockpit in cruise flight and of a Commuter Train in transit during midday.

However, given the ubiquitous nature of LFN, control populations are not easy to find. Since the inadequate selection of control populations has given rise to conflicting results (ASTDR, 2001), it is pertinent to tackle this issue head on.

LFN is not legislated, and is therefore allowed to proliferate in almost every sector of human society. LFN exposure is not an exclusive feature of blue-collar workers. In fact, LFN exposure is an integral part of many leisurely activities and of many public transportation settings. Figures 1-5 and Table 3, compare the LFN levels of the cockpit of the Airbus-340 (Alves-Pereira *et al.*, 2001) with several locations commonly used by the public at large. Even the common passenger vehicle is a significant source of LFN (See Figure 5 and Table 3). So what is the profile of an adequate control population? Consider the following: control populations in any study are not usually monitored in terms of previous LFN exposure; thus, any control population of any study can be skewed because of the existence of a confounding factor – LFN. Moreover, considering the whole-body effects of excessive LFN exposure, compromising the cardio respiratory and autonomic nervous systems, the degree of error may be significant.

In the specific cases where the investigation focuses on LFN exposed individuals in a certain industrial plant (for example), a control population selected merely on the criterion that they *do not work* at the industrial plant under study is invalid, because LFN exposure exists in many locations of our everyday life (See Figures 1-5). The most blatant example of inadequate selection of control populations is the Vieques Heart Study (ASTDR, 2001). Here, individuals who resided in an LFN-rich island (LFN produced by military training exercises) were compared to individuals who lived on another island. Living on another island and age-matching were the sole criteria for the selection of the control population in this study. This assumes that no LFN exposure exists on the

Table 3. Comparison of dBA and dBLin values in several, LFN-rich environments

Location	dBA	dBLin
Cockpit A-340*	72.1	87.3
Bar	98.4	104.4
Dance Club	110.3	127.5
Commuter Train	65.2	92.1
Subway	70.9	93.6
Common Automobile	71.2	100.8

*dBA values for the A-340 were obtained within the 6.3 -20000 Hz range. All other dB-level values were obtained within the 1.6 -5000 Hz range

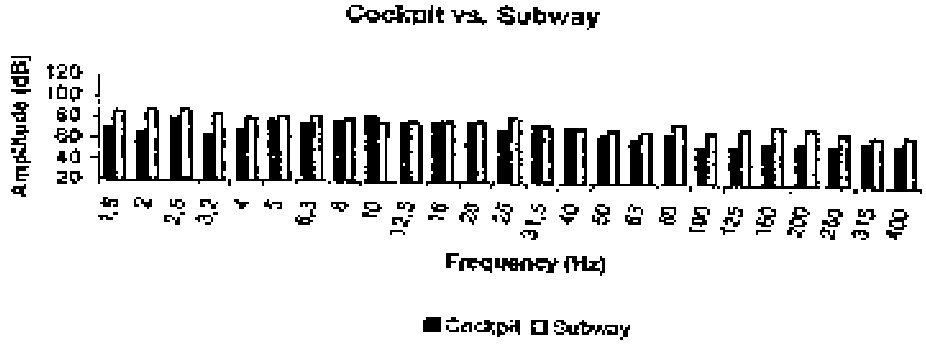

Figure 4. Frequency distributions, within the 1.6 – 500 Hz range, of the Airbus-340 cockpit in cruise flight and of a Lisbon Subway train, in transit.

other island, which is, of course, absurd, and is evidenced in the published results (ASTDR, 2001). Given what is known to date, control populations for LFN studies must be selected on the basis of negative VAD-related tests, (i.e., no pericardial nor cardiac valve thickening, and normal $P_{0.1}(CO_2)$ index), or must otherwise be considered non-controls.

Lastly, animal models also require control populations, and animal studies rarely monitor their acoustic environments. Hence, animal studies may also incorporate a significant confounding factor LFN. The situation is further aggravated by the fact the many animal facilities are located in basements, where LFN components may reach significant amplitudes. If fine biochemical pathways are under study, and LFN is present but not monitored, how reliable are the results?

Two Anecdotal Stories of False Controls

The Technical Drawing Division, at OGMA, seemed to be an excellent location from which to select a comparison population, also employed at OGMA, but not exposed to occupational LFN. A 34-year-old male, with just this occupational profile, exhibited abnormal brain potentials, consistent with values obtained for VAD patients (Castelo Branco *et al.*, 1999b). Without his knowledge, his residential area, means of transportation and leisure activities, were investigated for possible sources of LFN noise. None were identified. Upon inquiry, his family and friends described him as reserved and quiet, but with sudden episodes of verbal aggressiveness, normally triggered by acoustic events. He was intolerant of any type of sound, including music and, like many others diagnosed with VAD, would complain of "hearing too much". A later audiogram disclosed losses in the lower frequencies, as with other VAD patients. All other VAD-related diagnostic tests came back positive: brain MRI revealed hyperintense foci in T2 of the deep white matter, and echocardiography revealed mitral valve and pericardial thickening. But where was he being exposed to noise? During the neurological examination, which revealed the existence of the palmo-mental archaic reflex, the man finally explained: his parents owned and operated a water mill, and lived in a house directly above. The permanent low hum of the operating water mill was a constant in his home, where he lived until the age of 26. Unfortunately, the mill has since been closed down, and acoustic evaluations of the mill in operation are no longer feasible.

Another interesting case is that of a 50-year-old executive director, who has worked in a Lisbon bank for the past 30 years. Apart from the usual air-heating and -cooling office devices, and urban traffic, the LFN exposure of this individual was not thought to be significant. However, echocardiography disclosed thickened pericardium and cardiac valves. The $P_{0.1}(CO_2)$ index value was below 30%. No symptoms were reported. Where was he being exposed to LFN? He lived in Montijo, a town across the River

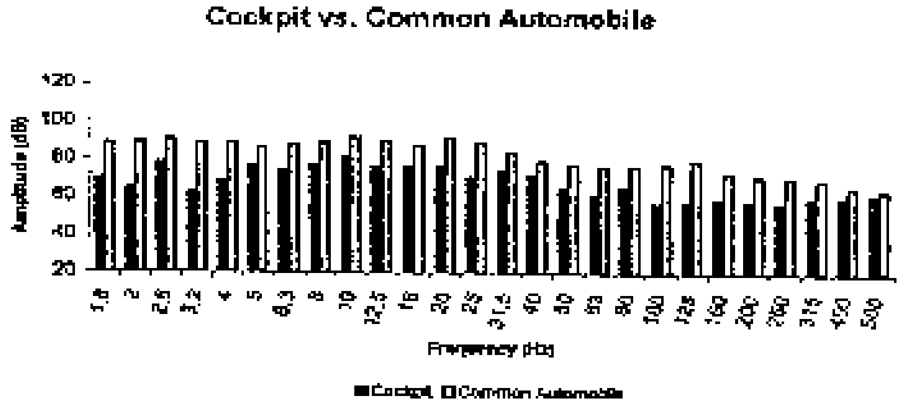

Figure 5. Frequency distributions, within the 1.6 – 500 Hz range, of the Airbus-340 cockpit in cruise flight and of a Common Automobile (Fiat Punto).

Tagus, and his daily car commute in heavy rush hour traffic takes 3 hours, approximately 100 Km. His cars have been equipped with diesel engines. In 1990, he restored his house in Galiza, Spain, just north of the northern Portuguese border and, since then, drives up there every weekend, approximately 400 Km each way. On a weekly basis, this man covers more 1500 Km in his diesel-engine cars. Figure 5 compares the frequency distribution of a gasoline automobile with that of the Airbus-340 cockpit. The data strongly suggest that the source of this man's LFN exposure is the large amount of hours spent driving. Acoustical studies in his specific car models are still underway.

Misdiagnosis of Vibroacoustic Disease
Stress-related syndrome

One of the most common commentaries about the signs and symptoms included in the Mild and Moderate Stages of VAD is their similarity to many generalized stress-related syndromes (Table 1). Although a cursory view might suggest this, a more in-depth approach demonstrates that this is not the case. VAD is specifically characterized by an abnormal proliferation of extra cellular matrices in the absence of an inflammatory process. Lowered cortisol levels and elevated peaks of circulating norepinephrine were observed in LFN-exposed workers (Sobrinho *et al.*, 1989), as well as, changes of auditory evoked responses (Castelo Branco, 1988) and of endogenous potentials that were correlated with CNS lesions - hyperintense foci in 12 of the subcortical and periventricular white matter, basal ganglia and brain stem (Pimenta *et al.*, 1999). To the authors' knowledge, this is not consistent with stress-related syndromes reported in the medical literature.

LFN exposure is more analogous to extreme stress situations, where similar brain lesions and cognitive impairment have been observed (Martinho Pimenta *et al.*, 1992). Also, disseminated intravascular coagulation is frequently the only abnormal autopsy finding in young paratroopers, deceased during military training exercises - an extreme stress situation - giving credence to the popular expression, "it was a blood-curdling experience" (Castelo Branco, 1992). In LFN-exposed workers, an increased rate of platelet aggregation has been identified, simultaneously with other LFN-induced pathology (Castelo Branco *et al.*, 2003e). Hence, regarding VAD as some generalized stress syndrome is not a tenable position, given its inconsistencies with what is known to date about generalized stress syndromes.

Malingering

Another common occurrence among VAD patients is the incredulity of physicians when confronted with complaints involving almost all organs and systems. OGMA medical records show that some physicians scribbled "malingerer" on the side. In a candid exposure of his medical condition, Mr. Jonathan Arnot, age 40, a ship machinist from Scotland and diagnosed with VAD, wrote how the suspicion of

malingerer greatly affected his life:

"I had often been suspected of malingering (...) The social implications of being considered a malingerer, even on behalf of family members employed within the health industry, were quite demoralizing. (...) Without a diagnosis I was left in a no-man's-land where none of the medical specialists could suggest treatment. I felt I was left to see whether my symptoms developed further into an accepted illness, or if they would just resolve themselves with the passage of time. (...) I felt that doctors prejudged my case and assumed that I was either looking for a sick note to have time off work, or that I was trying to build a case to sue someone. Neither of which was anywhere near the truth, I simply could not afford to fall ill (...) Loss of self-esteem, and loss of standing in the eyes of my children and friends must also be taken into account. Social exclusion due to the lack of spending cash, and the emotional effect of the constant suggestion that I was just malingering are merely a few of the actual costs of falling ill with an occupational illness that is not yet proscribed in the UK." (Arnot, 2003).

Mr. Arnot exhibited very thickened cardiac structures (particularly the pericardium), a $P_{0.1}(CO_2)$ index of 38%, and increased latencies of P3 endogenous potentials, all consistent with the VAD clinical picture.

In general, physicians are not sufficiently knowledgeable to question the patient as to his/her occupation. Even if the patient works in the home, the residential location is rarely questioned in terms of acoustic environment. In fact, the insistence that acoustic phenomena only affect humans via the auditory system is helping to jeopardize the health of many young men and women. What neurologist sends a patient diagnosed with epilepsy to receive an echocardiogram? Skepticism as to the existence of a whole-body pathological entity caused by acoustic phenomena has been immense (von Gierke and Mohler, 2002). And yet, for decades, scientists have been gathering evidence supporting just that notion (Alves-Pereira, 1999). Sometimes, scientists say they first encountered VAD within the military in the 1970s (Brenner, 2003). Additionally, some VAD cases have been misdiagnosed as Chronic Fatigue Syndrome.

Dose-responses

Dose-responses for LFN exposure have not yet been established. Waiting for dose-response values to accept the existence of a disease does not seem to be an ethical, nor logical, course of action. In truth, obtaining dose-response values for LFN-exposed humans, considering its aforementioned ubiquitous nature, is a daunting task. Dosimeters specifically designed to evaluate LFN have not yet been developed and, as previously mentioned, legislated noise assessment procedures do not contemplate LFN as a hazard. Therefore, LFN dose-response values for humans are, most probably, some years (and Euros) away. However, in LFN-exposed animal models, insight into dose-responses has already been obtained (Castelo Branco *et al.*, 2003c). In Wistar rats exposed to continuous LFN for 48 hours, and then kept in silence for up to 7 days, tracheal epithelia of exposed and controls only became indistinguishable after 7 days of post-exposure silence (Castelo Branco *et al.*, 2003e, 2003f). Wistar rats that were gestated and born in LFN, and subsequently kept silence for one year, still exhibited visible and dramatic damage of respiratory epithelia after the year in silence (Castelo Branco *et al.*, 2003c, 2003g). The implications of these studies are far-reaching and speak for themselves, especially if one considers that many female workers carry their pregnancies to term while working in LFN-rich environments.

As a final note on dose-responses, it must be recognized that different organic tissues possess different acoustic properties, i.e., the acoustic impedance of lung tissue is different than that of the liver, and the resonant frequency for the brain is different than that for the bladder. Thus, dose-responses must be established on the basis of the frequency of the acoustic event. An individual working in a LFN environment where there is a predominance of infrasound (<20 Hz), will develop slightly different pathological features than an individual who works in an environment where the acoustic energy is predominantly concentrated in the 50-100 Hz range. Hence, the issue of dose-responses must always be carefully approached.

Prevention

Previous studies have indicated that approximately 30% of the studied LFN exposed individuals do not develop severe stages of VAD, although they exhibit mild forms of Stage I and II symptoms (Castelo Branco, 1999b; Castelo Branco and Rodriguez, 1999). This *is not* equivalent to stating that 70% will develop Stage III disabilities. The foremost concern is to prevent the development of disabilities that incapacitate individuals for further professional activity. Studies have indicated that, without prevention, approximately 5% of occupationally LFN-exposed individuals develop pathologies severe enough to require early disability retirement (Castelo Branco *et al.*, 1999b).

At OGMA, from 1980 to 1989, 21 aircraft technicians received compulsory early disability retirement. In 1989, on the heels of the echocardiography results based on 1987 autopsy findings (see above), a screening and monitoring medical protocol was developed for all LFN-exposed personnel. All incoming job candidates received echocardiograms as part of the routine physical examination. If pre-existing thickening of cardiac structures were identified, incoming job candidates would not be hired for jobs that implied working in LFN-rich environments. All LFN-exposed employees who already worked at OGMA began to receive annual echocardiograms, endogenous evoked potentials, and blood pressure was closely monitored. If and when LFN-exposed workers developed very thickened cardiac structures, and/or shifts in the P3 endogenous component to frontal positions, and/or difficult to control and unstable (labile) blood pressure, then they were removed from the LFN-rich work environment and placed at another, non-LFN-rich workstation. From 1989-1996 there were zero compulsory early disability retirements among LFN-exposed personnel (Castelo Branco *et al.*, 1999b).

Recovery periods should also be an integral part of any prevention programme against LFN-induced pathology. For personnel that *must* remain more than the usual 8 hours within a LFN-rich environment, extended recovery periods, i.e., periods away from the LFN-rich environment, should be mandatory. Acoustic materials that impede the propagation of LFN are also in development by several teams worldwide, and might provide future answers to protect workers form this agent of disease. Lastly, it should be strongly emphasized that the development of LFN-induced pathology is caused by a *cumulative* effect of LFN exposure, and whether the source is occupational, or not, is irrelevant to the biological organism. Moreover, the evolution of VAD will be directly linked with the overall exposure received from *all* LFN-rich environments to which the individual is exposed, occupational and/or environmental and/or leisurely.

Current Working Hypotheses

Studies that describe acoustic environments merely in terms of an overall dB-level cannot be scientifically compared to those that provide frequency distributions analysis.

Figures 4 and 5 compare the frequency distribution obtained in the cockpit of the Airbus-340 at cruise flight, with that obtained within a subway and a common passenger vehicle, respectively. See Table 3 for overall average values. For the subway, the dBA-level was 70.9 and for the car it was 71.2. These acoustical environments are considered comparable by the scientific community at large. In fact, they are not. dBLin levels were 93.6 for the subway and 100.3 for the car. The difference between dBA and dBLin levels, and the lack of usefulness of dBA measurements within the context of LFN-induced pathology, has been extensively discussed elsewhere (Alves-Pereira *et al.*, 2003a; 2003c, Alves-Pereira, 1999). The dBA value measures the overall average amplitude of the acoustical energy that is being captured (i.e. heard) by the human auditory system, and its usefulness is directly (and exclusively) related to the avoidance of hearing impairment. The dBLin value measures the overall average amplitude of the acoustical energy present in the environment, i.e., it measures the amplitude of what is actually present, and not just what can be heard. Looking at the distributions of both environments (Figures 4, 5), it is clear that within the 1.6-500 Hz range, the car has higher levels at all bands than the cockpit. This is not the case with the subway. Hence, two situations arise: a) it is not scientifically sound to compare the results of noise-related studies that describe their acoustical environments merely in terms of a dB-level measurement (i.e., without a frequency spectrum analysis), and b) the results of noise related studies that do not report the frequency distribution of their acoustical environments cannot be compared to those that do.

Individual susceptibility is a confounding factor

Individual susceptibility was identified early on as a important factor influencing symptom severity, and clinical evolution (Castelo Branco, 1989). Several parameters were evaluated, such as blood and tissue compatibility markers, in order to search for a LFN susceptibility indicator. To date, none have been formally identified (Castelo Branco and Rodriguez Lopez, 1999). Animal models gestated and born in LFN-rich environments still exhibit severe respiratory tract damage, even after one year of post-birth continuous silence (Castelo Branco *et al.*, 2003g). Moreover, they also exhibit behavioral differences when compared with those LFN-exposed animal models that were not gestated in LFN-rich environments. Hence, it is suspected that the situation of the individual's mother during pregnancy is one factor (of perhaps several) that may substantially contribute to an increased individual susceptibility to LFN. In ongoing research projects, the VAD-questionnaire now includes questions pertaining to this matter. If occupational LFN exposure is the focus, then non-occupational LFN exposure can also introduce a confounding factor. As is shown in Figures 1-5, LFN is ubiquitous. Hence, VAD-related questionnaires must explore *all* habitual and non-habitual locations where individuals may be exposed to LFN, including *in utero*.

LFN environments with acoustical energy predominantly within the infrasonic range (<20 Hz), accelerates the rate of pericardial thickening.

In 1999, volunteer commercial airline pilots and flight attendants received echocardiograms within the scope of VAD-related studies. Despite equal time of occupational activity, pilots disclosed a faster rate of pericardial thickening than did flight attendants (this was not a gender related feature since male flight attendants also participated) (Araújo *et al.*, 2001). In a subsequent acoustical analysis of both cockpit and cabin, the cockpit revealed statistically significant higher levels of infrasound than in the cabin (Alves-Pereira *et al.*, 2001). Infrasound in the cockpit varied with altitude, airspeed and aircraft model, which indicates that much of the infrasonic energy present in the cockpit is due to the impact of the airflow on the leading edge of the aircraft (Alves-Pereira *et al.*, 2001).

The onset of auto-immune diseases is accelerated by LFN exposure.

As discussed above, in the Associated Pathology of VAD, auto-immune diseases, particularly lupus, are very common among LFN individuals (Torres *et al.*, 2001; Araújo *et al.*, 2001; Matsumoto *et al.*,1992, 1989; Jones *et al.*, 1976; Soutar *et al.*, 1974; Lippmann *et al.*, 1973). One of the reasons may be the presence of non-apoptotic cellular death, with no inflammatory process, seen in the pericardial fragments of VAD patients (Castelo Branco *et al.*, 1999a, 2001, 2003a,b).

The respiratory system is a target for LFN.

Four VAD patients had atypical cases of pleural effusion that persisted in spite of therapy. Three of these cases were of unknown origin, although the fourth may have been caused by diphenylhydantoin (Castelo Branco, 1999a). The follow-up recovery periods were very prolonged, even in the case where diphenylhydantoin was suspended. Treatment took several months, and recovery was not only slow and irregular, but no conclusion was ever reached about the aetiology or choice of treatment. In the 1987 autopsy, focal lung fibrosis was identified, however no importance was attributed to this finding since chemicals, fumes and dusts were assumed to be present in this man's occupational environment (Castelo Branco, 1999a). In 1992, still concerned about the enigmatic cases of pleural effusion, animal models were used to study the respiratory tract response to LFN exposure. In LFN-exposed rodents, the amount of tracheal cilia was visibly reduced, and subsequent formal morphometric studies confirmed this feature (Oliveira *et al.*, 2002). Tracheal subepithelial fibrosis was also identified (Castelo Branco *et al.*, 2003c). Structural changes of the lung parenchyma included irregular distribution of thickened alveolar walls, dilated alveoli, and irregularly distributed fibrous foci (Castelo Branco *et al.*, 2003c). Pleural cells lost their phagocytic ability, and the pleural parietal leaflet had a marked reduction in the amount of microvilli per mesothelial cell (Oliveira *et al.*,1999). Subsequently, respiratory function tests and high resolution CT scan of the lung were administered to LFN-exposed workers, with and without respiratory symptoms. Focal lung fibrosis and air-trapping were identified in these workers, independent of the existence of respiratory complaints (Reis Ferreira *et al.*, 1999). Other authors have described the immediate subjective effects of large amplitude LFN tones on the respiratory system that included coughing, gagging sensation, and awareness of chest wall pressure (Mohr *et al.*, 1966; Cole *et al.*, 1966). An in-depth review of noise and the respiratory system has been reported elsewhere (Alves-Pereira *et al.*, 2003c).

LFN-exposure specifically causes squamous cell carcinomas of the respiratory tract.

To date, 100% of the respiratory tumours in VAD patients have been squamous-cell carcinomas: 10 in the upper right lobe of the lung (7 smokers) and 2 in the glottis (1 non-smoker) (Castelo Branco, 2001). This hypothesis has been further corroborated by the observation of metaplasia and displasia in the respiratory epithelium of LFN-exposed Wistar rats (Castelo Branco *et al.*, 2003c; 2003g). In the general population, squamous cell carcinomas of the lung account for 40% of all lung tumours (Skuladottir, 2001). However, cancer-related epidemiological studies do not usually describe the breakdown of tumour-type, which is very unfortunate. Global cancer statistics, without a breakdown of tumour-type, do not contain the essential, and crucial, information required for any in-depth statistical study, and the results can be misleading. Among VAD patients, the incidence of lung cancer, in general, is about the same as that of the Portuguese population, but in VAD patients, *all* tumours are located in the upper right lobe, and *all* are squamous-cell carcinomas (Castelo Branco, 2001). This is not equivalent to saying that all squamous-cell carcinomas all triggered by LFN-exposure, because certainly other agents might also induce the appearance of this type of respiratory tract tumour. What the data *does* demonstrate is that LFN-induced respiratory tract tumours are all of a single type: squamous cell-carcinomas.

Actin and tubulin based structures are particular targets for LFN.

Microvilli are composed of actin filaments, as are the stereocilia in cochlear auditory hair cells. In LFN-exposed animals, both cochlear stereocilia and respiratory tract brush cell microvilli become fused structures (Castelo Branco *et al.*, 2003c, Alves-Pereira *et al.*, 2003b). A first approach might suggest that the commonality of these structures may be their finger-like, somewhat cylindrical shapes. However, cilia, found in the respiratory tract and in the pericardium, exhibit an entirely different behavior in the presence of LFN. Cilia in the pericardial fragments of VAD patients simply cease to exist (Castelo Branco *et al.*, 2003a,b; 2001; 1999a). In the respiratory tract of LFN-exposed animals, cilia appear sheared, as if clipped by scissors, and some images even captured these apparently sheared cilia lying upon the epithelial surface (Castelo Branco *et al.*, 2003c). Shaggy cilia and completely bald ciliated cells were also observed in LFN-exposed rodents. In two VAD patients (one non-smoker), scattered areas of damaged tracheal cilia were identified, and multiple ciliary axonemes were seen surrounded by the same membrane (Reis

Ferreira *et al.*, 2003c).

Elevated annoyance levels to noise are a sign of previous, excessive LFN exposure.

Cochlear stereocilia are actin-based structures that, in Wistar rats, fuse as a response to LFN exposure (Castelo Branco *et al.*, 2003c). Rats are particularly sensitive to the sound of a "blown kiss" and react by jerking their heads and becoming tense. After LFN-exposure, the "blown kiss" causes them to rise on their hind legs, often falling backward, with tremors. Fused cochlear stereocilia, if it also occurs in humans, may explain the unusual auditory complaints of VAD patients, such as, "I hear too much; I can't stand any type of noise, not even music" (Castelo Branco,1999b). If fused among themselves and to the tectorial membrane, cilia cannot freely vibrate as is intended when the sound pressure wave is transduced within the cochlea (Alves-Pereira *et al.*, 2003c). In fact, by becoming a rigid structure, any attempt at vibrating them might, understandably, produce discomfort. How closely related this phenomenon is to the concept of "annoyance" is still unclear. However, a relationship is clearly suggested, especially since annoyance has already been specifically associated with the presence of LFN (Persson-Waye and Rylander, 2001).

The whole-body response to excessive LFN exposure can be explained by principles of biotensegrity.

At a cellular level, the pericardial mesothelial-cell (MC) layer exhibits a peculiar morphological behaviour. The MC layer consists of a one-cell-deep surface, and is in direct contact with the pericardial sac. Hence, it is critical to the sliding effect necessary to an intact cardiac cycle. MC interconnect laterally with each other via cytoskeletal intermediate filaments and desmosomes. In pericardial fragments obtained from VAD patients, MC are seen in a process of extrusion from the surface layer into the pericardial sac (Castelo Branco *et al.*, 2003a,b). Desmosomes are no longer evenly distributed along the lateral edges of MC, and instead are concentrated, in groups of more than two, in the upper portions of the MC lateral borders. The lower portions seem to be forming gaps, with great plasticity, in which microvilli are identifiable (Castelo Branco *et al.*, 2003a). Biotensegrity systems can absorb external forces, and redistribute them throughout a network of tension and compression elements, but with no torque or bending moments (Wang *et al.*, 1997). Consider the MC layer as a structural surface composed of individual viscoelastic elements (the MC interconnected by cytoskeletal intermediate filaments and desmosomes) and that has to cope with abnormally large mechanical forces. Extrusion of MC into the pericardial sac strongly suggests that the MC layer is attempting to maintain the structural integrity, despite the abnormal biomechanical conditions.

Final Commentary

The agent of disease has already been identified – Low Frequency Noise.

Specific LFN effects have already been well defined: abnormal growth of extra-cellular matrices, in the absence of an inflammatory process, seen in both cardiovascular and respiratory system structures, in both LFN-exposed human and animal models.

The genotoxicity of LFN exposure has been demonstrated in both human and animal models.

Non-invasive diagnostic methods have already been defined: echocardiography to visualize thickened cardiac structures, $P_{0.1}(CO_2)$ index to measure the dramatically reduced respiratory drive, and evoked potentials that disclose important topographical changes and increased latencies in the P3 and N2 components, both indicative of cognitive impairment.

Large-scale epidemiological studies are still unpublished, in-depth studies of LFN-induced physiopathology are lacking, and case-control studies have not yet appeared in the medical literature. In fact, to the authors' knowledge, no other independent team has published results on echo-imaging studies on LFN-exposed individuals. Why? One of the main (scientifically-related) reasons is that LFN-induced is not "high-priority" topic in most scientific forums, hence grant approval rate for LFN-related studies is very low. Other, more political and financial reasons exist, however they are, of course, beyond the scope of this report.

The bottom line is: VAD is not acknowledged as a pathological entity, and individuals who exhibit VAD clinical pictures are malingerers (if workers) or neurotic (if females and/or housewives). At best, they are considered "overly sensitive" individuals. Moreover, since LFN exposure is not considered a health hazard by the authorities, it is rarely evaluated. Additionally, LFN-related studies are not "fashionable", and thus grant money for this field is practically non-existent. Given the data collected to date and the worldwide suffering of millions of LFN-exposed citizens, this *status quo* situation is unethical, unsustainable, and downright obscene.

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References

Águas AP, Esaguy N, Castro AP, Grande NR, and Castelo Branco NAA. (1999a) Acceleration of lupus erythematosus-like processes by low frequency noise in the hybrid NZB/W mouse model. *Aviation Space Environmental Medicine*, 70 (March, Suppl): A132-6.

Águas AP, Esaguy N, Castro AP, Grande NR, and Castelo Branco NAA. (1999b) Effect low frequency noise exposure on BALB/C mice splenic lymphocytes. *Aviation Space Environmental Medicine*, 70 (March, Suppl): A128-31.

Alves-Pereira M and Castelo Branco NAA. (1999) Vibroacoustic Disease. The need for a new attitude towards noise. *Proceedings of the International Conference on Public Participation and Information Technologies*, October 20-22, Lisbon, Portugal: 340-7. Available: www.citidep.pt/papers/articles/alvesper.htm.

Alves-Pereira M. Extra-aural noise-induced pathology. A review and commentary. (1999) *Aviation Space Environmental Medicine*, 70 (March, Suppl): A7-21

Alves-Pereira M, Castelo Branco MSNA, Motylewski J, Pedrosa A, and Castelo Branco NAA. (2001) Airflow-induced infrasound in commercial aircraft. *Internoise2001*, The Hague, Holland: 1011-14.

Alves-Pereira M, Joanaz de Melo J, Motylewski J, Kotlicka E and Castelo Branco NAA (2003a). Legislation hinders low frequency noise research. *Proc. Scuola Superiore. G Reiss Romoli-Telecom, Italia* (SSGRRw). L'Aquila, Italy, No. 103: 7 pages. Available: http://www.ssgrr.it/en/ssgrr2003w/papers/135.pdf

Alves-Pereira M, Castelo Branco NAA. (2003b) Ciliated cells, cochlear cilia and low frequency noise. *Proceedings of the 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 366-367.

Alves-Pereira M, Reis Ferreira J, Joanaz de Melo J, Motylewski J, Kotlicka E, Castelo Branco NAA. (2003c) Noise and the respiratory system. *Revista Portuguesa Pneumologia*, 9(5): 367-379.

Araujo A, Pais F, Lopo Tuna JMC, Alves-Pereira M, and Castelo Branco NAA. (2001) Echocardiography in noise-exposed flight crew. *Internoise2001*, The Hague, Holland. 1007-10.

Arnot JW. (2003). Vibroacoustic disease 1: The personal experience of a motorman. *Institute of Acoustics* (U.K.). 25(Pt 2): 66-71.

ASTDR-Agency for Toxic Substance and Disease Registry, USA. (2001) Expert review of the Vieques heart study. Summary report for the Vieques heart study expert panel review. Contract No. 200-2000-10039, August 17 2001. Available:
www.atsdr.cdc.gov/NEWS/viequesheart/report.html.

Brauner, M. (2003) Infrasound: I'm all shook up! In *Sun-Herald* August 24th, 2003 Available. www.sun-herald.com/NewsArchive2/082403/tp3ch18.htm

Baluhov VD, Barsukov AF, and Artamonova VG (1998) Clinical and functional evaluation of health status of workers exposed to infrasound, noise and general vibration. *Meditsina Truda Prom Ekologia*, 5: 22-6. (In Russian)

Calverly PMA. (1997) Control of breathing. In *Lung function tests. Physiological principles and clinical applications*. Hughes JMB and Pride NB, eds, London, WB Saunders.

Castelo Branco NAA. (1988) The auditory evoked response in military pilots. *Proceedings AGARD Conference on Electrical and Magnetic Activity in the CNS*, AGARD-CP-432, 42: 1-7.

Castelo Branco NAA. (1989) Human susceptibility to noise and vibration. *MEDICEF Direct Information*, 2: 100 (Abstract).

Castelo Branco NAA. (1992) Extreme stress situations. *Revista Portuguesa Medicina Militar*, 40 (1): 22. (Abstract)

Castelo Branco NAA. (1999a) A unique case of vibroacoustic disease. A tribute to an extraordinary patient. *Aviation, Space and Environmental Medicine* 70 (3, Suppl): A27-31

Castelo Branco NAA. (1999b) The clinical stages of vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A32-9.

Castelo Branco NAA (2001). The respiratory system as a target of low frequency noise. Reports on human and animal models. *Proceedings of the 8th International Congress on Sound and Vibration*, Hong Kong, P.R. China: 1501-8.

Castelo Branco NAA and Rodriguez Lopez E. (1999) The vibroacoustic disease – An emerging pathology. *Aviation, Space and Environmental Medicine* 1999; 70 (3, Suppl). A1-6.

Castelo Branco NAA, Águas AP, Sousa Pereira A, Monteiro E, Fragata JIG, Tavares F, and Grande NR. (1999a) The human pericardium in vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A54-62.

Castelo Branco NAA, Rodriguez Lopez E, Alves-Pereira M, and Jones DR. (1999b) Vibroacoustic disease: some forensic aspects. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A145-51.

Castelo Branco NAA, Águas A, Sousa Pereira A, Monteiro E, Fragata JIG, and Grande NR. (2001) The pericardium in noise-exposed individuals. *Internoise 2001*, The Hague, Holland: 1003-6.

Castelo Branco NAA, Fragata JI, Martins AP, Monteiro E, and Alves-Pereira M. (2003a) Pericardial cellular death in vibroacoustic disease. *Proceedings of the 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 376-377.

Castelo Branco NAA, Fragata JI, Monteiro E, and Alves-Pereira M. (2003b) Pericardial features in vibroacoustic disease patients. *Proceedings of the 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 380-381.

Castelo Branco NAA, Alves-Pereira M, Martins dos Santos J, and Monteiro E. (2003c) SEM and TEM study of rat respiratory epithelia exposed to low frequency noise. In *Science and Technology Education in Microscopy: An Overview*, A. Mendez-Vilas (ed.), Formatex: Badajoz, Spain, Vol. II, pp505-33.

Castelo Branco NAA, Martinho Pimenta AJ, Reis Ferreira J, Alves-Pereira M. (2003d) Monitoring vibroacoustic disease. *Proceedings of the Scuola Superiore G. Reiss Romoli-Telecom Italia* (SSGRRw), L'Aquila, Italy, No. 102: 5 pages. Available:
http://www.ssgrr.it/en/ssgrr2003w/papers/129.pdf.

Castelo Branco NAA, Barreira R, Crespo FF, Freira J, Afonso H, Castelo Branco MSN, and Alves-Pereira M. (2003e) Hemostasis and coagulation changes in airline pilots. *Proceedings of the 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 118-120.

Castelo Branco NAA, Gomes-Ferreira P, Monteiro E, Costa e Silva A, Reis Ferreira J, and Alves-Pereira M. (2003f) Respiratory epithelia in Wistar rats after 48 hours of continuous exposure to low frequency noise. *Revista Portuguesa Pneumologia*, 9(6): 473-479.

Castelo Branco NAA, Monteiro E, Costa e Silva A, Reis Ferreira J, and Alves-Pereira M. (2003g) Respiratory epithelia in Wistar rats born in low frequency noise plus varying amount of additional exposure. *Revista Portuguesa Pneumologia*, 9(6): 481-492.

Castro AP, Aguas AP, Grande NR, Monteiro E, and Castelo Branco NAA. (1999) Increase in CD8+ and CD4+ T lymphocytes in patients with vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A141-4.

Cohen A. (1976) The influence of a company hearing conservation program on extra-auditory problems in workers. *Journal of Safety Research*, 8: 146-62.

Cole JN, Mohr GC, Guild EG, and von Gierke HE. (1966) The effects of low frequency noise on man as related to the Apollo Space Program. *AMRL Memorandum* B-66.

Cotes JE. (1993) *Lung function. Assessment and applications in medicine*. Blackwell Scientific Publishing, London, pp376.

Dart, EE. (1946) Effects of high speed vibrating tools on operators engaged in airplane industry. *Occupational Medicine*, 1, 515-50.

Gibson GJ. (1996) *Clinical tests of the respiratory function*. Chapman and Hall Medicine, London, pp101-109.

GIMOGMA. (1984) Noise and vibration at the origin of hypo- and hyper acoustic sensitivities in an industrial population. *Revista Portuguesa Medicina Militar*, 32: 17-20.

Gomes L, Martinho Pimenta AJF, and Castelo Branco NAA. (1999) Effects of occupational exposure to low frequency noise on cognition. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A115-8.

Grechkovskaia NV and Parpalei IA. (1997) The impact of the working conditions on morbidity in workers in jobs hazardous for vibration and noise in aviation enterprises. *Lik Sprava*, 5: 20-3. (In Russian)

Holt BD. (2000) The pericardium. In *Hurst's The Heart*, Fuster V, Wayne Alexander R, and Alexander F, eds., McGraw-Hill Professional Publishing, New York, pp2061-82.

Izmerov NF, Suvorov GA, Kuralesin NA, and Ovakimov VG. (1997) Infrasound: body's effects and hygienic regulation. *Vestn Ross Akademii Medi-ina Nauk* 7: 39-46. (In Russian)

Jones RN, Turner-Warwick M, Ziskind M, Weill H. (1976) High prevalence of antinuclear antibodies in sandblasters' silicosis. *American Review of Respiratory Diseases*, 113: 393-95.

Laird DA. (1928) Experiments on the physiological cost of noise. *Journal of the National Institute of Industrial Psychology*, 4: 251-58.

Lippmann M, Eckert HL, Hahon N, Morgan WKC. (1973) Circulating antinuclear and rheumatoid factors in coal miners. A prevalence study in Pennsylvania and West Virginia. *Annals of Internal Medicine*, 79: 807-11.

Magomedov MM and Kunel'skaia NL. (1997) Early diagnosis of sensorineural hearing loss among female workers of textile factories. *Vestn Otorinolaringologie*, 5: 8-11. (In Russian)

Marciniak W, Rodriguez E, Olsowska K, Botvin I, Araujo A, Pais F, Soares Ribeiro C, Bordalo A, Loureiro J, Prazeres de Sá E, Ferreira D, Castelo Branco MSNAA, and Castelo Branco NAA. (1999) Echocardiography in 485 aeronautical workers exposed to different noise environments. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A46-53.

Martinho Pimenta AJF, Silva Simões JMC, Castelo Branco MSNA, and Castelo Branco NAA. (1993) Pathology of extreme stress situations. *Revista Portuguesa Medicina Militar*, 40 (2-4): 31-53. (In Portuguese, Abstract in English)

Martinho Pimenta AJF and Castelo Branco NAA. (1999a) Neurological aspects of vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A91-5.

Martinho Pimenta AJF and Castelo Branco NAA. (1999b) Epilepsy in vibroacoustic disease - A case report. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A122-7.

Martinho Pimenta AJF and Castelo Branco NAA. (1999c) Facial dyskinesia induced by auditory stimulation. A report of four cases. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A119-21.

Martinho Pimenta AJF, Castelo Branco MSNA, and Castelo Branco NAA. (1999a) The palmo-mental reflex in vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A100-6.

Martinho Pimenta AJF, Castelo Branco MSNA, and Castelo Branco NAA. (1999b) Balance disturbances in individuals with vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A96-9.

Matoba T. (1983) Increased left ventricular function as an adaptive response in vibration disease. *American Journal of Cardiology*, 15: 1223-6.

Matsumoto Y, Yasue T, Mizuno N and Yoshida I. (1992) An immunoserological study of patients with vibration syndrome. *Occupational and Environmental Health*, 63: 357-9.

Matsumoto Y, Kawabe M, Yasue T, Yuguchi M, and Yoshida I. (1989) Two cases of scleroderma associated with vibration syndrome. *Japanese Journal of Dermatology*, 99: 155-61.

Mohr GC, Cole JN, Guild E, and von Gierke HE. (1965) Effects of low-frequency and infrasonic noise on man. *Aerospace Medicine*, 36: 817-24.

Oliveira MJ, Pereira AS, Águas AP, MonteiroE, Grande NR, and Castelo Branco NAA. (1999) Effects of low frequency noise upon the reaction of pleural milky spots to mycobacterial infection. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A137-40.

Oliveira MJ, Pereira AS, Castelo Branco NAA, Grande NR, and Águas AP. (2002) In utero and post-natal exposure of wistar rats rats to LFN/high intensity noise depletes the tracheal epithelia of ciliated cells. *Lung*, 179: 225-32.

Persson Waye K, Rylander R. (2001) The prevalence of annoyance and effects after long-term exposure to low frequency noise. *Journal of Sound and Vibration*, 240(3): 483-97.

Pimenta MG, Martinho Pimenta AJF, Castelo Branco MSN, and Castelo Branco NAA. (1999) ERP P300 and brain magnetic resonance imaging in patients with vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A107-14.

Reis Ferreira JM, Couto AR, Jalles-Tavares N, Castelo Branco MSN, and Castelo Branco NAA. (1999) Airflow limitations in patients with vibroacoustic disease. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A63-9.

Reis Ferreira J, Mendes CP, Antunes M, Martinho Pimenta J, Monteiro E, Alves-Pereira M and Castelo Branco NAA. (2003a) Diagnosis of vibroacoustic disease – preliminary report. *Proceedings 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 112-114.

Reis Ferreira J, Mendes CP, Castelo Branco NAA, Monteiro E and Alves-Pereira M. (2003b) The human lung and pleura in vibroacoustic disease. *Proceedings 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 386-387.

Reis Ferreira J, Mendes CP, Castelo Branco NAA, Monteiro E and Alves-Pereira M. (2003c) The human trachea in vibroacoustic disease. *Proceedings 8th International Congress of Noise as a Public Health Problem*, Rotterdam, Holland: 388-389.

Rumancev GI. (1961) Investigations concerning the hygienic evaluation of vibration in factories producing reinforced concrete. *Gigiena Truda Professional Zabol*, 5: 6-12 (in Russian).

Silva MJ, Dias A, Barreta A, Nogueira PJ, Castelo Branco NAA, and Boavida MG. (2002) Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice. *Teratogenesis, Carcinogenesis and Mutagenesis*, 22(3): 195-203.

Silva MJ, Carothers A, Castelo Branco NAA, Dias A, and Boavida MG. (1999a) Increased levels of sister chromatid exchanges in military aircraft pilots. *Mutation Research - Genetic Toxicology and Environmental Mutagenesis*, 44(1): 129-34.

Silva MJ, Carothers A, Castelo Branco NAA, Dias A, Boavida MG. (1999b). Sister chromatid exchanges workers exposed to noise and vibration. *Aviation, Space and Environmental Medicine*, 70 (3, Suppl): A40-5.

Skuladottir H. (2001) Epidemiology of lung cancer. In: Spiro SG (ed) Lung Cancer. *European Respiratory Monograph*, 6 (17): p. 1-12.

Sobrinho L, Martins AS, Brito JLR, Castelo Branco MSNAA, and Castelo Branco NAA. (1989) Hormone changes in patients with the whole-body noise and vibration disease. MEDICEF-Direct Information, 2: 98 (Abstract).

Soutar CA, Turner-Warwick M, and Parkes WR. (1974) Circulating antinuclear antibody and rheumatoid factor in coal pneumoconiosis. *British Medical Journal*, 3: 145-7.

Torres R, Tirado G, Roman A, Ramirez R, Colon H, Araujo A, Pais F, Marciniak W, Nóbrega J, Bordalo e Sá A, Lopo Tuna JMC, Castelo Branco MSNAA, Alves-Pereira M, and Castelo Branco NAA. (2001) Vibroacoustic disease induced by long-term exposure to sonic booms. *Internoise 2001*, The Hague, Holland: 1095-98.

von Gierke H and Mohler S. (2002) Letter to the editor: 'vibroacoustic disease' *Aviation, Space and Environmental Medicine*, 73 (8). 828-830.

Wang N, Butler JP, and Ingber D. Mechanotransduction across cell surface through the cytoskeleton (in Reports). *Science-New Series*, 260 (5111): 1124-7.

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Vibroacoustic Disease: Biological effects of infrasound and low frequency noise explained by mechanotransduction cellular signalling

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Abstract

At present, infrasound (0-20 Hz) and low frequency noise (20-500 Hz) (ILFN, 0-500 Hz) are agents of disease that go unchecked. Vibroacoustic disease (VAD) is a whole-body pathology that develops in individuals excessively exposed to ILFN. VAD has been diagnosed within several professional groups employed within the aeronautical industry, and in other heavy industries. However, given the ubiquitous nature of ILFN and the absence of legislation concerning ILFN, VAD is increasingly being diagnosed among members of the general population, including children. VAD is associated with the abnormal growth of extra-cellular matrices (collagen and elastin), in the absence of an inflammatory process. In VAD, the end-product of collagen and elastin growth is reinforcement of structural integrity. This is seen in blood vessels, cardiac structures, trachea, lung, and kidney of both VAD patients and ILFN-exposed animals. VAD is, essentially, a mechanotransduction disease. Inter- and intra-cellular communication is achieved through both biochemical and mechanotranduction signalling. When the structural components of tissue are altered, as is seen in ILFN-exposed specimens, the mechanically-mediated signalling is, at best, impaired. Common medical diagnostic tests, such as EKG, EEG, as well as many blood chemistry analyses, are based on the mal-function of biochemical signalling processes. VAD patients typically present normal values for these tests. However, when echocardiography, brain MRI or histological studies are performed, where structural changes can be identified, all consistently show significant changes in VAD patients and ILFN-exposed animals. Frequency-specific effects are not yet known, valid dose-responses have been difficult to identify, and large-scale epidemiological studies are still lacking.

Keywords
Extra-cellular matrix, actin, tubulin, collagen, tensegrity.

1. Introduction

This review paper deals with the biological effects of infrasound (0-20 Hz) and low frequency noise (20-500 Hz). For the past 60 years, there has been much controversy and acrimonious debate over whether or not acoustical phenomena can cause extra-auditory effects on living organisms (Alves-Pereira, 1999). At present, the only officially (and legally) recognized consequence of noise exposure is hearing loss, albeit noise-induced annoyance, sleep disturbances and hypertension have been gaining more recognition over the past several years.

The scientific understanding of non-auditory, noise-induced biological effects can only be achieved if several obstacles are overcome. These obstacles pertain to the way the scientific community, in general, and biological scientists, in particular, view noise pollution and cellular signalling: noise only causes hearing impairment and cellular signalling is accomplished only through biochemical pathways. These untenable positions are powerful (scientific) hindrances that have impeded valuable research efforts. There are other key obstacles related to the awareness and recognition of infrasound and low frequency noise as an agent of disease, but these are associated with the political, financial and social features of our collective societies and are, therefore, beyond the scope of this report.

Much of the literature pertaining to this field of study has been produced by non-English-speaking authors. Although the majority possess an abstract in English, full translations of all these scientific papers (from Chinese, Russian, Slovenian, Japanese and Polish, for example) have been difficult to obtain. Additionally, many of the early papers produced by this team (from 1980 through 1989) were published in Portuguese with abstracts in English. Hence, several scientific papers in this review are only referred to abstracts.

Herein will be demonstrated that excessive exposure to infrasound and low frequency noise causes extra-auditory pathology, specifically, vibroacoustic disease, and that the physiological and biological basis for this disease can only be understood if the concept of mechanotransduction cellular signalling is taken into account.

2. Noise pollution

Historically, it is understandable that noise exposure has always been associated with hearing loss. According to the Epic of Gilgamesh, a Babylonian king who lived in 2700 BC, the Great Flood was brought to the planet Earth because the demi-gods were unable to sleep due to the noise produced by humans (Sandars, 1972). In Ancient Greece (600 BC), metalwork involving hammers was banned within city limits (Ward, 1973). In Ancient Rome, legislation existed pertaining to the noise associated with the iron wheels of wagons that disrupted sleep, while in certain cities of Medieval Europe, horse carriages were not allowed during night time (World Health Organization, 1999).

But with the advent of machines, a different kind of noise became ubiquitous. Sometimes, a low rumble from public transportation systems in urban and suburban settings, sometimes a hum from an air-conditioning unit, a refrigerator or a fan, this noise does not cause hearing impairment. But it may cause annoyance. As a definition of annoyance, the European Commission Noise Team (2000) maintains: "Annoyance is the scientific expression for the non-specific disturbance by noise, as reported in a structured field survey. Nearly every person that reports to be annoyed by noise in and around its home will also experience one or more of the following specific effects:

Reduced enjoyment of balcony or garden; When inside the home with windows open: interference with sleep, communication, reading, watching television, listening to music and radio; Closing of bedroom windows in order to avoid sleep disturbance. Some of the persons that are annoyed by noise also experience one or more of the following effects: Sleep disturbance when windows and doors are closed; Interference with communication and other indoor activities when windows and doors are closed; Mental health effects; Noise-induced hearing impairment; Hypertension; Ischemic heart disease." Hence, the parameter "annoyance" is, in itself, of a subjective nature.

2.1. dBA versus dBLin

Quantifying noise based on the subjective awareness of humans has guided the vast majority of noise-related biomedical studies. In fact, the foundational unit of noise legislation – the dBA - is grounded solely in the acoustical phenomena that humans can perceive with their ears, i.e., sound. The "A" on the dB unit refers to the usage of a filtering or weighting network that simulates human hearing and, thus, its purpose is to measure the acoustical phenomena present in the environment that can cause hearing impairment. Humans are considered to perceive sound between 20 and 20 000 Hz, but non-uniformly, i.e., there is an acoustical window where the human ear is most susceptible: 500 - 8000 Hz. It is within these frequency bands that hearing impairment occurs - legal deafness is assessed at 4000 Hz. Using the A-filter de-emphasizes all values of acoustical energy that occur below 500 Hz, and ignores all acoustical energy below 20 Hz. Fig. 1 demonstrates the usefulness of the dBA unit.

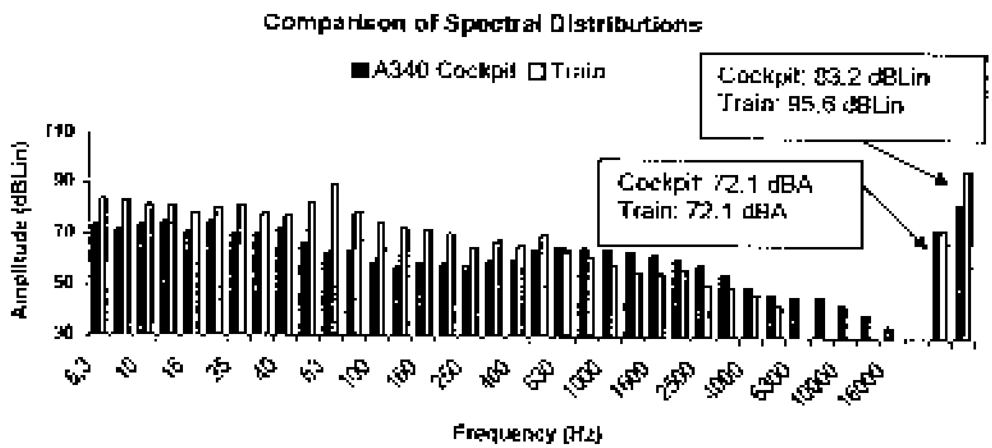

Fig. 1. Spectral distribution in 1/3 octave bands, without A-weighting (dB-Linear), obtained in a) cockpit of the Airbus-340 (Alves-Pereira et al., 2001a), at cruise flight, and b) in a Lisbon commuter train, while in motion, in the passenger position (Alves-Pereira et al., 2004a). The two bars on the right compare the overall (Leq) values in both dBA and dBLin, i.e., with and without A-weighting, respectively. As can be observed, the dBA values are the same while the dBLin values differ by 12 dB. The value in dBA represents what the human can *hear* while the dBLin value indicates the amount of acoustic energy present in the environment. Hence, in both cockpit and train, what will be *heard* will be the same, but the individual in the train will be exposed to a larger amount of acoustic energy.

Scientifically, the acoustical environments of the cockpit and train shown in Fig. 1 cannot be considered comparable because the distribution of acoustical energy throughout the different frequency bands is quite distinct. This distinction is not taken into account if the acoustic environments are solely described by a dBA value, as is clearly illustrated in Fig. 1. Nevertheless, it is this dBA value that most noise-related legislation requires to assess the risk of noise exposure, and it is this same dBA value that most biomedical scientists use to describe their experimental acoustical environments.

The usage of the dBA value for scientific study can only be justified if the purpose of the study is related to effects on, or via, the human auditory system. If the purpose is to study the biological effects of noise, then describing acoustical environments merely in terms of a dBA value is a scientifically unsound methodology. Example: Two different and independent teams of researchers expose the same animal population, in equal conditions, to an acoustical environment described as "80 dBA". Is it scientifically valid to compare the results of these two studies? As the example given in Fig. 1 clearly demonstrates, the answer is no, but the scientific community at large does so in its numerous published papers. At present, the general consensus of mainstream science is (still) that noise-induced extra-auditory pathology is a controversial, contradictory and inconclusive subject, hence non-existent and, therefore, not subjected to legislation (Alves-Pereira, 1999, 2005).

2.2. *"What you can't hear, won't hurt you"*

The title of this section is a quote, from Campanella (2001). There is no scientific evidence supporting this statement, and there is a colossal amount of scientific evidence indicating otherwise. Nevertheless, leading acousticians still opt to ignore this fact, and persist on perpetuating the notion that if hearing protectors are properly worn, no noise-induced extra-auditory effects will arise (von Gierke et al. 2001).

In fact, over the past 25 years, research conducted in Portugal (and, independently, in other countries, such as the Soviet Union/Russia, Japan and China) has been showing that acoustical phenomena, whether it is perceived by the auditory system, or not, can indeed cause organic changes in biological tissue (Alves-Pereira, 1999). As a result of the efforts of a multidisciplinary team of scientists, including medical doctors, mathematicians, physicists, biologists, engineers, and acousticians, a pathological entity has been defined – vibroacoustic disease (VAD) (See below) (Castelo Branco et al., 1999a, 2004a).

VAD is specifically caused by excessive exposure to infrasound and low frequency noise (ILFN - taken to be all acoustical phenomena occurring from 0 to 500 Hz). However, the acoustical energy responsible for VAD is never taken into account by typical noise measurements. As explained above, the scientific community and legislative bodies insist in accepting acoustical environments described merely in terms of a dBA value. Hence, they also perpetuate the erroneous notion that noise only affects the ear. The end result is a multitude of studies, focused on the biological effects of noise, but without the necessary methodology to allow them to be compared amongst each other. In the rare cases where information on the frequency distribution is provided, spectra are often measured in dBA units, which, once again de-emphasizes the amount of acoustical energy actually present in the environment, but gives a nice estimate of the noise being processed by the ear.

The scientifically-unsubstantiated, but prevalent notion that noise only affects hearing has had a tremendous impact on individuals who develop ILFN-induced pathology. The gravity and magnitude of this issue will be further discussed in later sections.

2.3. Acoustic Pollution

It is high time that scientists begin to view acoustical phenomena within a framework usually applied to electromagnetic phenomena. Within the electromagnetic spectrum, the human eye perceives light in a certain range of frequencies, just as within the acoustical spectrum, the human ear perceives sound in a specific range of frequencies. There exist electromagnetic phenomena that are not perceived by any of the human senses during the actual exposure (x-rays, for example), and yet, excessive exposure to x-rays can cause severe biological damage. Without any subjective perception of the agent of disease, humans can nonetheless develop pathology caused by that unperceived agent of disease. While this is obviously true, it is apparently forgotten when one deals with acoustical phenomena, specifically ILFN. This may, in fact, be a unique case in the History of Medicine, whereby the agent of disease is considered to only have an effect on the host, if the host perceives that same agent of disease.

That specific electromagnetic frequencies influence specific types of tissues is a well-known fact, and is the basis for numerous medical diagnostic and therapeutic tools. Science has data regarding which frequencies cause which types of pathology, for example, ultraviolet radiation can cause ocular disease, such as cataracts. But in the acoustical spectrum, the only frequencies that are considered to pathologically affect humans are within the audible range (ultrasound is beyond the scope of this paper), and all of them are focused on the hearing apparatus. Acoustical phenomena within the ILFN range can affect several organs and tissues, but this depends also on the frequency of the acoustical event because every organ and tissue has its own acoustical properties (resonance frequency and acoustical impedance, for example).

Noise protection is, of course, focused exclusively on avoiding hearing impairment and minimizing annoyance. Thus, in some work environments where ILFN values can reach up to 90 and 100 dB (Alves-Pereira et al., 2004b), the only protection provided are hearing protectors. Returning to the analogy with the electromagnetic spectrum, this would be equivalent to providing dark glasses to individuals who work with x-rays.

Clearly, a new attitude toward noise and noise pollution is urgently required. The term *acoustic pollution* reflects the real nature of acoustical phenomena and how it impacts on humans. Acoustic pollution encompasses those frequencies that, being audible to humans, can cause hearing impairment. But it also includes all the other acoustical phenomena, ILFN *and* ultrasound, which may, or may not, pathologically affect human beings. Acoustic pollution deals with the entire acoustical landscape, and not just with the acoustical phenomena that produce sound to the human perception. In fact, where ILFN is concerned, dosimetry studies cannot be adequately carried out if the notion of acoustic pollution is not well understood. (See below.)

3. Chemical and mechanical cellular signalling

When new biological models successfully explain a larger number of biological events, usually that model is adopted and older, less applicable models are discarded.

While this may seem like a logical course of action, sometimes the inertia associated with human nature to accept change constitutes an impediment.

The conventional model of the biological cell assumes it to be an elastic cortex surrounding a viscous cytoplasm that contains an elastic nucleus at the centre. This is a "continuum" model and assumes that the load-bearing elements are infinitesimally small compared to the overall size of the cell. Although this model has successfully explained many cellular behaviours, it does not take into account the distinct functional contributions of the cytoskeleton network.

For the past 30 years, the Ingber Laboratory at Harvard Medical School has been demonstrating that the "balloon" model of the cell is inadequate. Instead, a cellular model based on tensegrity architecture has been proposed and has been successfully explaining many cellular and tissue behaviours, both during normal metabolic activity and in disease (Ingber 2003; 2004a,b, among others). This "new" cellular model is crucial to understanding the type of pathology developed by ELFN-exposed biological organisms because only the tensegrity model adequately explains how mechanical signals are transduced over cells and tissues.

At present, cell and tissue regulation is considered to be largely mediated by molecular conformations, intermolecular interactions, and linear signal transduction cascades. But this is proving to be a reductionist approach because the neglected mechanotransduction cellular signalling also plays a key role in cell and tissue communication (Ingber, 2004a). Modern medicine focuses on the importance of genes and chemical factors to control and explain tissue physiology and disease development. The "genome euphoria" (Ingber, 2003) disregards the physical (structural and mechanical) properties of cells and tissues despite the fact that in order to maintain normal cell behaviour (motility, growth, apoptosis), the ability of cells to sense and respond to mechanical stresses is of critical importance (Wang et al., 1993; Matthews et al., 2004; Alenghat et al., 2004, for example).

3.1. Tensegrity architecture

At the turn of the 20th century, mechanical interpretations of biological behaviour were a common methodology. Form and function of cells and tissues were of great importance to understanding biological processes. However, as the field of molecular biology developed, biochemicals and genes became the forefront of scientific interest. "Medicine went from a holistic view of describing the relation between form and function to a much more reductionist view of describing what life is made of. And the mechanics were thrown out like the baby with the bathwater" (Ingber, 2004b).

The term *tensegrity* (tensile integrity) was coined by R. Buckminster Fuller, "father" of the geodesic dome in Architecture, and of the bucky ball in Physics (Fuller, 1975). Tensegrity is a form of structural stabilization that minimizes weight by using discontinuous-compression and continuous-tension, as opposed to continuous-compression. To visualize the difference, compare a brick-on-brick type of construction (continuous compression) with a stick-and-elastic construction of a geodesic dome, where the sticks are the discontinuous-compression elements while the elastics provide the continuous tension. Anchoring points, or nodes are essential to tensegrity structures because it is through these points that mechanical forces are transduced throughout the constituent compression and tensile elements. Any local, external perturbation of a tensegrity structure will result in a well-organized redistribution of tensional forces throughout the entire structure, with the purpose of maintaining structural integrity.

3.2. Cellular tensegrity architecture

Cellular cytoskeletons (CSK) form isomeric networks of microtubules, intermediate tubules, intermediate filaments, and actin. Forces generated within the CSK are involved in cytoplasmic organelle transportation (mitochondria and synaptic vesicles), chromosome movement during mitosis, and tension generation in the muscle cell contraction process (Ingber, 2003a). The CSK receives signalling from other cells through cell-cell junctions, and from the extra-cellular matrix (ECM), through cell-matrix junctions. Table 1 summarizes the properties of both types of junctions.

Table 1
Properties of cell-cell anchoring junctions (adherens junction and desmosomes) and of cell-matrix anchoring junctions (focal adhesions and hemidesmosomes)

	Cell-Cell		Cell-Matrix	
Junction	Adherens Junction	Desmosome	Focal Adhesions	Hemidesmosomes
Intracellular (CSK) attachment filaments	actin	intermediate filaments	actin	intermediate filaments
Transmembrane adhesion protein	E-cadherin	Cadherin (desmoglein, desmocollin)	Integrin	Integrin ($\alpha_6\beta_4$, BP180)
Extra-cellular ligand	Cadherin (adjacent cell)	desmogleins, desmocollins (adjacent cell)	ECM proteins	ECM proteins
Intracellular anchor protein	α,β-catenins, vinculin, α-actinin, γ-catenin	desmoplakins, γ-catenin	talin, vinculin, α-actinin, filamin	plectin, BP230

In the CSK, microfilaments form a mesh network of fine cables that constitute the continuous-tension elements (elastics) of the cellular tensegrity model. The compression elements (sticks) are formed by microtubules that are anchored to the ECM through transmembrane proteins called integrins, at sites called focal adhesions. Integrins differ from other cell-surface receptors because they bind with relatively low affinity (Ka = 10^6-10^9 l/mole), and their highest concentration is on cell surfaces.

Previous studies have probed the functioning of focal adhesion integrin receptors through magnetic twisting cytometry (Wang et al., 1993) and magnetic microneedle manipulation followed by magnetic pulling cytometry (Matthews et al., 2004). At focal adhesions, CSK and ECM possess structural linkages in the form of integrin cell-surface receptors. Mechanical forces applied directly to integrin cell-surface receptors alter cell biochemical and gene expression in a stress-dependent way (Ingber, 2003; 2004a,b; Wang, et al., 1993; Matthews et al., 2004; Alenghat et al., 2004). When the same forces are applied to other types of membrane receptors, there is no such effect.

External forces applied to integrins can activate intercellular signalling pathways, such as, protein tyrosine phosphorylation, ion fluxes, cAMP production, and G protein signalling (Ingber, 2003; 2004a,b; Wang, et al., 1993; Matthews et al., 2004; Alenghat et al., 2004). These integrin linkages allow for mechanochemical transduction signalling that produce changes in cell form and function. This type of intracellular signalling is a critical regulator of cellular biochemistry, gene expression and tissue development

(Ingber, 2003; 2004a,b; Wang, et al., 1993; Matthews et al., 2004; Alenghat et al., 2004). There is a large variety of mechanochemical-transducing integrin receptors molecules; each type of integrin only binds to one ECM macromolecule, and cell-type specificity modulates integrin binding activities, i.e., in fibroblasts, ligands bind specifically to collagen, fibronectin and laminin. Hemidesmosomes (connecting the basal lamina to adjacent cells) are integrin receptors but that do not bind to the CSK through the actin cortex. Instead, hemidesmosome integrins connect directly with intermediate filaments. In the CSK, these are responsible for helping individual microtubules from buckling under compression, and link the nucleus the to surface membrane. Desmosomes connect intermediate filaments from cell to cell. The biological explanation for some diseases based on mechanotransduction impairment has already been successfully advanced (Ingber 2003; 2004a,b).

4. Vibroacoustic Disease

VAD is a systemic pathology, caused by excessive exposure to ILFN, and characterized by the abnormal proliferation of collagen and elastin, in the absence of an inflammatory process. VAD has been diagnosed in aeronautical technicians (Castelo Branco, 1999a), pilots and flight attendants (Araujo et al., 2001), as well as in an islander population exposed to environmental ILFN (Torres et al., 2001). Cases of VAD have also been documented among ship workers (Arnot, 2003) and in residential areas (Araujo et al., 2004, Monteiro et al., 2004).

4.1. Brief chronology of scientific inquiry over the past 25 years

In 1980, co-author Castelo Branco was appointed chief medical officer at an aircraft manufacturing, repair and rework facility (OGMA), owned and operated by the Portuguese Air Force, and employing around 3500 workers. The first step was to visit the workstations of all employees to assess the nature of the different occupational hazards, possible emergency situations that could arise, and types of required worker protection.

After maintenance is performed on an aircraft, Quality Control personnel carry out manufacturer's procedures while the aircraft is stopped on the tarmac, and has its engines test run at all possible speeds. During one of these run-up tests (EA3B, with afterburn) Castelo Branco observed a worker beginning to walk aimlessly, without purpose, and in the direction of the turbines. A co-worker grabbed him by the arm before he got too close, and the incident remained at that. After the run-up test, the co-worker was questioned about what had happened. Apparently it was not a rare occurrence, and in the 1960's someone *had not* been caught in time, which led to a fatality. The non-purposeful movements exhibited by the worker appeared to Castelo Branco to be of an epileptic nature.

OGMA was founded in 1918 and, since the 1960's, detailed medical records are kept for all workers (administrative and technical). Based on the observation during the run-up test, the second step was to survey all medical records to count how many technicians had previously been diagnosed with late-onset epilepsy, as detailed in their medical files. In the Portuguese general population, the incidence of epilepsy is 0.2%. In the group of 306 aircraft technicians employed at OGMA, 10% had been previously diagnosed with late-onset epilepsy (GIMOGMA, 1984a). Here began this team's inquiry into ILFN-induced pathology.

4.1.1. 1980

- Establishment that 10% (N=306) of the aircraft technicians employed at OGMA had been previously diagnosed with late-onset epilepsy (GIMOGMA, 1984a).

- Initiated neurophysiological examinations. The results from brainstem auditory evoked potentials (BAEP) were initially difficult to interpret, given their large dispersion. To better evaluate the BAEP recordings, taxonomic distances using clustering algorithms, and multivariate analysis of action currents distributions were applied, and a standardized method was developed using a control population (Castelo Branco et al., 1985; Marvão et al., 1985)

4.1.2. 1984-1988

- Publication of the first articles on initial findings under the team name of GIMOGMA: Epilepsy (GIMOGMA, 1984a), BAEP study (GIMOGMA, 1984b), and hyper-sensibility to noise (GIMOGMA, 1984c), otherwise known as noise intolerance or annoyance. A vascular involvement began to be suspected.

Until this point, it was thought that the neurological pathology observed in this group of workers, initially termed "vibration disease", was due to excessive exposure to vibration. Neurological parameters continued to be assessed.

- Studies showed abnormal magnetic resonance imaging of the central nervous system (Cruz Maurício et al., 1988) and cognitive potentials (P300) (Moniz Botelho et al., 1988) in aircraft technicians.
- Other, non-neurological changes were identified, including damaged dental alveolar structures (Cortez-Pimentel et al., 1988); haemostasis and coagulation changes (Crespo et al., 1988), and abnormal retinal angiography (van Zeller et al., 1988). The latter two suggested the pathology was of a vascular nature.
- Four cases of pleural effusion developed in these workers, all of unknown aetiology. They exhibited an atypical response to standard therapeutics, and endured unusually prolonged recovery periods.

During these years, "systemic vibration disease" was the term used to identify the pathology observed in aircraft technicians (Pimenta et al., 1988). This meant that the health problems these workers were developing were not necessarily restricted to the neurological system.

- September 1987: Autopsy of an aircraft technician (Castelo Branco, 1999b). The plethora of scientific data bequeathed by this deceased patient disclosed the real extent of this pathology: 11 scars of previous silent infarct events, two previously undetected malignant tumours (kidney and brain), thickened blood vessel walls, thickened pericardium, and focal lung fibrosis.

4.1.3. 1989-1992

During this period, it was determined that the fundamental agent of disease to which aircraft technicians were exposed was ILFN (Bento Coelho et al., 1994), hence, the pathological entity was, again, renamed: "whole-body noise and vibration syndrome" (Castelo Branco 1992).

- The thickened blood vessels and pericardium found in autopsy prompted echo-imaging studies, namely echocardiography for assessing pericardial thickening. All aircraft technicians presented abnormal pericardial and/or cardiac valve thickening (Araujo et al., 1989)
- Carotid angiodynography was used to assess carotid thickening (Albuquerque et al., 1991; Carmo et al., 1992). Simultaneously, other populations occupationally-exposed to ILFN began to be studied, such as helicopter (Carmo et al., 1992) and military (Canas et al., 1993) pilots.
- Wistar rats were chosen as animal models to investigate the effects of ILFN exposure on the respiratory tract, in an attempt to explain the atypical cases of pleural effusion, of unknown aetiology.

4.1.4. 1993-1999

In 1993, during a scientific meeting sponsored by our team, the term "vibroacoustic" was proposed for this pathological entity (Castelo Branco et al., 1999a), and "vibroacoustic syndrome" became the new name for the ailment observed in aircraft technicians and, now, also in aircraft and helicopter pilots (Castelo Branco et al., 1996).

- Animal studies showed that the respiratory tract could be considered a primary target for ILFN: abnormal amount of fibrosis/collagen was ubiquitous in trachea, lungs and pleura; damaged (sheared) tracheal and bronchial cilia; fused actin-based microvilli of tracheal and bronchial brush cells (Sousa Pereira et al., 1999a; Grande et al., 1999). The atypical cases of pleural effusion were partially explained by morphofunctional impairment of pleural microvilli (Sousa Pereira et al., 1999b), as well as of pleural phagocytic capabilities (Oliveira et al., 1999).
- Additional neurological disorders were identified in ILFN-exposed populations, such as the existence of the palmo-mental reflex, usually only seen in primates, newborns, and the elderly (Martinho Pimenta et al., 1999a); balance disturbances (Martinho Pimenta et al., 1999b), and facial dyskinesia induced by auditory stimuli (Rosado et al., 1993; Martinho Pimenta et al., 1999c).
- The genotoxicity of ILFN was demonstrated in both human (Silva et al., 1999; 2002a) and animal models (Silva et al., 2002b), and was confirmed by teratogenic features in mice (Castelo Branco et al., 2003g).
- Echocardiography was deemed an unreliable diagnostic tool because there is no established procedure to assess pericardial thickening and, thus, technician subjectivity introduced a large factor of error.
- The first human pericardial fragments were studied in VAD patients who required cardiac bypass surgery for other reasons (See below): abnormal amounts of collagen as well as the neo-formation of an extra layer of tissue was shown to be the cause underlying the pericardial thickening, providing anatomical confirmation of the autopsy and echo-imaging observations (Castelo Branco et al., 1996)

- Medical files of all aircraft technicians were chronologically reviewed since their admittance to OGMA. On-the-job accidents and incidents were correlated with the existence of unmonitored ILFN exposure of the workforce (Alvarez et al., 1993), and the clinical phases of the disease were outlined (Castelo Branco et al., 1995).

In 1999, the name "vibroacoustic disease" (VAD) was adopted, and the journal Aviation, Space & Environmental Medicine dedicated a supplemental issue to this new pathological entity (Castelo Branco et al., 1999c).

4.1.5. Since 2000

- Other ILFN-exposed professionals were studied, such as civil aviation pilots and cabin crewmembers, confirming echocardiography results of aircraft technicians and military pilots (Araujo et al., 2001).
- More neurological pathology was identified: VAD patients were found to be unable to hyperventilate when in the presence of excessive CO_2 (Reis Ferreira et al., 2003a).
- Mechanically-induced cellular death was identified in the pericardia of VAD patients and it was hypothesized that this situation could be related to the large incidence of auto-immune disorders in these patients (Castelo Branco et al., 2004b).
- Further rat studies suggested that fusion of cochlear cilia (actin-based structures) may provide a biomechanical explanation for noise intolerance, or annoyance (Castelo Branco et al., 2003a).
- The first case of large-scale environmental exposure to ILFN appeared in Vieques, Puerto Rico (Torres et al., 2001). Here, ILFN was caused by military training exercises. An isolated case came from Dublin, Ireland, where buses where the source of ILFN and induced VAD in a home-maker (Monteiro et al., 2004). Another from Lisbon, where ship-to-silo and silo-to-ship loading of cereals produces ILFN in a home where both parents and 10-year-old child exhibited VAD-related signs and symptoms (Araujo et al., 2004).
- In all VAD patients, bronchoscopic examinations disclosed lesions that, upon analysis, demonstrated the existence of abnormal amounts of collagen, and neo-formation of vascular beds. Disrupted collagen fibers were observed and correlated with a positive testing of anti-nuclear antibodies, providing a deeper understanding of auto-immune processes (Monteiro et al., 2004a).

4.2. Clinical stages of VAD

In order to identify the clinical stages of VAD, as observed in aeronautical technicians, a systematic and detailed review of the medical files pertaining to the initial group of 306 aircraft technicians was undertaken in the mid 1990's. This group of 306 male individuals were all employed by OGMA for more than 10 years, and were submitted to rigorous selection criteria, as per Table 2 (Castelo Branco, 1999a).

Table 2
Conditions for study population exclusion (Castelo Branco, 1999a).

Conditions	Comments
Streptococcal Infections	Due to their propensity to induce extra-cellular matrix changes
Diabetes mellitus	Same as above
Pre-existing Cardiovascular Disease	But not labile hypertension, because it is suspected to be a measure of individual susceptibility, and because lesions are distinct from those caused by established hypertension
Tobacco Abuse	Smokers of more than 20 cigarettes a day.
Alcohol Abuse	Drinkers with more than a liter of wine per day (10-12% alcohol content).
Drug Use	Users of any recreational or psychotropic drug.

A group of 140 technicians (average age of 42 years, SD=10.4) remained after the application of selection criteria, i.e., 166 individuals were excluded. The medical files of these 140 technicians were comprehensively and chronologically reviewed. Simultaneously, a sociologist and a social worker interviewed family and friends to obtain additional information on the individual's behaviour outside his professional activity. The methodology to obtain a correspondence between sign/symptom and years of occupational exposure was the 50% cutoff, i.e., the sign/symptom was included in the list if it was identified in 50% (N=70) of the study population. Thus, referring to Table 2, after 1-4 years of occupational exposure, at least 70 of these 140 individuals developed bronchitis, in smokers and non-smokers alike (smokers in study group: N=45). Or, after 10 years of occupational activity, at least 70 exhibited headaches and nose bleeds. It should be emphasized that these signs and symptoms are not mutually exclusive, and most VAD patients suffer from more than one or two of these clinical situations, simultaneously (Castelo Branco, 1999a; Castelo Branco et al., 2004a).

Table 3
Data from a group of 140 aircraft technicians. ILFN exposure time (years) refers to the amount of time it took for 70 individuals (50%) to develop the corresponding sign or symptom (Castelo Branco, 1999a).

Clinical Stage	Sign/Symptom
Stage I-Mild (1-4 years)	Slight mood swings, Indigestion & heart-burn, Mouth/throat infections, Bronchitis
Stage II-Moderate (4-10 years)	Chest pain, Definite mood swings, Back pain, Fatigue, Fungal, viral and parasitic skin infections, Inflammation of stomach lining, Pain and blood in urine, Conjunctivitis, Allergies
Stage III-Severe (> 10 years)	Psychiatricdisturbances, Haemorrhages of nasal, digestive and conjunctive mucosa, Varicose veins and haemorrhoids, Duodenal ulcers, Spastic colitis, Decrease in visual acuity, Headaches, Severe joint pain, Intense muscular pain, Neurological disturbances

Table 3 refers to the signs and symptoms developed specifically by aircraft technicians working the standard 8 hrs/day, 5 days/week. Not all ILFN-exposed workers have this exposure schedule. For example, ship machinists can spend 3 weeks onboard ship (i.e., exposed to substantial ILFN-rich environments) and 2 weeks at home (i.e., presumably not in ILFN-rich environments) (Arnot, 2003). Other professional activities exist where the ILFN-exposure time pattern is not the standard 8-hr/day exposure, such as with submarine and oil rig operators, astronauts, and environmental exposures in residential areas, where exposure can be continuous over long periods of time, and exists during sleeping hours. In these cases, the evolution of signs and symptoms could be greatly accelerated. For example, in the case of a Dublin homemaker, epileptic seizures consistent with VAD developed after 3 years of residence within a ILFN-infested home (Monteiro et al., 2004). If the ILFN exposure is environmental and/or leisurely, the standard 8hr/day model is also not applicable. Moreover, since different ILFN environments have unique frequency distributions, the fact that some frequency bands may be more predominant than others (i.e., concentrate more acoustical energy) can lead to the development of slightly different pathology.

4.3. Pathology associated with VAD

Other important pathologies were identified among these 140 aircraft technicians, but since they were not identified in 50% of the population, they were not included in Table 3. Nevertheless, their incidence is clinically important. Some kind of respiratory insufficiency was found in 24 of the 140 professionals, 11 were smokers. In 10 of the 24 cases, a mere light physical effort was necessary to produce symptoms. Notably, only 45 of the 140 individuals were smokers, 38 of which had over 20 years of occupational ILFN exposure.

Late-onset epilepsy was diagnosed in 22 individuals, some of whom saw their seizures subside when away from their workstation. Reflex epilepsy due to vibratory stimulus (Martinho Pimenta et al., 1999c) and visual stimulus was observed in two individuals. Auditory stimuli did not trigger seizures but, in some cases, triggered rage reactions and movement disorders (Martinho Pimenta et al., 1999d,e). Balance disturbances were also a common complaint, identified in 80 individuals, although the severity of the balance disturbance ranged from dizziness to severe vertigo (Martinho Pimenta et al., 1999f). Unique and sudden episodes of non-convulsive neurological deficit occurred in 11 individuals. These were diagnosed as cerebral ischemic vascular accidents, which was compatible with imaging studies. EEG and multi-modal evoked potentials showed considerable power changes that were in agreement with clinical psychological and neurological evidences. Delays in multi-modal evoked potentials (including endogenous), observed in all 140 patients, are a sign of progressive neurological deterioration and early aging process, as is the appearance of the archaic palmo-mental reflex, that affects about 40% of these 140 patients.

Endocrine disorders, the most common being thyroid dysfunction, were identified in 18 cases. The overall national Portuguese rate for adult thyroid dysfunction is 0.97% vs. the 12.8% identified in our group of 140 technicians. Similarly, diabetes was seen in 16 individuals (average age 39 years, SD=7.8) (11.4%), while the overall national rate for a similar age-group is 4.6% (Castelo Branco, 1999a). Among the 140 professionals, 28 had malignant tumours. Five of these 28 individuals exhibited simultaneous tumours of different types. All CNS tumours (N=5) were malignant gliomata, and all respiratory system tumours were squamous cell carcinomas (5 in lung, 1 in larynx). To date, and to the authors' knowledge, a total of 11 VAD patients have developed respiratory tract tumours: 9 in the lung, and 2 in the glottis (3 smokers); *all* have been squamous cell carcinomas (Mendes et al., 2004, Reis Ferreira et al., 2005). Other tumours were found in the stomach (N=10), colon and rectum (N=9), soft tissue (N=1), and bladder (N=1) (Castelo Branco, 1999a). All digestive system tumours were low-differentiated adenocarcinomas. These data led to the investigation of the genotoxicity of ILFN. In both human (Silva et al., 1999; 2002a) and animal (Silva et al., 2002b) models, ILFN induced an increased frequency of sister chromatid exchanges, effectively demonstrating that ILFN is a genotoxic agent.

More recently, in 2003, a new pathological sign was identified among VAD patients: decreased respiratory drive (Reis Ferreira et al., 2003a; Castelo Branco et al., 2003b). To date, pulmonary function tests are normal in VAD patients, except the $P_{0.1}(CO_2)$ index (and the metacholine reactivity test), which is a measure of the inspiratory pressure (or suction) developed at the mouth, 0.1 seconds after the start of inspiration. This initial respiratory drive originates in the autonomic (or involuntary) pathway of the neural control of the respiratory function. By rebreathing CO_2, normal individuals would present a minimum six-fold increase of the $P_{0.1}(CO_2)$ index when compared to normal $P_{0.1}$. If the neural control of respiration is compromised, then a less-than six-fold increase would be expected in the $P_{0.1}(CO_2)$ index (Calverly, 1999; Cotes, 1993; Gibson, 1996). In VAD patients, all $P_{0.1}(CO_2)$ index values are below 50%, when normal values would be above 60%.

Lastly, the issue of auto-immune diseases in ILFN-exposed individuals. In the electron microscopy studies of VAD-patient pericardial fragments, non-apoptotic cellular death was frequently observed (Castelo Branco et al., 2003c) (see below). Instead, biomechanical forces seemed to be responsible for the images of burst cells, with live organelles and no surrounding plasma membrane. Under these circumstances, the appearance of auto-immune diseases in these patients is not unreasonable. Indeed, previous studies have shown that ILFN exposure induces an accelerated onset of lupus in lupus-prone mice (Águas et al., 1999a). Lupus has also been identified in flight attendants (Araújo et al., 2001), and in entire families of islanders exposed to environmental ILFN (Torres et al., 2001). Vitiligo is another common finding, especially in the ILFN-exposed islander population. Vitiligo is associated with immune changes of CD8 and CD4 lymphocyte populations. These immune changes have also been observed in ILFN-exposed workers (Castro et al., 1999) and animal models (Águas et al., 1999b). Other authors have also corroborated the existence of auto-immune processes in noise-exposed workers (Matsumoto et al., 1989,1992; Jones et al., 1976; Soutar et al., 1974; Lippmann et al., 1973).

4.4. Some important considerations on behalf of VAD patients

Legally, the only pathology that can develop due to excessive noise exposure is hearing impairment. Therefore, occupational physicians rarely view VAD symptomatology as caused by excessive noise exposure. In fact, given the plethora of complaints associated with VAD (see Table 3), oftentimes physicians regard the patient as a malingerer or hypochondriac (Castelo Branco et al., 1999a), especially since routine medical tests (blood chemistry analysis, EKG and EEG, for example) do not corroborate the existence of any pathology. One of the reasons for this is that the majority of medical diagnostic tests are based on biochemical, and not biomechanical, pathways (see below). There are dire consequences for the patients, as have been candidly exposed by a Scotsman, who was employed as a motorman, and developed VAD (Arnot, 2003).

In the case of occupational exposure to ILFN, workers can develop disabilities requiring early retirement (Castelo Branco et al., 1999d). Usually ILFN-rich environments are associated with machinery that, in an ever-developing technological world, often becomes obsolete within a few years time. At present, many individuals who have developed VAD due to occupational exposures cannot prove that they have been exposed to ILFN because noise assessments do not take ILFN into account (as described above), and many of the ILFN sources have been retired.

5. Vibroacoustic disease in light of mechanobiology

The establishment of VAD has been problematic because of several, non-typical situations that seem to defy conventional medical concepts. For example, the production of collagen, in the absence of an inflammatory process, is consistently seen in the blood and lymphatic vessel walls (Castelo Branco et al., 1999b; Reis Ferreira et al., 2003b,c; Monteiro et al., 2004a), pericardium (Castelo Branco et al., 1999b; 2003c;), trachea (Reis Ferreira et al., 2003b), and lung and pleura (Reis Ferreira et al., 2003c) of VAD patients. It is also observed in the respiratory tract (Castelo Branco 2003a), kidney (Castelo Branco et al., 2003d), blood and lymphatic vessels (Martins dos Santos et al., 2002; 2004, respectively) of ILFN-exposed animals.

Much of the data collected on VAD and ILFN-exposed biological tissues has been in the form of ultrastructure micrographs, obtained with scanning (SEM) and transmission (TEM) electron microscopy. The following sections will describe the anatomical findings in VAD patients' pericardia, and in the respiratory tract and cochlea of ILFN-exposed rats, based on information obtained through histological and ultrastructural studies. The implications within the context of mechanobiology will be discussed.

5.1. The pericardium

The pericardium is a fibrous sac that encases the heart, with the purpose of maintaining it in its normal position. External forces, due to respiration or changes in body posture, are absorbed by the pericardium so as to keep the heart and its cardiac rhythm intact. Consisting of three tissue layers -- mesothelium, fibrosa and epipericardium - the pericardium is a highly organized mass of connective tissue, with a predominance of collagen fibers arranged in accordion-like bundles. Elastic fibers, much less numerous than collagen fibers, intersect the collagen bundles at right angles. This anatomical arrangement taken together with the viscoelastic properties of both collagen and elastin, provide the pericardium with the mechanical capability of protecting the integrity of the cardiac cycle. The thickness of normal parietal leaflet of the pericardium is <0,5 mm (Shabetai, 1994). The mesothelium is in direct contact with the pericardial sac, and is formed by a one-layer thick sheet of mesothelial (cuboidal) cell (MC). Anchoring junctions interconnect MC among themselves, through their cytoskeletal fibers - microtubules - interconnected through desmosomes (See Table 1). Microtubules do not rupture when stretched, can withstand larger stresses and strains than actin filaments, and are crucial to maintain cellular integrity.

Abnormally thickened pericardia were first observed by this team in autopsy (Castelo Branco, 1999b), and later confirmed through echocardiography (Araujo et al., 1989; Marciniak et al., 1999; Torres et al., 2001). No inflammatory process was present, no cardiac dysfunction was identified and, thus, pericarditis is not an issue in VAD patients. The strange feature was that despite the extraordinary enlargement, no diastolic impairment was observed: EKGs of VAD patients were normal, as were the cardiac functional parameters assessed through echocardiography. Simultaneously, echo-imaging did not have a 1 to 1 correspondence with anatomical structures, thus, it became important to understand what was occurring at the anatomical level.

Since one of the consequences of ILFN exposure is thickening of blood vessel walls (Castelo Branco 1999b; Castelo Branco et al. 1996; 1999b; 2003c; Reis Ferreira et al., 2003b,c) the recommendation for cardiac bypass surgery by other physicians is not uncommon among VAD patients. Hence, it was possible, with Hospital Ethics Committee approval and patients' fully informed consent, to study pericardial fragments of VAD patients (Castelo Branco et al., 1996; 1999b; 2004b). Pericardial thickening was confirmed anatomically, and a possible reason for the lack of diastolic dysfunction was uncovered (See Fig. 2).

1) 2) 3)

Fig. 2. 1) Light microscopy (x100) – VAD patient pericardium, with pericardial sac on right. Five (instead of the normal three) layers are identifiable: (A) mesothelial, (B) internal fibrosa, (C) loose tissue, (D) external fibrosa, and (E) epipericardium. The loose tissue is rich in vessels. No inflammatory cellularity was identified in any of the five layers. In both fibrous layers, wavy collagen bundles are visible, however the wave length of fibers in layer B (internal fibrosa) is smaller than that in layer D (external fibrosa). Taking together the increased amount of collagen bundles, in wavy, accordion-like arrangements, with different orientations in relation to each other, and with more than one elastic fiber accompanying the bundles at seemingly perpendicular angles (seen through electron microscopy, not shown), seems to suggest a pneumatic like structure, designed to absorb abnormally large external forces. Similarly, this functional arrangement also explains why there is no diastolic dysfunction, despite the thickened pericardial walls. 2) SEM of non-VAD patient pericardium. Normal three layers are visible: mesothelium (white arrow), fibrosa (black arrow) and epipericardium. 3) SEM of VAD patient pericardium. Fibrosa has split into two halves (arrows) that sandwich a newly-formed layer of loose tissue (L). Note that the scale in both 2) and 3) is the same. The wavy form of collagen bundles is a mechanically energy-efficient method to deal with the movement that the fibrosa must constantly undergo to follow the rhythm of the cardiac cycle. Similar to an accordion, collagen bundles will extend and contract in diastole and systole, respectively. However, during an episode of sudden and violent tachycardia (common in VAD patients), this rhythm can be greatly increased (up to 200 beats per minute, in a matter of seconds) and the mechanical stress imposed on the MC monolayer may threaten its structural integrity. One of the functions of the loose tissue layer must certainly be blood and nutrient supply to this much larger organ.

When electron microscopy was used to examine these pericardial fragments, an unusual amount of cellular death was observed. This peculiar type of cellular death was related to the mechanical bursting of cells, with images of seemingly live organelles outside of the burst cytoplasmic membrane (Figs. 3,5). Cellular debris was seen in all layers and in the vast majority of the images (Fig. 5). Individual, older MC were seen protruding into the pericardial sac, in a process that resembled surface extrusion of that cell (Fig. 6). Discontinuities in MC surface (in direct contact with the pericardial sac) (Fig. 5), with seemingly live organelles spewing into the pericardial sac (Fig. 6) were observed. Desmosomes, which laterally attach adjacent MC (Table 1), were more numerous than would be expected (Fig. 4). The lack of cellular anchoring junctions between MC and the subserousal basal layer (usually accomplished through hemidesmosomes, see Table 1) seems to be replaced by interdigitations whose form is reminiscent of anti-sesmic constructions (Fig. 4). MC morphology varied in accordance with the contraction wave of the cardiac rhythm (Castelo Branco et al., 1999b;2005a)

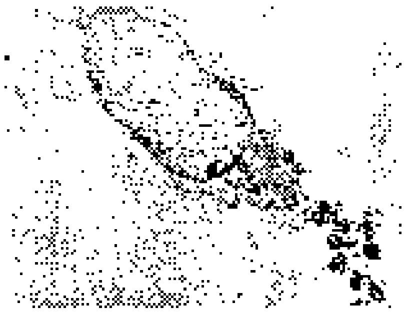

Fig. 3 (TEM) VAD patient parietal pericardium. Deep within the internal fibrosa layer: a burst myofibroblast near a small elastic fibre surrounded by abnormally abundant collagen bundles. Seemingly live organelles are outside the membrane. (x4000)

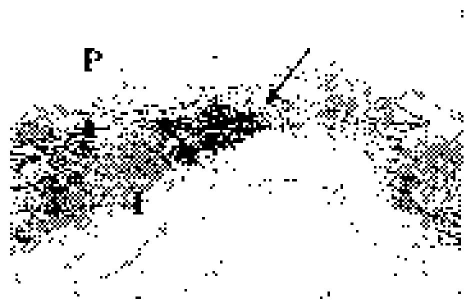

Fig. 4. (TEM) VAD patient pericardial fragment. Pericardial sac (P), Unusual number of cell-cell connections (arrow). Interdigitations (I) linking the MC layer with the subserosal basal layer, through structures reminiscent of anti-sesmic constructions. (x2800)

Fig. 5. (TEM) Pericardial sac (P), collagen bundles (C), cellular debris (x). Discontinuous membrane (arrow), partial loss of cytoplasm. Gaps seen near MC (circle) (x4000)

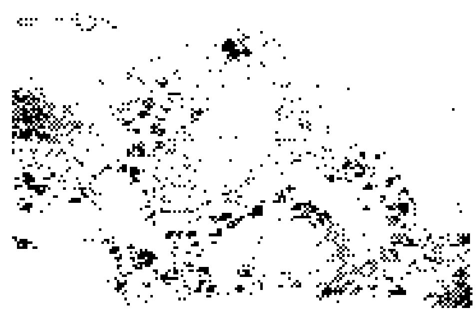

Fig. 6. (TEM) Mesothelial layer with older mesothelial cell (X) in the process of extrusion into the pericardial sac, and with large gaps on either side.

VAD patients often suffer sudden and violent tachycardia, and sudden peaks of increased arterial blood pressure (Castelo Branco, 1999a). This implies a violent and sudden kinetic changes in the cardiac (and pericardial) rhythm. During repeated, VAD-related tachycardia and hypertensive episodes, MC cells become enormously strained, and maintaining structural integrity of the MC monolayer might become an issue. Older MC cells may have insufficient tensile strength to undergo these violent tachycardia movements, and their extrusion (Fig. 6) from the mesothelium monolayer of cells may be an attempt to maintain structural integrity. The formation of gaps near these older MC cells (Figs. 5,6) seems to be an integral part of this extrusion process. The anchoring junctions between the mesothelium and its ECM sublayer seem to have been replaced with MC cytoplamsic interdigitations that dig deep into the ECM sub-layer (Fig. 4). This anchoring structure is not unlike modern anti-seismic constructions, where building blocks fit into each other like pieces in a vertical jigsaw puzzle, providing increased plasticity, and allowing the absorption of large mechanical forces without rupturing.

The existence of such a large amount of cellular debris has been linked to a working hypothesis: The cellular debris seen in VAD patients' pericardial layers can be related to the appearance of auto-immune diseases in ILFN-exposed individuals. Seemingly live organelles that exist outside the cellular membrane envelope (Figs. 3,5) will not be identified by the immune system. This could trigger auto-immune disorders. No inflammatory process is tied to the removal of debris. The only visible features are an increased amount of macrophages and neovascularization, with particular relevance to the lymphatic vessels, where the drainage of debris seems to occur

5.2. Actin-based structures -- brush cell microvilli and cochlear cilia

Brush cells (BC) exist in the respiratory and gastrointestinal tracts. BC possess microvilli uniformly distributed over the apical surface which is known to play a role in increasing absorption surface area. The function and existence of the respiratory BC in humans is largely unknown. In the rat respiratory tract, BC are surrounded by a ring of secretory cells (SC) (Fig. 7) (Castelo Branco et al., 2003e). In ILFN-exposed rodents, microvilli clustered together and, with increasing exposure time, became fused (Fig. 8) (Castelo Branco et al., 2003a,f,g). Cochlear stereocilia also appeared fused in ILFN-exposed rats, both among themselves as well as with the upper tectorial membrane (Figs. 9,10) (Alves-Pereira et al., 2003a).

Why BC microvilli respond to prolonged ILFN stress by fusing is unknown. However, the fact that actin filaments can form both rigid (but flexible) bundles as well as gel-like networks, taken together with the fact that motor proteins connect the actin filaments core to the plasma membrane, microvilli fusion does not seem to be such a remote possibility, given the right triggering events.

If fusion of cochlea stereocilia, as a response to prolonged ILFN exposure, also occurs in humans, then this may explain the unusual auditory complaints of VAD patients. Common auditory complaints of VAD patients include "hearing too much" and "not being able to stand any type of noise, not even television or music". However, their audiograms only present hearing losses within the lower frequency bands (250 Hz, 500 Hz), and their tympanograms are normal (Castelo Branco, 1999a). If fused among themselves and to the tectorial membrane, cilia cannot freely vibrate as is intended when the sound pressure wave is transduced within the cochlea. In fact, by becoming a rigid structure, any attempt at vibrating them might, understandably, produce discomfort. How closely related this phenomenon is to the concept of "annoyance" is still unclear, however a relationship is clearly suggested, especially since annoyance has already been specifically associated with the presence of ILFN (Persson-Waye et al., 2001). In ongoing studies, fusion of actin-based structures in ILFN-exposed rodents has also been observed in the duodenum (Fonseca et al., 2005).

Fig. 7. (SEM) Non-exposed rat bronchial epithelium. The BC, in the center of the image, exhibits a tuft of microvilli that are individually identifiable, uniformly distributed, and sprouting upward into the airway. Surrounding the BC are SC with microvilli of different sizes. Tufts of cilia featuring vesicles are also visible. No sheared, shaggy or wilted cilia are visible. No edema is present.

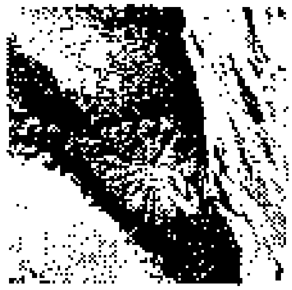

Fig. 8. (SEM) Rat bronchial epithelium exposed to 2160 hours of continuous ILFN. A BC is in the center of the image. Its microvilli are not sprouting upward and, instead, have fused, forming a central indentation that seems to be spreading outward. The prominent SC that surround the BC are swollen forming deep valleys at the intercellular junctions. SC microvilli are very irregular. Ciliary vesicles are visible.

Fig. 9. (SEM) Rat cochlear stereocilia exposed to 4799 hours of occupationally-simulated ILFN. Cochlear stereocilia are fused amongst themselves and with the upper tectorial membrane.

Fig. 10. (SEM) Rat cochlear stereocilia exposed to 4799 hours of occupationally-simulated ILFN. Cochlear stereocilia after removal of the tectorial membrane, portions of which remain fused to the stereocilia, forming bridges between adjacent cells.

5.3. Other considerations

Given the data obtained to date, the same type of analysis could be made of ILFN-exposed rat kidney glomeruli (Castelo Branco et al., 2003d; Martins dos Santos et al., 2005), or of rat tracheal epithelia (Castelo Branco et al., 2003a,f,g), or of VAD patients bronchoscopic biopsy results (Monteiro et al., 2004; Reis Ferreira et al., 2006), or of VAD patients vocal abnormalities (Mendes et al., 2005;2006). The behaviour of respiratory tract cilliary populations is of particular interest in that they are composed of tubulin, they are anchored to the CSK actin cortex and, with ILFN exposure, they appear clipped, sheared and/or shaggy (Alves-Pereira et al., 2003c). Pericardial cilia was also non-existent in VAD patients (astelo Branco et al., 1999b). The suspicion that the tensegrity model of the cell could explain the findings in ILFN-induced biological structures was hinted at in 1999 (Alves-Pereira) and has since been the object of separate study and independent publications (Alves-Pereira 2003a-d;2004c).

Most medical diagnostic procedures are not based on mechanobiological features of disease. Hence, what is analysed, quantified or tested are usually parameters that depend on biochemical pathways. It cannot, therefore, be surprising that VAD present normal routine tests, such as blood chemistry analysis, EKG, and EEG, for example. With echo-imaging, where structural components can be observed, ILFN-induced pathology can be identified. With light and electron microscopy studies, morphofunctional changes can, again, be identified. However, conventional medical tests only become significantly altered in later, and irreversible, stages of VAD (See Table 3). With the tensegrity model of the cell, new avenues of research open up in the area of biochemically-based tests from which biomechanical pathology can be extrapolated.

Pharmacological intervention in VAD is several years (and many Euros) away from becoming a reality. However, given that VAD is a mechanotranduction disease *par excellence* it now becomes clear where this intervention must focus: on the cellular signalling processes directly related to mechanotransduction.

6. Conclusions

ILFN is neglected as an agent of disease, and mechanotransduction is underestimated as an integral part of cellular signalling. Since VAD is caused by ILFN and explained through mechanotransduction pathways, it is not surprising that it is taking so long for the medical and scientific community to understand its existence. However, with knowledge comes responsibility, and the time has now come to take a more active position against needless suffering. The following recommendations are proposed.

6.1. Noise assessment

Hearing impairment is still a major issue within the EU and other countries, thus ceasing to perform measurements with dBA units is not a logical course of action. However, ILFN-rich environments need to be taken into account. Hence, it is proposed that *all* noise measurements be accompanied by a 1/3 octave band analysis, with no weighting (in dBLin), and down to the lowest limiting frequency permitted by the equipment at hand. If spectral analysis is not possible, then at least dBC and/or dBLin Leq measurements should be performed. In this way, not only is the acoustical environment documented for future legal and forensic purposes, but the adequate protection and prevention measures can be taken if it is known how much, and what kind, of ILFN is present in the environment.

The same principle applies to biomedical studies, where ILFN is a possible contaminant. This is particularly true for animal studies where laboratories are kept in building basements, along with HVAC systems and elevator machinery. With human populations, it is important to obtain ILFN-exposure histories, since the effects of ILFN are cumulative (Castelo Branco et al., 1999d) and occur independent of whether the exposure was occupational, residential or leisurely. For example, an office worker may have no immediate exposure to noise on-the-job, but may live next to a bus terminal.

Control populations are especially targeted for comprehensive surveys of previous ILFN-exposure histories because, by definition, they *must not* have prior exposure to ILFN. Fetal and leisurely exposures to ILFN must be included in the individual's prior history of ILFN exposure (Castelo Branco et al., 2003a,g; Araujo et al., 2004). The inadequate selection of control populations has already led to wasteful uses of resources and, of course, misleading results (ASTDR, 2001). Given the ubiquitous nature of ILFN, control populations with zero prior ILFN exposure are extremely difficult to gather. Thus, it could be feasible to undertake studies where the bio-effects of ILFN-exposed populations are compared, but only if their acoustical exposures are sufficiently well documented, in terms of exposure times and acoustical spectra.

6.2. Dosimetry

Adequate dosimetry of ILFN will be very difficult to achieve until science considers the acoustical spectrum as analogous to the electromagnetic spectrum, i.e., different frequencies have different effects on the different tissues. Thus, breaking the (lower) acoustical spectrum into infrasound versus audible frequencies is much too rudimentary.

It is proposed that the ILFN (0-500 Hz) portion of the acoustical spectrum be divided into the sub-categories listed in Table 4. Biological tissue is very sensitive to lower frequencies, below 100 Hz. Specific frequencies have been known to have a deleterious impact on specific biological tissue (Nekhoroshev et al., 1991,1992; Svigovyi et al., 1987; Sidorenko et al., 1988, for example), and a 2 Hz exposure can produce different effects than an 8 Hz exposure (Nekhoroshev et al., 1991,1992). Dividing the acoustical spectrum in sub-categories would eventually force bioscientists to specify the acoustical energy within each specific sub-category

Table 4
Proposed subdivision of the lower portion (0-500 Hz) of acoustical spectrum, by 1/3 octave bands.

Sub Category	1/3 Octave Bands (Hz)*	Observations
A	0 - 6.3	6.3 Hz is often the lower limiting frequency of standard noise measuring equipment software.
B	8 - 12.5	Unusual behaviour in the frequencies of 8, 10 and 12.5 Hz has been detected, in residential, occupational and natural environments (unpublished results).
C	16 - 25	Overlapping the conventional threshold for human hearing (20 Hz).
D	31.5 - 63	Where many machine emit noise, includes the 50 Hz associated with high voltage electrical distribution.
E	63 - 160	Resonance of the thorax
F	200 - 500	Upper limit, with 250 Hz and 500 Hz already included in audiogram

evaluations.

*The 1/3 octave band analysis divides the acoustical spectrum into frequency bands, referred to by their central frequency. Thus, when measuring in 1/3 octave bands, values are obtained for the 1/3 octave frequency bands whose central frequency is, in Hz: 6.3, 8, 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400 and 500 (see Fig. 1). Hence, in this Table, the apparent discontinuities in the 1/3 Octave Bands column are due to the way in which science segments the acoustical spectrum.

One of the most immediate problems with adequately measuring ILFN is the lack of readily available (and relatively inexpensive) instrumentation. As is well known, much of the monitoring equipment designed to assess physical agents is geared toward assessing the parameters that have been established by legislation. Thus, it is difficult (or much too expensive) to acquire the instrumentation that could adequately measure how long the acoustical energy remains at a certain dB level, for each 1/3 octave band. This would be an ideal parameter for assessing ILFN-induced pathology.

With animal models, some form of ILFN-exposure dosimetry has already been achieved. It is known that after a 48-hour continuous exposure to ILFN, it is necessary 7 days for full recovery (Castelo Branco et al., 2003f). However, large scale epidemiological studies are still lacking, mostly due to the difficulty of selecting adequate control populations, and funding.

6.3. Pharmacological intervention

With the integration of the tensigrity cellular model, VAD can now be viewed as a mechanotransduction disease *par excellence*. As such, new avenues of research have opened up regarding the possibility of pharmacological intervention. Since actin- and tubulin-based structures seem to be the most affected, it would make sense to focus on these biomechanical elements in order to avoid irreversible damage to individuals who *must* remain in ILFN environments for extended periods of time, such as ship and submarine workers, offshore oil and gas platforms workers, human activity onboard spacecraft, and the general population who is environmentally exposed to ILFN in the home.

6.4. Diagnosing vibroacoustic disease

For the purposes of an informal diagnosis, an echocardiogram to evaluate pericardial and cardiac valve thickening is essential to establish a VAD diagnosis because pericardial thickening with no diastolic dysfunction, and in the absence of an inflammatory process is a specific sign of VAD (Holt, 2000). However, given the limitations of echo-imaging procedures (discussed above) the echocardiogram is insufficient for legal and forensic purposes. Thus, if legal proof of VAD is required, then a more invasive procedure is necessary – the bronchoscopic examination (Reis Ferreira et al., 2006).

Other complementary diagnostic tests include brainstem auditory evoked potentials and cognitive evoked potentials (P300), brain magnetic resonance imaging, PCO_2 rebreathing test, blood coagulation factors and a thorough neurological examination.

Suspicion of VAD should arise if the patient exhibits one or more of the following complaints:

- "I hear too much, I'm very sensitive to noise, I can't stand any type of noise, Noise drives me crazy, Whenever there's a loud noise, all I feel like doing is screaming";

- "I wake up tired, It's not that I don't sleep enough hours, it just seems like I don't rest during my sleep";
- "Sometimes, while in a shopping mall or a restaurant, I feel like I can't breath, like I must get out of there or else";
- "I have a lot of heart palpitations, Sometimes it feels like my heart is going to leap out of my chest";
- "I have this cough, and I don't smoke, My throat is constantly irritated and I get hoarse for no reason, The over-the-counter medication doesn't do anything";

Or if the patient enters with one of the following diagnosis:

- Late-onset epilepsy;
- Balance disorders;
- Migraine;
- Respiratory tract tumour, especially if a non-smoker;
- Recommendation for cardiac bypass surgery;
- Auto-immune disease, particularly systemic lupus erythematous and vitilligo;

The authors urge physicians to listen to their patients and question them about their noise exposures.

References

Águas, A.P., Esaguy, N., Castro, A.P., Grande, N.R., Castelo Branco, N.A.A., 1999a. Acceleration of lupus erythematosus-like processes by low frequency noise in the hybrid NZB/W mouse model. Aviat. Space Environ. Med., 70 (March, Suppl), A132-6.

Águas, A.P., Esaguy, N., Castro, A.P., Grande, N.R., Castelo Branco, N.A.A., 1999b. Effect low frequency noise exposure on BALB/C mice splenic lymphocytes. Aviat. Space Environ. Med., 70 (March, Suppl), A128-31.

Albuquerque e Sousa, J., Dinis da Gama, A., Macedo, M. V., Cassio J., Castelo Branco N.A.A., 1991. Carotid angiodynographic studies in individuals occupationally exposed to noise and vibration. Aviat. Space Environ. Med., 62, 134. (Abstract)

Alenghat F.J., Nauli S.M., Kolb R., Zhou J., Ingber, D.E., 2004. Global cytoskeletal control of mechanotransduction in kidney epithelial cells. Exp. Cell. Res., 301, 23-30.

Alvarez, M., Taborda, F., Gomes, L., Marçal, C., Soutenho, A., Marmelo, J., Castelo Branco, N.A.A., 1993. Epidemiology of on-the-job accidents at OGMA. Rev. Port. Med. Mil., 4, 35-40. (In Portuguese)

Alves-Pereira, M., 1999. Extra-aural noise-induced pathology. A review and commentary. Aviat. Space Environ. Med., 70 (March, Suppl), A7-21

Alves-Pereira, M., Castelo Branco, M.S.N., Motylewski, J., Pedrosa, A., Castelo Branco, N.A.A., 2001a. Airflow-induced infrasound in commercial aircraft. Proceedings of Internoise 2001, The Hague, Holland, pp. 1011-14.

Alves-Pereira, M., Castelo Branco, N.A.A., 2003a. Ciliated cells, cochlear cilia and low frequency noise. Proceedings of the 8th International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 366-367.

Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2003b. Pericardial biomechanical adaptation to low frequency noise stress. Proceedings First International Meeting on Applied Physics, Badajoz, Spain, No. 354 (6 pages).

Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2003c. Actin and tublulin-based structures under low frequency noise stress. Proceedings First International Meeting on Applied Physics, Badajoz, Spain, No. 355 (5 pages).

Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2003d. Low frequency noise exposure and biological tissue, reinforcement of structural integrity? Proceedings First International Meeting on Applied Physics, Badajoz, Spain, No. 356 (6 pages).

Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2004a. Low frequency noise in trains. Proceedings of Internoise 2001, Prague, Czech Republic, No. 643 (5 pages)

Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2004b. Public transportation and low frequency noise, a health hazard? Proceedings of the Eleventh International Congress on Sound and Vibration, St. Petersburg, Russia, pp. 1761-1766

Alves-Pereira, M., Joanaz de Melo, J., Marques, M.C., Castelo Branco, N.A.A., 2004c. Vibroacoustic disease – the response of biological tissue to low frequency noise. Proc. 11th International Meeting on Low Frequency Noise, Vibration and its Control. Maastricht, The Netherlands, 30Aug-1Sep, 2004, 295-308.

Alves-Pereira, M., 2005. ...And again low frequency noise - A possible solution. Proceedings of the 12th International Congress on Sound & Vibration, Lisbon, Portugal, No. 584 (8 pages).

Araujo, A., Ribeiro, C.S., Correia, M.J.F., Pais, F., Castelo Branco, N.A.A., 1989. Echocardiographic appearances in patients with the whole-body noise and vibration disease. MEDICEF- Direct Information (France), 2, 101-2.

Araujo, A., Pais, F., Lopo Tuna, J.M.C., Alves-Pereira, M., Castelo Branco, N.A.A., 2001. Echocardiography in noise-exposed flight crew. Proceedings of Internoise 2001, The Hague, Holland, 1007-10.

Araujo, A., Alves-Pereira, M., Joanaz de Melo, J., Castelo Branco, N.A.A., 2004. Environmentally-induced vibroacoustic disease in a suburban family. Proceedings of the Eleventh International Congress on Sound and Vibration, St. Petersburg, Russia, pp. 1767-1774.

Arnot, J.W., 2003. Vibroacoustic disease I, The personal experience of a motorman Institute of Acoustics (U.K.), 25(Pt 2), 66-71.

ATSDR-Agency for Toxic Substance and Disease Registry (USA), 2001. Expert review of the Vieques heart study. Summary report for the Vieques heart study expert panel review. Contract No. 200-2000-10039 www.atsdr.cdc.gov/NEWS/viequesheartreport.html.

Bento Coelho, J.L., Ferreira, A., Serrano, J., Taborda, F., Castelo Branco, N.A.A., 1994. Noise exposure in the aeronautical industry. Proceedings of Internoise 1994, Yokohama, Japan, pp. 741-5

Calverly, P.M.A., 1999. Control of breathing. In, Hughes, J.M.B., Pride, N.B. (Eds.), Lung function tests. Physiological priniciples and clinical applicatrons. WB Saunders, London.

Campanella, A., 2001. What you can't hear won't hurt you. The Kokomo Perspective (Indiana, USA), October 17th, 1-3.

Carmo, G., Albuquerque e Sousa J., Dinis da Gama, A., Castelo Branco, N.A.A., 1992 Carotid angiodynographic studies in helicopter pilots. Aviat. Space Environ. Med., 63, 385. (Abstract)

Canas, J., Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1993. ERP P300 and MRI studies of the CNS in military pilots, A comparative study of early degenerative brain processes. Aviat. Space Environ. Med., 64, 451. (Abstract)

Castelo Branco, M.S.N., Castelo Branco, N.A.A., Entrudo, A., Marvão, J., 1985. A standardization method of the brainstem auditory evoked potentials. J. Soc. Ciências Med. Lisboa, 149, 214-20. (In Portuguese)
*Recipient of the National Ricardo Jorge Public Health Award, 1985

Castelo Branco, N.A.A., 1992. The whole-body noise and vibration syndrome. Rev Port. Med. Mil., 40, 16.

Castelo Branco, N.A.A., 1999a. The clinical stages of vibroacoustic disease. Aviat Space Environ. Med., 70 (3, Suppl), A32-9.

Castelo Branco, N.A.A., 1999b. A unique case of vibroacoustic disease. A tribute to an extraordinary patient. Aviat. Space Environ. Med., 70 (3, Suppl), A27-31.

Castelo Branco, N.A.A., Martinho Pimenta, A.J.F., 1995. The basic clinical and pathophysiological aspects of the vibroacoustic syndrome. Aviat. Space Environ Med., 66, 504. (Abstract)

Castelo Branco, N.A.A., Águas, A.P., Sousa Pereira, A., Monteiro, E., Fragata, J.I.G., Grande, N.R., 1996. The pericardium in the vibroacoustic syndrome. Cardiovas. Diag. Prog., 13(4), 284. (Abstract)

Castelo Branco, N.A.A., Rodriguez Lopez E., 1999a. The vibroacoustic disease – An emerging pathology. Aviat. Space Environ. Med., 70 (March, Suppl), A1-6.

Castelo Branco, N.A.A., Águas, A.P., Sousa Pereira, A., Monteiro, E., Fragata, J.I.G., Tavares, F., Grande, N.R., 1999b. The human pericardium in vibroacoustic disease. Aviat. Space Environ. Med., 70 (3, Suppl), A54-62.

Castelo Branco, N.A.A., Alves-Pereira, M. (Coords.), 1999c. Vibroacoustic disease. Aviat. Space Environ. Med., 70 (March, Suppl), A1-154.

Castelo Branco, N.A.A., Rodriguez Lopez, E., Alves-Pereira, M., Jones, D.R., 1999d. Vibroacoustic disease, some forensic aspects. Aviat. Space Environ. Med., 70 (3, Suppl), A145-51.

Castelo Branco, N.A.A., Alves-Pereira, M., Martins dos Santos, J., Monteiro, E., 2003a. SEM and TEM study of rat respiratory epithelia exposed to low frequency noise. In, Mendez-Vilas A. (Ed.), Science and Technology Education in Microscopy, An Overview. Formatex, Badajoz, Spain, Vol. II, pp. 505-33.

Castelo Branco, N.A.A., Martinho Pimenta, A.J., Reis Ferreira, J., Alves-Pereira, M. 2003b. Monitoring vibroacoustic disease. Proceedings of the Scuola Superiore. G. Reiss Romoli-Telecom Italia (SSGRRw), L'Aquila, Italy, No. 102, 5 pages. http://www.ssgrr.it/en/ssgrr2003w/papers/129.pdf.

Castelo Branco, N.A.A., Fragata, J.I., Martins, A.P., Monteiro, E., Alves-Pereira, M., 2003c. Pericardial cellular death in vibroacoustic disease. Proceedings of the 8[th] International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 376-377.

Castelo Branco, N.A.A., Monteiro, E., Martins dos Santos, J., Alves-Pereira, M., 2003d. Low frequency noise and intra-cellular edema. Proceedings of the 8[th] International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 378-9.

Castelo Branco, N.A.A., Monteiro, E., Costa e Silva, A., Reis Ferreira, J., Alves-Pereira, M., 2003e. Respiratory epithelia in Wistar rats. Rev. Port. Pneumol., IX, 5, 381-88.

Castelo Branco, N.A.A., Gomes-Ferreira, P., Monteiro, E., Costa e Silva, A., Reis Ferreira, J., Alves-Pereira, M., 2003f. Respiratory epithelia in Wistar rats after 48 hours of continuous exposure to low frequency noise. Rev. Port. Pneumol., IX, 6, 473-479.

Castelo Branco, N.A.A., Monteiro, E., Costa e Silva, A., Reis Ferreira, J., Alves-Pereira, M., 2003g. Respiratory epithelia in Wistar rats born in low frequency noise plus varying amounts of additional exposure. Rev. Port. Pneumol., IX, 6, 481-492.

Castelo Branco, N.A.A., Alves-Pereira, M., 2004a. Vibroacoustic disease. Noise & Health Vol 6 (23), 3-20.

Castelo Branco, N.A.A., Fragata, J.I., Monteiro, E., Alves-Pereira, M., 2004b. Pericardial cellular death in vibroacoustic disease patients. Proceedings of the 11th International Congress on Sound & Vibration, St. Petersburg, Russia, 1753-1760.

Castelo Branco, N.A.A., Fragata, J.I., Martins, A.P., Monteiro, E., Alves-Pereira, M., 2005. The pericardium in vibroacoustic disease I -- Morphological features. Proceedings of the 12th International Congress on Sound & Vibration, Lisbon, Portugal, July 11-14, 2005, No. 568 (9 pages).

Castro, A.P., Aguas, A.P., Grande, N.R., Monteiro, E., Castelo Branco, N.A.A., 1999. Increase in CD8+ and CD4+ T lymphocytes in patients with vibroacoustic disease. Aviation, Space and Environmental Medicine, 70 (3, Suppl), A141-4.

Cortez-Pimentel J.A.B., Castelo Branco, N.A.A., 1988. Systemic vibration disease VII, the dento-alveolar structure. Rev. Port. Med. Mil., 36 (1), 123-27. (In Portuguese, Abstract in English)

Cotes, J.E., 1993. Lung function. Assessment and applications in medicine. Blackwell Scientific Publishing, London, pp. 376.

Crespo, F., Ferreira A.C.N., Castelo Branco M.S.N., Castelo Branco N.A.A., 1988. Systemic vibration disease III, coagulation and hemostasis study in patients with this disease. Rev. Port. Med. Mil., 36, 86-9. (In Portuguese, Abstract in English)

Cruz Mauricio, J., Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1988. Systemic vibration disease IV, central nervous system imaging through magnetic resonance. Rev. Port. Med. Mil., 36, 90-96. (In Portuguese, Abstract in English.)

European Communities, 2000. The noise policy of the European Union – Year 2. Luxembourg.
http://europa.eu.int/comm/environment/noise/pdf/noisebrochure.pdf

Fonseca, J., Mirones, J., Martins dos Santos, J., Alves-Pereira, M., Castelo Branco, N.A.A., 2005. Gastrointestinal problems in vibroacoustic disease. Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, 2005, No. 577 (8 pages).

Fuller, R.B., 1975. Synergetics. Macmillan, New York.

Gibson, G.J., 1996. Clinical tests of the respiratory function. Chapman & Hall Medicine, London, pp. 101-109.

GIMOGMA*, 1984a. Epilepsy of vascular aetiology, a clinical picture of vibration disease? Rev. Port. Med. Mil., 32, 5-9. (In Portuguese)

*GIMOGMA – Grupo de Investigação Médica das OGMA – was the acronym for the medical research team that began its activity at OGMA, and that today is represented by the Center for Human Performance.

GIMOGMA, 1984b. Evoked potential study in a population exposed to occupational vibration. Rev. Port. Med. Mil., 32, 10-16 . (In Portuguese)

GIMOGMA, 1984c. Vibration and noise as the cause of acoustic hypo- and hyper-sensibility in an industrial population. Rev. Port. Med. Mil., 32, 17-20. (In Portuguese)

Grande, N., Águas, A.P., Sousa Pereira, A., Monteiro, E., Castelo Branco, N.A.A., 1999. Morphological changes in the rat lung parenchyma exposed to low frequency noise. Aviat. Space Environ. Med., 70 (3, Suppl), A70-7

Holt, B.D., 2000. The pericardium. In, Furster, V., Wayne Alexander, R., Alexander, (Eds). Hurst's The Heart. McGraw-Hill Professional Publishing, New York, pp. 2061-82

Ingber, D.E., 2003. Mechanobiology and diseases of mechanotransduction, Ann. Med., 35, 1-14.
http://web1.tch.harvard.edu/research/ingber/homepage.htm

Ingber, D.E., 2004a. Mechanochemical basis of cell and tissue regulation. N.A.E. Bridge, 34(3), 4-10.
http://www.nae.edu/NAE/bridgecom.nsf/weblinks/MKEZ65RHQL?OpenDocument

Ingber, D.E., 2004b. In, Fliesler, N. The mechanical cell. Children's Dream Magazine. http://www.childrenshospital.org/research/Site2029/mainpageS2029P23sublevel24.html

Jones, R.N., Turner-Warwick, M., Ziskind, M., Weill, H., 1976. High prevalence of antinuclear antibodies in sandblasters' silicosis. Am. Rev. Resp. Dis., 113, 393-95.

Lippmann, M., Eckert, H.L., Hahon, N., Morgan, W.K.C., 1973. Circulating antinuclear and rheumatoid factors in coal miners. A prevalence study in Pennsylvania and West Virginia. Ann. Int. Med., 79, 807-11.

Marciniak, W., Rodriguez, E., Olsowska, K., Botvin, I., Araujo, A., Pais, F., Soares Ribeiro, C., Bordalo, A., Loureiro, J., Prazeres de Sá, E., Ferreira, D., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999. Echocardiography in 485 aeronautical workers exposed to different noise environments. Aviat. Space Environ. Med., 70 (3, Suppl), A46-53.

Martinho Pimenta, A.J.F., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999a. The palmo-mental reflex in vibroacoustic disease. Aviat. Space Environ. Med., 70 (3, Suppl), A100-6.

Martinho Pimenta, A.J.F., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999b. Balance disturbances in individuals with vibroacoustic disease. Aviat. Space Environ. Med., 70 (3, Suppl), A96-99

Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1999c. Facial dyskinesia induced by auditory stimulation. A report of four cases. Aviat. Space Environ. Med., 70 (3, Suppl), A119-21).

Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1999d. Epilepsy in vibroacoustic disease - A case report. Aviat. Space Environ. Med., 70 (3, Suppl), A122-7

Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1999e. Facial dyskinesia induced by auditory stimulation. A report of four cases. Aviat. Space Environ. Med., 70 (3, Suppl), A119-21.

Martinho Pimenta, A.J.F., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999f. The palmo-mental reflex in vibroacoustic disease. Aviat. Space Environ. Med., 70 (3, Suppl), A100-6.

Martinho Pimenta, A.J.F., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999g. Balance disturbances in individuals with vibroacoustic disease. Aviat. Space Environ. Med., 70 (3, Suppl), A96-9.

Martins dos Santos, J., Grande, N.R., Castelo Branco, N.A.A., Zagalo, C., Oliveira, P., 2002. Vascular lesions and vibroacoustic disease. Eur. J. Anat., 6(1), 17-21.

Martins dos Santos, J., Grande, N.R., Castelo Branco, N.A.A., Zagalo, C., Oliveira, P., Alves-Pereira, M., 2004. Lymphatic lesions in vibroacoustic disease. Eur. J. Lymphology, 12(40), 13-16.

Martins dos Santos, J., Albuquerque e Sousa, A., Marques, M.C., Monteiro, E., Alves-Pereira, M., Castelo Branco, N.A.A., 2005. Urinary system in vibroacoustic disease – Current findings and ongoing studies. Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, No. 578 (8 pages).

Marvão, J.H., Castelo-Branco, M.S.N., Entrudo, A., Castelo Branco, N.A.A., 1985. Changes of the brainstem auditory evoked potentials induced by occupational vibration. J. Soc. Ciências Med., 149, 478-486. (In Portuguese)

Matsumoto, Y., Kawabe, M., Yasue, T., Yuguchi, M, Yoshida, I., 1989. Two cases of scleroderma associated with vibration syndrome. Jap. J. Dermatology, 99, 155-61.

Matsumoto Y, Yasue T, Mizuno N & Yoshida I., 1992. An immunoserological study of patients with vibration syndrome. Occupational & Environmental Health, 63, 357-9.

Matthews, B.D., Overby, D.R., Alenghat, F.J., Karavitis, J., Numaguchi, Y., Allen P.G., Ingber D.E., 2004. Mechanical properties of individual focal adhesions probed with a magnetic microneedle. Biochem. Biophys. Res. Comm., 313, 758–764.

Mendes, A., Alves-Pereira, M., Castelo Branco, N.A.A., Silva, J., Pires, F., 2005. Vibroacoustic disease and voice acoustics analysis. Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, No. 62 (9 pages).

Mendes, C.P., Reis Ferreira, J., Alves-Pereira, M., Castelo Branco, N.A.A., 2004. Respiratory pathology in vibroacoustic disease I – Tumours. Proceedings Noise & Transport 2004, St. Petersburg, Russia, No. s3-4 (5 pages).

Mendes, A., Alves-Pereira, M., Castelo Branco, N.A.A., Silva, J., Pires, F., 2006. Voice acoustic patterns of patients diagnosed with vibroacoustic disease. Rev. Port. Pneumol. (In press).

Moniz Botelho, J., Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1988. Systemic vibration disease V, P300 and brain mapping. Rev. Port. Med. Mil., 36, 97-115. (In Portuguese, Abstract in English.)

Monteiro, M.B., Reis Ferreira, J., Mendes, C.P., Alves-Pereira, M., Castelo Branco, N.A.A., 2004. Vibroacoustic disease and respiratory pathology III – Tracheal and bronchial lesions. Proceedings Internoise 2004, Prague, Czech Republic, August 22-25, No. 638 (5 pages).

Nekhoroshev, A.S., Glinchikov, V.V., 1991. Effect of infrasound on morphofunctional changes in myocardium exposed to infrasound. Gig. Sanit., 12, 56-8. (In Russian, Abstract in English)

Nekhoroshev, A.S., Glinchikov, V.V., 1992. Morphological research on the liver structures of experimental animals under the action of infrasound. Aviakosm. Ekolog. Med., 26, 56-9. (In Russian, Abstract in English)

Oliveira, M.J.R., Sousa Pereira, A., Águas, A.P., Monteiro, E., Grande, N.R., Castelo Branco, N.A.A., 1999. Effects of low frequency noise upon the reaction of pleural milky spots to mycobacterial infection. Aviat. Space Environ. Med., 70 (March, Suppl), A137-40.

Persson-Waye, K., Rylander, R., 2001. The prevalence of annoyance and effects after long-term exposure to low frequency noise. J. Sound Vib., 240(3), 483-97.

Pimenta, A.J.F., Castelo-Branco, N.A.A., Manaças, J.E., Brito, J.L.R., Martins, A.S., 1988. Systemic vibration disease II, clinical elements. Rev. Port. Med. Mil., 36 (2/3), 72-85. (In Portuguese, Abstract in English)

Reis Ferreira, J., Mendes, C.P., Antunes, M., Martinho Pimenta, A.J.F., Monteiro, E., Alves-Pereira, M., Castelo Branco, N.A.A., 2003a. Diagnosis of vibroacoustic disease – preliminary report. Proceedings 8th International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 112-114.

Reis Ferreira, J., Mendes, C.P., Castelo Branco, N.A.A., Monteiro, E., Alves-Pereira, M., 2003b. The human trachea in vibroacoustic disease. Proceedings 8th International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 388-389.

Reis Ferreira, J., Mendes, C.P., Castelo Branco, N.A.A., Monteiro, E., Alves-Pereira, M., 2003c. The human lung and pleura in vibroacoustic disease. Proceedings 8th

International Congress of Noise as a Public Health Problem, Rotterdam, Holland, 386-387.

Reis Ferreira, J., Mendes, C.P., Alves-Pereira, M., Castelo Branco, N.A.A., 2005. Respiratory pathology in vibroacoustic disease I – Current findings. Proceedings 12th International Congress on Sound & Vibration, Lisbon, Portugal, No. 571 (7 pages)

Reis Ferreira, J., Monteiro, M., Tavares, F., Serrano, I., Monteiro, E., Mendes, C.P., Alves-Pereira, M., Castelo Branco, N.A.A., 2006. Involvement of central airways in vibroacoustic disease patients. Rev. Port. Pneumol. (Accepted for publication)
*Recipient of the 2005 Annual Award of the Portuguese Lung Association.

Rosado, P., Martinho Pimenta, A.J.F., Castelo Branco, N.A.A., 1993. The vibroacoustic syndrome IV. Facial dyskinesia induced by auditory stimulation. Aviat. Space Environ. Med., 64, 451. (Abstract).

Sandars, N.K., 1972. The epic of Gilgamesh. Peguin Books, London.

Shabetai, R., 1994. Diseases of the pericardium. In, Schlant, R.C., Wayne Alexander, R. (Eds.), Hurst's The Heart, arteries and veins. McGraw-Hill, New York, pp. 1547-1649

Sidorenko, I.I., Zelikman, M.K., Kaplina, A.V., 1988. Changes in eye tissues exposed to local action of infrasound. Oftalmol. Zh., 2, 109-11. (In Russian)

Silva, M.J., Carothers, A., Castelo Branco, N.A.A., Dias, A., Boavida, M.G., 2002a. Increased levels of sister chromatid exchanges in military aircraft pilots. Mut. Res Gene. Toxicol. Environ. Mutagen., 44(1), 129-34.

Silva, M.J., Dias, A., Barreta, A., Nogueira, P.J., Carothers, A., Castelo Branco, N.A.A., Boavida, M.G., 2002b. Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice. Teratogen. Carcinogen. Mutagen., 22(3), 195-203.

Silva, M.J., Carothers, A., Castelo Branco, N.A.A., Dias, A., Boavida, M.G., 1999. Sister chromatid exchanges workers exposed to noise and vibration. Aviat. Space Environ. Med., 70 (3, Suppl), A40-5 (1999).

Sousa Pereira, A., Grande, N.R., Castelo Branco, N.A.A., 1999a. The effect of low frequency noise on rat tracheal epithelium. Aviat. Space Environ. Med., 70 (3, Suppl), A86-90.

Sousa Pereira, A., Grande, N.R., Castelo Branco, M.S.N., Castelo Branco, N.A.A., 1999b. Morphofunctional study of rat pleural mesothelial cells exposed to low frequency noise. Aviat. Space Environ. Med., 70 (3, Suppl), A78-85.

Soutar, C.A., Turner-Warwick, M., Parkes, W.R., 1974. Circulating antinuclear antibody and rheumatoid factor in coal penumoconosis. Brit. Med. J., 3, 145-7.

Svigovyi, V.I., Glinchikov, V.V., 1987. The effect of infrasound on lung structure. Gig. Truda. Prof. Zabol., 1, 34-7 (In Russian, Abstract in English)

Torres, R., Tirado, G., Roman, A., Ramirez, R., Colon, H., Araujo, A., Pais, F., Marciniak, W., Nóbrega, J., Bordalo e Sá, A., Lopo Tuna, J.M.C., Castelo Branco, M.S.N., Alves-Pereira, M., Castelo Branco, N.A.A., 2001. Vibroacoustic disease induced by long-term exposure to sonic booms. Proceedings Internoise 2001, The Hague, Holland, 1095-98.

Van Zeller, P., Oliveira, F.C., Tavares, C., Freitas, A.M., Castelo Branco, N.A.A., 1988. Systemic vibration disease VI, retinal angiography. Rev. Port. Med. Mil., 36 (2/3), 117-125. (In Portuguese, Abstract in English).

von Gierke H, Mohler S., 2002. Letter to the editor, vibroacoustic disease. Aviat. Space Environ. Med., 73(8), 828-30.

Wang, N., Butler, J.P., Ingber, D.E., 1993. Mechanotransduction across the cell surface and through the cytoskeleton. Science (in Reports), New Series, 260(5111), 1124-1127.

Ward, W.D., 1973. Noise-induced hearing damage. In, Paparella, M.M., Shumrick, D.A., (Eds.) Otolaryngology. W. B. Saunders Co., Philadelphia, PA.

World Health Organization, 1999. Guidelines for Community Noise. Berglund, B., Lindvall, T., Schwela, D.H. (Eds).
http://www.who.int/docstore/peh/noise/guidelines2.html

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1. VIBROACOUSTIC DISEASE I – THE PERSONAL EXPERIENCE OF A MOTORMAN.

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A first-hand account of the development of vibroacoustic disease (VAD) in a 39-year-old motorman is provided. Employed for 10 years for a roll on roll off ferry operator sailing to the Hebridean Islands off the West Coast of Scotland, he was extensively exposed to low frequency noise (LFN) which led to the development of VAD. The progression of symptoms is described until the author's early disability retirement. The cost of VAD in this individual's life is evaluated. The problem affecting workers' health and employers' pockets is staggering, and there is an urgent need to implement measures that will protect young workers from developing LFN-induced disabilities. The costs associated with possible VAD-related sick leave are discussed as well as the social costs to the workers and their families. LFN is not yet recognized as an agent of disease, nor is VAD a proscribed illness in the U.K.

VIBROACOUSTIC DISEASE I: THE PERSONAL EXPERIENCE OF A MOTORMAN

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1 INTRODUCTION

The aim of this paper is to provide a first-hand account of the development of vibroacoustic disease (VAD) in a motorman. I will describe the physical changes and the various costs incurred during the last five years of my professional activity, as I gradually became ill with VAD. My story is not an isolated case. In fact, VAD may be the cause of long term limiting illnesses in a large number of people who live and work in environments rich in low frequency noise (LFN) (≤ 500 Hz, including infrasound) [1].

Research indicates that the number of affected workers may be significant. Based on my personal experience, I am convinced that if protective solutions were to be implemented, an appreciable improvement would be seen in the number of workers who are off work due to sickness and incapacity. By revealing the cost of illness, I hope to emphasize the need for those exposed to LFN-rich environments to be informed of the risks involved and to be given a list of early symptoms. This would allow them to make their own choices and seek help before permanent and irreversible damage sets in.

VAD is caused by an all-pervading and insidious agent of harm - LFN. Unless the patient is aware of the early symptoms, VAD is difficult to recognize until it is too late; especially since it has not yet reached the mainstream general practitioners, nor the occupational medicine professionals. The sheer number of workers that are possibly being affected by LFN exposure will stress the importance of developing and applying solutions against this agent of disease.

2 CASE HISTORY

2.1 Employment

At the age of 17, I left school and became apprenticed to an engineering company. Eventually, after thirteen years of working as a land-based mechanic, I was hired as a motorman for a roll on roll off ferry operator sailing to the Hebridean Islands off the West Coast of Scotland. My job description consisted of performing maintenance on running medium speed diesel engines, and involved working in ship's engine rooms and machinery spaces. The usual onboard schedule was twelve hours a day, seven days per week, for periods of three weeks followed by two weeks at home in rotation.

From my Department of Transport, Seamen's Discharge Book, no. UK 092704, I worked onboard seven different vessels for nearly ten years, and was exposed to a total of 38,640 hours of LFN-rich environments. This amount of hours would be achieved in approximately 15 to 18 years of normal shore-side employment. However, crew members live onboard ships and are therefore continuously exposed to LFN-rich environments, even during their break and sleep periods.

2.2 Personal Information

On January 15th, 2001, I was a 39 year old motorman, married and with two young children, and who had just been signed off sick from work. I have never smoked, never taken recreational drugs and I rarely drink alcohol and never to excess. I have no history of cardiovascular disease, hypertension, nor diabetes. My hobbies are local history, motor boating, swimming and do-it-yourself home improvements. I also used to enjoy cycling and hill walking. My residential environments have always been in rural parts of Britain, far from any sources of LFN.

My medical history was unremarkable. I had worked since leaving school without break, and without significant periods of sick leave, apart from a case of acute tonsillitis during which I was signed off work for a month.

2.3 From Early Warning Signs to Disabling Pathology

Within the first few years I noticed that the hearing in my right ear was much worse than in my left. For example, when I was in the engine room I could lift the ear protector off my right ear and hear virtually nothing from the roar of the main engines; if I lifted the left ear protector the noise was actually painful. The engine room was very noisy and our main concern at the time was for the pain that the main engine vibration was causing to our feet and knees. After three years the knee pain became permanent.

After approximately four years of professional activity in ships engine rooms, I began to experience what I now know to be the early stages of VAD. I began to feel what I imagine to be 'hangover' symptoms. I considered this to be particularly unfair since these symptoms appeared without my having incurred in any of the behaviors that normally cause hangovers. When off the ship, I experienced increased bowel urgency and frequency. Also at around the same time, after working very closely with the main engines for a whole three week period, I experienced extra heart beats, or flutters (tachycardia). I was sent to a Cardiologist for investigations by which time my complaint had resolved itself and no further investigations were made.

I began to have panic attacks while sleeping, and awoke abruptly, jumping up to catch my breath. I also experienced broken sleep due to burning and pins & needles sensations in my hands, later diagnosed as bilateral Carpal Tunnel Syndrome, and associated with holding vibrating equipment. Fatigue was slowly beginning to settle in. Bouts of depression began appearing, and with time became more frequent. My family noticed changes in my mood and complained that I was becoming less and less sociable. I developed a short-tempered disposition and felt more irritable.

There was an increasing pain and burning sensations in both of my knees. I lost muscle mass from around my knees. My legs became weaker and I began to have to climb stairs on all fours. At times my vision would blur, both at home and onboard ship. I noticed that I could not tolerate bright light. I used to experience a dry, tickly cough while on board the ship, and I found I was less able to fight off minor infections. All of us found that we had small nose bleeds and congested nasal passages, along with a dry irritating cough, but only while onboard ship. We thought it was caused by air dryness. Coughing often started roughly half an hour after being in the engine room. We all found this a problem and lived on cough medicine and vitamin tablets. Often the only way to stop coughing would be by thumping myself on the chest as hard as could, like an ape beating it's chest.

Areas of numbness and over-sensitivity appeared in different places on my skin. I noticed muscle twitches and spasms in my spine, and I hurt my back more easily. I was unable to control my stomach muscles as they would tighten so much by themselves that I had difficulty in breathing. When I came home from sea I couldn't bear my children running up to hug me as my stomach muscles were so painful, even before the appearance of an umbilical hernia. I developed an increased need to urinate and always felt that I had not completely emptied my bladder. Impotence developed. Noise and crowds became intolerable. Depression set in more permanently.

After about 7 years of occupational exposure, I began to notice a perverse behaviour: I would catch myself making the wrong decision, such as opening the wrong valve or switching the wrong switch. It wasn't that I would forget to do the right thing, but I actually became convinced that I had done the correct thing. I had already witnessed this behaviour among many of the older crew-members with whom I had worked: they would draw attention to themselves by making the wrong choice, i.e., deliberately setting off fire alarms and then claiming they didn't remember, or denying they had caused the entire event.

Muscle twitches, spasms and muscle tightening became more severe and lasted for longer periods of time, often spanning whole weeks going from attack to attack. Usually, these symptoms subsided substantially during my shore leave, and two weeks at home allowed me to recovery sufficiently to return to another three weeks at sea.

In January 2001, I signed off sick with severe back pain and muscle spasms, and I have never returned to work since then. After seeing the Ferry Company doctor I was signed off unfit for duty at sea (ENG 3) with suspected spinal nerve damage. This medical condition was later excluded through the magnetic resonance imaging (MRI) tests.

Later in January 2001, I had an x-ray of the lower back showing Spondylolisthesis at L5. In February 2001, I had a private consultation with an Orthopaedic Consultant, and since nerve entrapment was suspected, a private MRI scan of my lower spine was taken in March 2001. In May 2001 I was given an ultra-sound scan of bladder at Oban hospital, showing that I was retaining urine. In August 2001 I received uro-dynamic tests at the Southern General Urology Department, which suggested that I might suffer from detrusor muscle instability, thus causing poor bladder control. Detrusitol was prescribed with limited success.

In December 2001, I underwent surgery for an umbilical hernia. It was not until after this surgery that all my health problems got worse. I suffered from increasingly broken sleep due to poor breathing and burning fingers related to carpal tunnel syndrome. My headaches became more and more severe. I noticed that I had real difficulty in concentrating for periods during the day. I suffered from daily fatigue attacks lasting three to four hours.

In October 2001, I had a consultation a Professor of Neurology, Dr. Ian Bone, from the Southern General Hospital, in Glasgow. After 16 months of tests, during which many medical conditions were excluded, such as spinal nerve damage and copper poisoning, Dr. Bone suggested that I might be suffering from VAD, as identified by Dr Nuno Castelo Branco and published on the British Medical Association's (BMA) Medline database[7]. Professor Bone arranged for a cranial MRI scan to search for possible brain lesions as seen in VAD.

2.4 The Value of a Formal Diagnosis

Desperate to find treatment for my debilitating symptoms, I found a large amount of information about VAD on the BMA Medline database. I posted a question about VAD on an Internet discussion forum and by good fortune I received an answer from one of the Portuguese experts who have been studying the effects of long-term exposure to LFN for more than twenty years, and who identified VAD. I was put in contact with the lead scientist of the VAD project, Dr. Nuno Castelo Branco.

My initial idea was to inquire about possible therapies that might be available. However, over email and without a full examination, any suggestions would be out of order. It was suggested that if I could travel to Portugal, I could be adequately examined and further advised. I traveled to Portugal and was given a wide range of physical examinations to determine whether or not I was suffering from VAD. The hallmark of VAD is pericardial thickening in the absence of an inflammatory process and with no diastolic dysfunction[3]. Echocardiography demonstrated that I had this condition. Other

VAD tests were also positive, and the team led by Dr. Nuno Castelo Branco formally diagnosed me with VAD.

I found there was great emotional value in simply meeting and talking with medical professionals who specialized in my illness and who understood what I was experiencing. I particularly found that once given a diagnosis demonstrating the cause of my symptoms, I could reassure myself that I was not going crazy. I had often been suspected of malingering, and was informed that this was not a unique situation, and many patients had been thus accused[1]. The social implications of being considered a malingerer, even on behalf of family members employed within the health industry, were quite demoralizing.

Without a diagnosis I was left in a no-man's-land where none of the medical specialists could suggest treatment. I felt I was left to see whether my symptoms developed further into an accepted illness, or if they would just resolve themselves with the passage of time. I suggest that this is a harmful practice in itself, since the individuals who are in need of help are powerless to help themselves, and the very people who should be able to help do nothing. I also believe that leaving people to wait on Incapacity benefit without a diagnosis of any sort is a dreadful waste of skills and experience.

It would be a much more efficient way to deal with workers who are incapacitated from their normal duties if, at the General Practice level, a simple decision could be taken to place the affected person onto a realistic retraining program while they await further tests and diagnosis. This would mean that the worker could find an alternative employment while waiting to find out what caused their ill health.

As my aim is to return to work and enjoy as normal a life as is possible, diagnosis is, of course, extremely valuable when approaching my doctors for treatment and therapy.

3 COST

3.1 Emotional and Social

Over the past two years, the cost to myself and my family in trying to find a diagnosis and treatment for my condition cannot be measured simply in terms of cash. Loss of self-esteem, and loss of standing in the eyes of my children and friends must also be taken into account. Social exclusion due to the lack of spending cash, and the emotional effect of the constant suggestion that I was just malingering are merely a few of the actual costs of falling ill with an occupational illness that is not yet proscribed in the UK.

I felt that doctors prejudged my case and assumed that I was either looking for a sick note to have time off work, or that I was trying to build a case to sue someone. Neither of which was anywhere near the truth, I simply could not afford to fall ill. What I truly wanted was to get treatment and get back to work as soon as possible. Today, having gone through the full circle and being in the process of returning to work as a self employed man, I feel that I have valid and pertinent questions regarding the effectiveness of the UK's system of dealing with people who are incapacitated from their usual employment.

When one marriage partner falls ill with a long term limiting illness such as that caused by VAD it naturally causes a great deal of stress between husband and wife. When, as with VAD, the illness is not proscribed, the stressors acting on the marriage relationship multiply. Stress multiplies because of things like: greatly reduced family income, prevention from claiming other benefits such as free prescriptions, doubts about the true illness of the debilitated partner i.e. whether they are as ill as they make out. These aspects, taken together with the physical debilitations described above, are a sure recipe to hinder a healthy relationship.

The information I have gathered among researchers and colleagues alike clearly indicate that my clinical, social and financial situation is very far from being a unique case.

3.2 Pounds and Pennies

A close estimate of the financial costs incurred by my family is in the region of £50,000, due to loss of earnings, retraining, actively seeking diagnosis, and the increased expenditure associated with ill health. I have been led to believe that the number of people employed in the transport industry that sign off sick from work is twice the national average. As a Rail Maritime & Transport Union representative, I have participated in negotiations concerning pay and working conditions. I and several others present at these meetings were told that because of the high rates of sickness in the Company (a thick wad of sick notes was waved at us from across the table), we could not hope to have the rise we asked for.

Studies to date suggest that as many as 70% of people exposed for long periods to LFN may develop severe stages of VAD. Approximately 30% of the individuals studied do not develop the acute pathology associated with low frequency noise exposure[1]. Studies show that as many as 50% of men occupationally exposed to LFN for more than ten years will develop permanent debilitating illnesses, eventually leading to early disability retirement[1].

The Confederation of British Industry (CBI) and the Chartered Institute of Personnel and Development (CIPD) estimated that the direct annual cost of sickness absence ranges from £434 to £486 per employee per year[4]. Total days of certified incapacity per year for men and women have risen from £503 million in the financial year 1990/91 to £856.8 million in the year 2000/01. Days of incapacity for men of my age (81.3 million days), with a possible 20 to 25 year exposure to occupational LFN, shows a 31 fold increase to that of men under 20 years of age (2.6 million days)[5]. In 2001/02, 26% (£27.6 billion) of the UK Social Security benefit expenditure was spent on the Sick and Disabled[6].

During my stay in Lisbon, VAD researchers informed me of their success story at O.G.M.A. (an aircraft manufacturing, maintenance and rework facility which belonged to the Portuguese Air Force), where the initial studies on VAD were conducted in the early 1980's[1]. From 1987 until 1997, an echocardiography monitoring program was established among all noise-exposed workers, mostly aircraft technicians. From 1980 to 1989, there were 21 disability retirements among this group of professionals. From 1989 to 1996 there were none[1]. Similarly, during this period of time, on-the-job accidents and incidents statistically significantly reduced, and absenteeism dropped from 8.5% to 2.3%[1]. By monitoring the evolution of LFN-induced pathology, workers were removed from the noisy job before their symptoms became disabling. Given their technical qualifications, it was fairly easy to place them in other, similar jobs but where exposure to LFN was not an issue. This was only possible because the company's administration decided to allow this sort of intervention, and later reaped its benefits.

3.3 Estimate Number of People Exposed to Noise and Vibration in the UK

Noise and vibration are intimately connected. The vibration of solids can produce acoustic phenomena (noise), and noise impacting on solids can produce structural vibration. However, in the vast majority of "noisy" occupational environments, noise (especially LFN) and vibration are present simultaneously. LFN is rarely assessed, but vibration levels have been the object of interest of several research teams throughout the world. Therefore, the results obtained from a recent survey of vibration exposure levels in the UK could be used as an approximate conservative estimate of the number of people exposed to the vibroacoustic agent of disease.

Questionnaires were sent out to a random selection of 21,201 men and women from 34 general practices from across the UK, and to a further 993 men and women selected at random from the

Armed services. During the Summer of 1997 and Winter of 1997/98, 12,907 usable responses (61% response rate) were returned. In a one-week period 7.2 million men and 1.8 million women are exposed to whole body vibration at work, if the occupational use of cars, vans and motorcycles is included. Results suggest that for all occupational sources of exposure, the personal estimated vibration dose value (eVDV) for about 374,000 men and 9000 women exceeds the action level vibration dose value of $15ms^{-1}$, as defined in British Standard 6841[7].

4 FINAL COMMENTARY

Today, I have successfully retrained as a self employed CORGI registered gas installer thereby largely avoiding noise and vibration. However, my VAD symptoms still interfere with my work. Specifically, after using any type of vibration tool, I have an episode, consisting of blurred vision, severe headaches, and an overall physical and psychological indisposition. My colleagues, and many workers in the UK, continue at risk of developing on-the-job VAD. Symptoms develop over years of professional exposure to LFN and are the cause of a large number of absences due to illness. VAD can be very disabling, and can crush an individual's social and family life. Because VAD is not yet mainstream among general practitioners, nor among occupational medicine professionals, VAD goes undiagnosed in the vast majority of the cases. In fact, malingering seems to be a more frequent diagnosis than any real pathological condition. Most workers are unaware that their symptoms are directly related to their occupational environments, and are suspiciously regarded by the surrounding community. The financial toll on the UK Social Security budget is immense, as well as on company budgets due to high levels of absenteeism. I urge the appropriate authorities to implement protective measures against LFN and to inform employees who are exposed to noise and vibration, so they will be able to protect themselves.

5 REFERENCES

1. N.A.A. Castelo Branco and M. Alves-Pereira (Coord), Vibroacoustic Disease, Aviation Space & Environmental Medicine, Vol 70 No 3, Section II, Supplement (1999).
2. N.A.A. Castelo Branco, The Clinical Stages of Vibroacoustic Disease, Unique Identifier 10189165, Medline Identifier 99203048.
3. B.D. Holt, The pericardium. In. V. Fuster , R. Wayne Alexander R, and F. Alexander (Eds). Hurst's The Heart, 10th ed, McGraw-Hill Professional Publishing, 2061-82. (2000).
4. C. Barham and J. Leonard, Trends and Sources of data on sickness absence, Labour Market Division, Office for National Statistics, www.statistics.gov.uk/cci/article.asp?id=723
5. Department for Work and Pensions, Sickness, Invalidity and Incapacity Benefit: Days of Certified Incapacity, www.statistics.gov.uk/statbase/expodata/spreadsheets/D3994.xls
6. Department for Work and Pensions, Figure 8.4, Social security benefit expenditure: by recipient group 2001/02, Great Britain, www.statistics.gov.uk/statbase/expodata/spreadsheets/D6474.xls
7. K.T. Palmer, D.N. Coggon, H.E. Bendall, and M.J. Griffin, Whole Body Vibration Occupational Exposures and their Health Effects in Great Britain. www.hse.gov.uk/research/crr_pdf/1999/CRR99233.pdf

Echocardiographic Evaluation in 485 Aeronautical Workers Exposed to Different Noise Environments

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Introduction: Vibroacoustic disease (VAD) is a heterogeneous and systemic entity, caused by long-term (≥10 yr) exposure to noise environments characterized by large pressure amplitude and low frequency (LPALF) (≥90 dB SPL, ≤500 Hz), and not explained by other possible etiologic agents. The goal of this study was to identify possible structural changes in hearts of men with suspected VAD. **Methods:** A total of 485 men were divided into 3 noise groups: no noise exposure (<70 dB), n = [illegible] (Group I); moderate noise exposure (>70 dB and <90 dB), n = 111 (Group II); and intense noise exposure (≥90 dB), n = [illegible] (Group III). Echo-Doppler studies were performed (HP SONOS). Data were recorded on videotapes. Three observers performed blinded evaluations of 26 echo Doppler parameters. For the purpose of the present study only 12 morphological parameters were compared among the groups: thickening of the mitral, aortic, tricuspid and pulmonary valves, pericardium and endocardium; mitral valve regurgitation, prolapse and ruptured chordae tendineae; and inflow velocities. Thickness and severity of the applicable parameters were scored on a semi-grade scale [illegible]. **Results:** All evaluated parameters were statistically significantly different in Group I vs. Group III, except flow velocity [illegible]. Comparison of Group I vs. Group II revealed statistically significant differences in mitral, aortic, tricuspid and pericardial thickening, with the strongest evidence for mitral and pericardial thickening. **Conclusions:** This confirms the results of previous studies. Occupational exposure to noise environments characterized by LPALF noise causes structural changes in the heart. Mitral valve and pericardial thickening constitute the first signs of VAD.

Keywords: noise, vibration, occupational, thickening, pericardium, mitral, tricuspid valve, aortic valve, endocardium.

VIBROACOUSTIC DISEASE (VAD) is a [illegible] organic and systemic entity, caused by long term (≥10 yr) exposure to noise environments characterized by large pressure amplitude and low frequency (LPALF) (≥90 dB SPL, ≤500 Hz), and not explained by other possible etiologic agents (4,5,9,14). Since 1987, attention has been paid to the echoimages in VAD patients. In previous echocardiography studies performed on VAD patients, 100% had thickening of some cardiac structure, with the vast majority presenting thickened pericardia and mitral valves (1,2,17).

In 1983, Matoba (15) first described pericardial thickening in noise exposed workers. His population consisted of 25 chainsaw workers where, in spite of the predominant high frequency noise, there is also an important infrasonic component within the lower frequency bands. These pericardial changes were not identified in the entire population, probably because of differences in total exposure time and individual susceptibility.

A few years later in 1987, we performed an autopsy on a patient from this population (7), and found marked thickening of the pericardium and mitral valve. In the clinical history of this man there was no reference to any symptoms that could be linked to cardiac problems. Unfortunately, there was no echocardiogram for this patient. Since then we have been performing echocardiograms on our entire population and presented our first results in 25 patients in 1989 (1); thickening of the pericardium or mitral valve was found in 100%, aortic valve (70%), endocardium (90%) and tricuspid valve (60%). At this time, only the morphological study of the cardiac structures was performed. Later, Doppler studies were carried out (2); the pericardium was again the most common thickened structure, found in 100% population (n = 56). No statistical differences in the E/A ratio, related to either age or exposure time were found with Pulsed Wave Doppler. In 1993, in a population of 134 VAD patients employed in LPALF noise environments, we found that all subjects had thickening of at least one cardiac structure (17). Pericardial thick-

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ening was found in 130 individuals. No changes in mitral valve character were observed in any of the patients.

The goal of this study was to identify possible structural changes in hearts of men with suspected VAD.

METHODS

At OGMA, an aeronautical plant of 1500 workers, a random selection of 486 healthy male Caucasian employees with no known vascular risk factors were chosen as our study population. The exclusion criteria used is described elsewhere in this Supplement (Castelo Branco and E. Rodrigues, Table I, page A2). The average age of the population was 37.9 yr (range 19–63).

Employee workstations were classified into three categories depending on noise characterization, and study groups were divided accordingly: Group I (control group), n = 48, no noise exposure (≤70 dB), e.g., administrative personnel; Group II, n = 113, moderate LPALF noise (>70 dB and < 90 dB), e.g., ancillary workstation technicians; and Group III, n = 324, intense LPALF noise (≥90 dB), e.g., aeronautical technicians.

An echocardiogram was performed on the entire population using HP 1500 SONOS, 2-D, M mode, color Doppler analysis and spectral Doppler. All 486 echocardiograms were recorded on VHS video tape. They were later blindly evaluated by three independent observers (Poland, Portugal and Russia) who focused on the following parameters: 1) thickening of mitral valve; 2) tricuspid valve; 3) pulmonary valve; 4) aortic valve; 5) endocardium; 6) pericardium; 7) mitral valve regurgitation; 8) prolapse; 9) ruptured chordae tendinae; 10) velocity flow A; 11) velocity flow E and 12) E/A ratio. Applicable parameters were evaluated using a seven-grade score system from 0 to 3 points (0,0.5,1,1.5,2,2.5,3): 0 points for no thickening (regurgitation or prolapse) and 3 points for maximum thickening (or severe regurgitation or prolapse). The results were compared among all groups. Statistical analysis was performed using the SPSS package (16). Statistical significance was established as follows: not significant if p < 0.01, significant if p < 0.001, and highly significant if p < 0.0001.

RESULTS

Please see Tables I–IV for summary of results, and Figs. 1–4.

Mitral valve thickening: Mitral thickness was identified as a more intensely lit screen image, less motion and an obvious thickened area. (See Fig. 1.) In some cases the leaflets had similarities to myxoma. Mitral leaflet thickness was normal in Group I (control group). There were statistically significant (s.s.) differences between the control group and both other groups as well as between Group II and Group III (p < 0.0001).

Aortic valve thickening: All groups presented s.s. differences regarding aortic valve thickening, being highly significant in Groups I vs. III and II vs. III.

Tricuspid valve thickening: Tricuspid valve thickening presented s.s. differences when comparing all groups, and was highly significant in Groups I vs. III and II vs. III.

TABLE I. MEAN SCORES FOR EACH NOISE GROUP.

Group*	Mean Score (SD)	No. Cases
Mitral valve thickening		
I	0.41 (0.50)	48
II	0.96 ([illegible])	113
III	1.40 (0.58)	324
Aortic valve thickening		
I	0.35 (0.47)	48
II	0.47 (0.51)	113
III	1.02 (0.59)	324
Tricuspid valve thickening		
I	0.21 (0.41)	39*
II	0.58 (0.51)	97*
III	1.15 (0.43)	315*
Pulmonary valve thickening		
I	0.25 (0.54)	[illegible]
II	0.35 (0.50)	[illegible]
III	1.19 (0.41)	[illegible]
Endocardial thickening		
I	0.31 (0.47)	48
II	0.74 (0.44)	113*
III	1.47 (0.57)	324
Pericardial thickening		
I	0.47 (0.50)	48
II	0.95 (0.74)	112*
III	1.41 (0.59)	324

* Group I: ≤70 dB; Group II: >70 dB and <90 dB; Group III: ≥90 dB.
* The number of cases for this parameter is different than that for other parameters due to the lack of visibility in some of the videotaped echocardiograms.

Pulmonary valve thickening: Differences in pulmonary valve thickening were highly s.s. between Groups I and III, s.s. between Groups II and III, and not significant in Groups I vs. II.

Endocardial thickening: Differences in endocardial thickening were only s.s. between Groups I and III, and were not significant in Groups I vs. II and II vs. III (see Table II).

Pericardial thickening: There were highly s.s. differences among all groups regarding pericardium thickening (see Figs. 1–4 and Table II).

Mitral valve regurgitation, prolapse and ruptured chordae tendinae: For all these parameters, s.s. differences were found between Groups I and III (see Table III). The severity of mitral regurgitation and prolapse in the Group III (≥90 dB) was significantly higher than those of the control Group I (≤70 dB).

Flow velocity: Only flow velocity A, and E/A ratio registered s.s. differences between Groups I and III (see Table IV).

DISCUSSION

Valves

Morphological changes of cardiac valves include thickening, calcification, degeneration and/or restriction of leaflet movement (3). In general, some of the more common reasons for morphological changes of the tricuspid and mitral valves are rheumatic fever, endocarditis, myxomatous proliferation or connective tissue diseases (3). None of these conditions existed in our population.

Morphological changes of the aortic valve are most frequently due to overloading which may lead to sec-

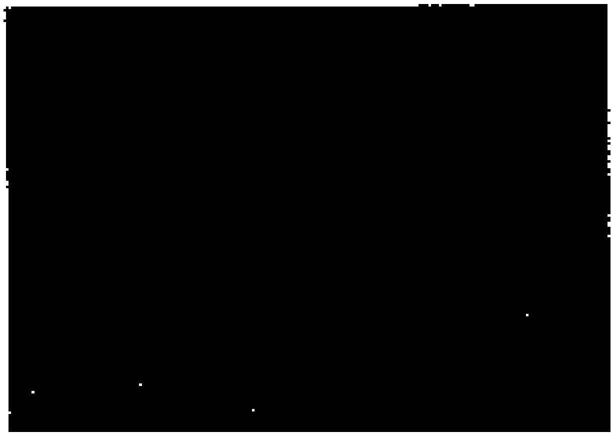


Fig. 1. [illegible]

nosis. In young adults, stenosis of the aortic valve is largely due to congenital defects of the mitral valve. In our population we did not find anyone with such congenital defects. The normal aging process can also produce stenotic valves in the elderly (3). The average age of our population was 37.3 yr. For the pulmonary valve, the vast majority of morphological changes are due to congenital stenosis (1). This condition was non-existent in our population.

Highly statistically significant differences ($p < 0.0001$) between Groups I (≤70 dB) and III (≥90 dB) were found for thickening in all valves.

TABLE II. DEGREE OF SIGNIFICANCE WHEN COMPARING THE VARIOUS NOISE GROUPS.

Cardiac Parameters	Groups*		
	I vs. III	I vs. II	II vs. III
Mitral valve thickening	hs†	hs	hs
Aortic valve thickening	hs	s	ns
Tricuspid valve thickening	hs	s	ns
Pulmonary valve thickening	hs	n	s
Endocardial thickening	hs	n	n
Pericardial thickening	hs	hs	hs

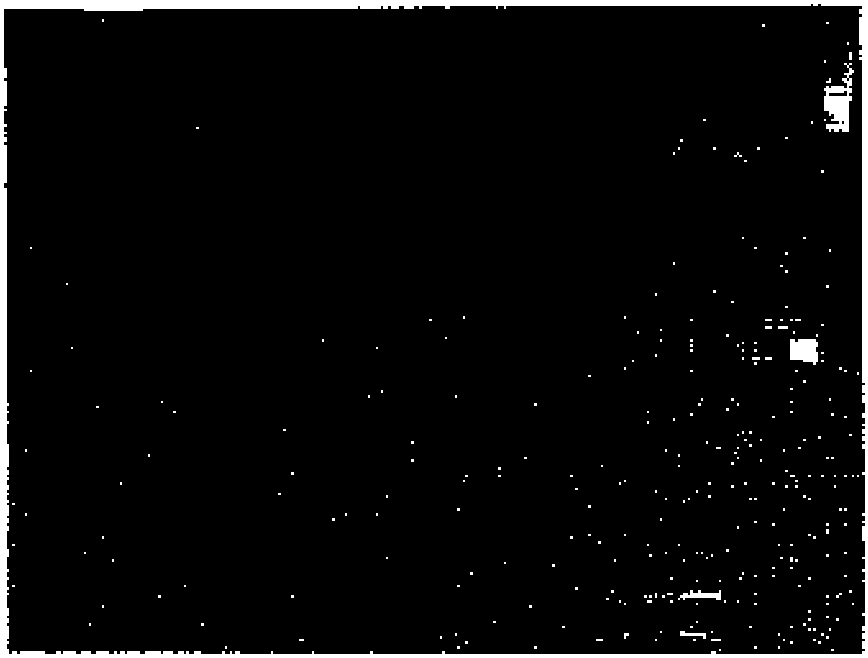
* Group I: <70 dB; Group II: >70 dB and <90 dB; Group III: >90 dB.
† n = non significant, $p > 0.01$; s = significant, $p < 0.01$; hs = highly significant, $p < 0.005$.

Endocardia

Intensely hi images and thickening of the endocardium is a situation that can be observed in conditions such as ischemic heart disease, hypertension, endomyocardial fibrosis, and radiation exposure (3). Subjects with pre-existing cardiovascular disease were excluded from our population. Other conditions described above were not present in our population.

Intensely hi images and endocardium thickening appeared more evident in Group III than in Group I with a high degree of statistical significance ($p < 0.005$). Comparison among Groups I-II and II-III were not significant ($p < 0.01$).

Fig. 3. Parasternal long axis view of a patient with thickened cardiac structures in systole (A) and in diastole (B): right ventricle anterior wall (1); right ventricle (2); ventricle septum (3); aorta anterior wall (4); aorta posterior wall (5); mitral valve anterior leaflet (6); left ventricle (7); mitral valve posterior leaflet (8); left ventricle posterior wall (9); pericardium (10); and left atrium (11).



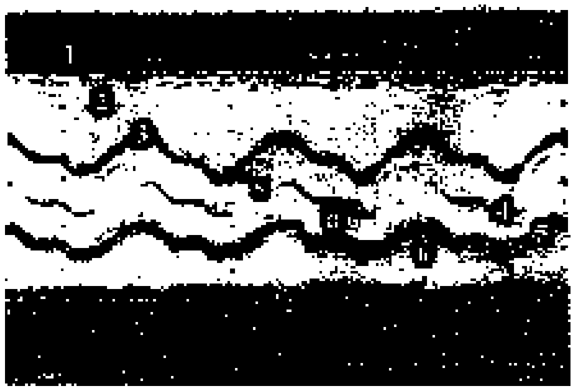


Fig. 3. M-mode [illegible] aortic [illegible] systole [illegible] diastole [illegible] left atrium [illegible]

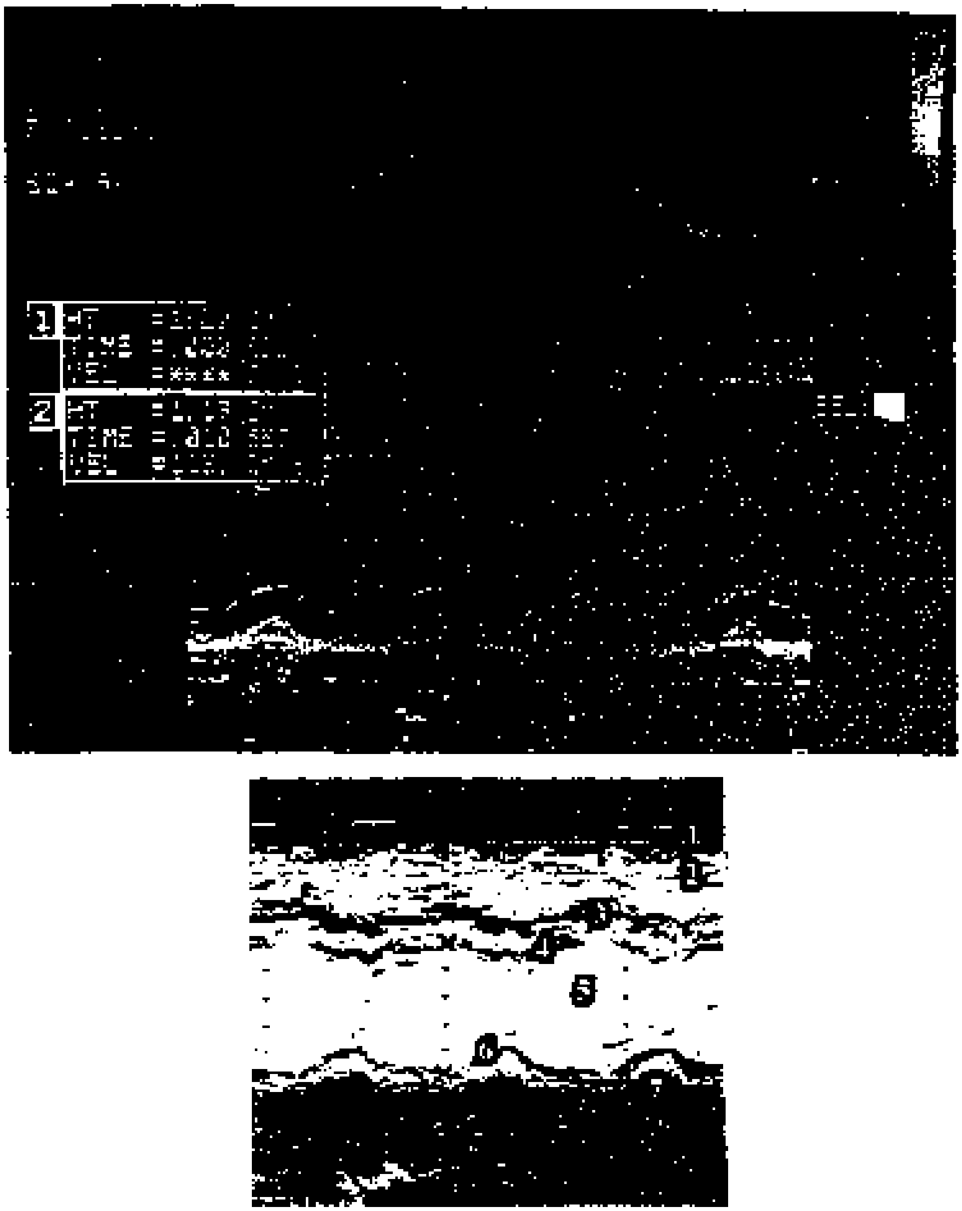


Fig. 4. An M-mode recording in a VAD patient demonstrating thickened pericardium: right ventricle anterior wall (1); right ventricle (2); right side of the interventricular septum (3); left side of the interventricular septum (4); left ventricle (5); posterior wall of the left ventricle (6); and the pericardium (7).

TABLE III. INCIDENCE OF CASES WITHIN EACH NOISE GROUP.

Noise Groups*	I (N = 48)	II (N = 117)	III (N = 229)
Mitral regurgitation	23.3[†]	44.2	56.0**
Mitral prolapse	4	9	15**
Ruptured chordae tendinae	2.3	10	17.4**

* Group I: ≤90 dB; Group II: >90 dB and ≤90 dB; Group III: >90 dB.
[†] Values are in percentages (%) of group.
** p < 0.001 compared to Noise Group I.

Mitral Valve Regurgitation

Mitral regurgitation can be associated with a variety of conditions, e.g., rheumatic heart disease, connective tissue diseases, endocarditis, dilatation of valve annulus, congenital defects, mitral valve prolapse, and ruptured chordae tendinae. The latter two conditions were identified in many subjects of Group III, but it is unclear whether these conditions were directly related to the cases of regurgitation. All other conditions were nonexistent in our population.

Mitral Valve Prolapse

Echocardiography is an extremely reliable diagnostic tool for mitral valve prolapse. With this method, during systole one can clearly see one or both valve leaflets billowing into the left atrium. In this population, 4% of Group I vs. 15% in Group III had prolapsed mitral valve. In accordance with Braunwald (3), 3–5% of the population at large has mitral valve prolapse of varying degrees, mostly as a primary condition but also caused by hereditary connective tissue diseases, von Willebrand's disease, congenital thoracic deformities and others. In Marfan Syndrome, 90% of the patients have mitral valve prolapse (3). In our population none of these conditions existed.

Ruptured Chordae Tendinae

This condition may occur as a consequence of rheumatic fever, endocarditis, congenital abnormalities, ischemic heart disease, dilation of left ventricle, and direct trauma to the chest. None of these conditions existed in our population. In most cases, however, ruptured chordae tendinae is an idiopathic situation.

TABLE IV. DEGREES OF SIGNIFICANCE WHEN COMPARING MITRAL VALVE FLOW PARAMETERS AMONG ALL NOISE GROUPS.

Noise Groups*	I vs. II (N = 48)	I vs. III (N = 357[†])	II vs. III (N = 346[†])
Velocity Flow E	n[‡]	n	n
Velocity Flow A	hs	n	n
E/A ratio[§]	s	n	n

* Group I: ≤90 dB; Group II: >90 dB and ≤90 dB; Group III: >90 dB.
[†] The number of cases for this parameter is different than that for other parameters due to the lack of visibility in some of the videotaped echocardiograms.
[‡] n = not significant, p < 0.05; s = significant, p < 0.001; hs = highly significant, p < 0.0001.
[§] All E/A values were within normal values.

Flow Velocity

Unexpectedly, it was Group II which had the lower value of E/A. When we divided the entire population into three age groups, (A <39, >39 B <45, C >45), the E/A parameter decreased as expected. It should be noted that even though there was a statistically significant difference between Groups I and III, all E/A values were within normal limits.

Pericardium

Evaluation of the pericardium using computed tomography (CT) and magnetic resonance imaging (MRI) is a frequent method used in cardiac diagnosis (10,13). Echocardiography and Doppler ultrasound are also very useful in evaluating cardiac abnormalities (5,8). Both M-mode and two dimensional echocardiography may be very useful in diagnosing thickened cardiac structures. These echocardiographic signs have a high degree of sensitivity and specificity (3).

Pericardial thickening is not a very common finding (3). Some of the unusual cases can be observed in collagenous diseases, infections, tumors and in asbestosis (10,11,13,15,19). None of these conditions were identified in our population.

Pericarditis is a condition that could lead to pericardium thickening. Pericarditis is usually commonly caused by viral, bacterial (especially tuberculosis), fungi and parasite infections, uremia, acute myocardial infarction, neoplasm, and direct chest trauma (3,10–14,18,19). Autopsy findings indicate that pericardial inflammation has an incidence of 2–6% and only 0.1% of the hospital-admitted population has symptoms of pericarditis (3). No element of our population had been identified with pericarditis nor pericardial inflammation. Differences in pericardial thickening were found to be highly statistically significant in all Group comparisons (see Table II).

Pericardial Thickening and VAD

All the known reasons for pericardial thickening (e.g., pericarditis, asbestosis, etc.) have been eliminated within our population. The degree of pericardial thickening seemed to increase with the level of noise (comparing mean scores in Table I with noise level in each of the Groups).

Pericardial thickening has been identified by this team in noise-exposed individuals not employed by the aeronautical industry (5). Moreover, anatomical correspondence to this echo-image of pericardial thickening has been obtained through ultrastructural studies of pericardial fragments of VAD patients[1] (6). In VAD, pericardial thickening is due to the formation of an extra layer of loose tissue, sandwiched in between two thickened layers of fibrosa which contains an overabundance of collagen fibers (5). We believe that this type of pericardial thickening is specific to VAD, i.e., it is induced by LPA LF noise exposure.

[1] These patients underwent surgery for other reasons (6).

CONCLUSIONS

The overall results of the echocardiographic evaluation regarding thickening of mitral, tricuspid, aortic and pulmonary valves, pericardium and endocardium suggest that occupational exposure to LPALF noise may induce the morphological changes observed in these subjects. This confirms the results of previous studies (1,2,17). The group of subjects diagnosed with VAD had a more obvious thickening of the cardiac structures. These findings are unusual for the population at large of the same age group (average 37 yr, range 19–63). The degree of thickening increased with the level of noise.

The most considerable thickening was found in the pericardium and mitral valve. Considering that all known reasons for pericardial thickening were eliminated from our population, we believe that this form of thickening identified in these patients is VAD specific, and is caused by exposure to LPALF noise.

The incidence of mitral valve regurgitation, prolapse and ruptured chordae tendinae is also unusual for the population at large, and suspicion is warranted that these conditions may be directly related to individuals' exposure to noise.

Given these results, we strongly suggest that all workers in noise environments be evaluated not only with an audiogram, for the purpose of hearing protection, but also by echocardiography so as to avoid the evolution of VAD.

ACKNOWLEDGMENTS

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REFERENCES

1. Araujo A, Sousa Ribeiro C, Correia MJF, et al. Echocardiographic appearance in patients with low frequency noise and vibration [illegible]. [illegible] [illegible] Information [illegible] 7:[illegible].
2. Araujo A, Sousa Ribeiro C, Pais F, et al. Echocardiographic study of men occupationally exposed to noise and vibration. Aviat Space Environ Med 1999; [illegible].
3. Braunwald E. Heart disease. 5th ed. Philadelphia: W. B. Saunders Co. 1997.
4. Castelo Branco NAA. The clinical stages of vibroacoustic disease. Aviat Space Environ Med 1999; 70(3, Suppl.):A32–9.
5. Castelo Branco NAA, Rodriguez E, Alves-Pereira M, Jones DR. Vibroacoustic disease: some forensic aspects. Aviat Space Environ Med 1999; 70(3, Suppl.):A145–51.
6. Castelo Branco NAA, Águas AP, Sousa Pereira A, et al. The human pericardium in vibroacoustic disease. Aviat Space Environ Med 1999; 70(3, Suppl.):A54–62.
7. Castelo Branco NAA. A unique case of vibroacoustic disease. A tribute to an extraordinary patient. Aviat Space Environ Med 1999; 70(3, Suppl.):A27–31.
8. Chandraratna PA. Echocardiography and Doppler ultrasound in the evaluation of pericardial disease. Circulation 1991; 84:[illegible]–[illegible].
9. European Commission on Health and Safety. Editorial: A new professional disease: the vibroacoustic syndrome. [illegible] [illegible], 1995.
10. Didier D, Ratib F, Gedaloh M. Imaging of the pericardium using magnetic resonance. Radiology 1993; [illegible].
11. [illegible] NA, Underwood SR, [illegible] RM. Asbestos-related pericardial thickening detected by magnetic resonance imaging. Respir Med 1993; 87:[illegible]–17.
12. [illegible] [illegible]. The spectrum of pericardial tamponade in systemic lupus erythematosus. Report of ten patients. Arthritis Rheum 1992; [illegible].
13. Kopes W, Tschoisloff D. Pericardium – radiologic diagnosis. Radiology 1997; 37:[illegible]–[illegible].
14. Martinho Pimenta AJF, Castelo Branco NAA. Neurological aspects of vibroacoustic disease. Aviat Space Environ Med 1999; 70(3, Suppl.):A91–5.
15. [illegible] [illegible]. Increased left ventricular function as an adaptive response to strenuous exercise. Am J Cardiol 1993; [illegible].
16. Nie NH, Hull CH, Jenkins JG, et al. Statistical package for the social sciences. New York: McGraw-Hill Inc., 1970.
17. Pais FP, Araújo A, Sousa Ribeiro C, et al. Echocardiographic evaluation in patients with the vibroacoustic syndrome [abstract]. Aviat Space Environ Med 1996; 67:[illegible].
18. [illegible] R, [illegible] A, [illegible] C, et al. Evaluation of cardiac involvement in systemic lupus erythematosus. Clinical and echocardiographic study. Rev Rheum Mal Osteoartic 1993; [illegible]–[illegible].
19. [illegible] S, [illegible] PA, [illegible] M, De [illegible] P. Pericardial effusion associated with asbestos exposure. Thorax 1992; 47:1097–8.

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France's

NATIONAL ACADEMY OF MEDICINE

calls for 1.5 km setback for all

Industrial Wind Turbines

from residences

March 29, 2006

Abstract: In a 17-page report issued earlier this month, entitled "Repercussions of wind turbine operations on human health" ("Le retentissement du fonctionnement des éoliennes sur la santé de l'homme"), the top medical society of France (The National Academy of Medicine) acknowledged that industrial wind turbines pose a significant health hazard to people living nearby, and it has asked the French government to impose an immediate moratorium on all wind turbine construction within a 1.5 km radius of people's homes while further research is conducted on health effects of wind turbine noise and infrasound.

Following is a translation of a notice of the report by Dr. Chantal Gueniot in Panorama du Médecin, 20 March 2006 (translated courtesy of Eric Rosenbloom). The full (French) text of the Academy's report follows this notice.

Panorama du Médecin
20 March 2006

"Wind Turbines: The Academy Cautious"

The harmful effects of sound related to wind turbines are insufficiently assessed, warns the Academy.

Wind turbines, which are multiplying throughout the French countryside, will have to be considered as industrial installations and to comply, by that fact, to specific regulations that take account of the harmful effects of sound as particularly produced by these structures, determined a working group assembled by the National Academy of Medicine and presided over by professor Claude-Henri Chouard (Paris).

People living near the towers, the heights of which vary from 10 to 100 meters, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma. Studies conducted in the neighborhoods of airports have clearly demonstrated that chronic invasive sound involves neurobiological reactions associated with an increased frequency of hypertension and cardiovascular illness. Unfortunately, no such study has been done near wind turbines. But, the sounds emitted by the blades being low frequency, which therefore travel easily and vary according to the wind, they constitute a permanent risk for the people exposed to them.

Since 2 July 2003, the law has required a construction permit for wind turbines over 12 meters, including an impact study if their [combined] power is over 2.5 megawatts. An investigation conducted by the Ddass [Direction Départementale des Affaires Sanitaires et Sociales] in Saint-Crépin (Charent-Maritime) revealed that sound levels 1 km from an installation occasionally exceeded allowable limits. While waiting for precise studies of the risks connected with these installations, the Academy recommend halting wind turbine construction closer than 1.5 km from residences.

Dr Chantal Guemot

ACADÉMIE NATIONALE DE MÉDECINE

RAPPORT

Le retentissement du fonctionnement des éoliennes sur la santé de l'homme

Claude-Henri CHOUARD**

L'Association APSA (Association pour la protection des Abers) a demandé par lettre du 7 mars 2005 au Ministre de la Santé et des Solidarités, que soit étudiée l'éventualité d'une action nocive des éoliennes sur la santé de l'homme. Elle en a adressé une copie pour information au Président de l'Académie nationale de médecine. Le Conseil d'Administration de celle-ci a jugé nécessaire, dans sa réunion du 15 mars 2005, de se saisir du problème, et d'en confier l'examen à un Groupe de Travail spécialement créé à cet effet.

1- Introduction

Le développement des parcs d'éoliennes en France est un des moyens de pallier la dépendance énergétique du pays. Cependant les populations vivant dans certains cas tout à côté des éoliennes expriment des doléances fonctionnelles diverses et se plaignent des bruits très particuliers de ce voisinage. Depuis une dizaine d'années, la réglementation concernant l'installation de ces engins comporte une étude d'impact sur l'environnement, sur la flore autant que sur la faune, ornithologique notamment. Mais, pour l'homme, l'éventualité de nuisances, notamment sonores, induites par le fonctionnement de ces engins a été minimisée, et son appréciation spécifique n'a pas été réglementée [1].

Cette carence faussement rassurante a été sans doute une des raisons de l'inquiétude de ces populations, et elle a eu pour effet de laisser se développer, pour expliquer les troubles ressentis, des rumeurs pathogéniques discutables, notamment celles qui concernent la responsabilité des infrasons. Ces rumeurs n'ont pu qu'amplifier l'importance des troubles fonctionnels.

On comprend que ces doléances et ces craintes aient été alors largement diffusées, parce qu'elles servaient d'arguments supplémentaires aux Associations qui s'opposent à l'installation de ces engins pour des motifs écologiques, esthétiques ou économiques, qui, eux, relèvent de la politique générale, et non des compétences de l'Académie.

Actuellement, dans la littérature scientifique, on retrouve très peu de données sur les dangers potentiels des éoliennes pour l'homme. Faire le point des connaissances actuelles et apprécier l'éventualité de cette nocivité a constitué la mission de ce groupe de travail, et l'a conduit à proposer au Conseil d'Administration un certain nombre de recommandations.

** Membre de l'Académie nationale de médecine

2- Les éoliennes

Les éoliennes, qu'elles soient isolées, ou regroupées en grand nombre en formations improprement appelées "fermes éoliennes", sont une source d'énergie "renouvelable" qui suscite un intérêt mondial. En France, malgré les polémiques induites par leur fonctionnement, ce "gisement" énergétique commence à se développer (voir Annexe A), car ces implantations bénéficient depuis plusieurs années d'incitations financières importantes. Celles-ci représentent un intérêt pécuniaire évident pour les particuliers et les communes accueillant ces engins

Mais elles n'intéressent que les propriétaires qui louent le terrain nécessaire à l'implantation, sans que les habitants du voisinage plus ou moins proche en tire le moindre avantage. Quand il s'agit de petits propriétaires, souvent retraités qui, de plus, voient la valeur de leur modeste bien immobilier s'effondrer, ces derniers éprouvent un sentiment d'injustice, qui amplifie la nuisance du bruit auquel cette partie de la population est soumise. De plus, les actions menées par les industries privées, auxquelles est dévolue la responsabilité d'installer les éoliennes, relèvent du marketing, dont les techniques conduisent parfois, pour obtenir l'accord préalable des populations, à minimiser les inconvénients liés à la proximité de ces engins; mais la déception, ressentie après coup, de découvrir des nuisances insoupçonnées, majore sûrement le retentissement psychique de la gêne rencontrée.

Malgré l'article 98 dévolu aux éoliennes dans la loi du 2 juillet 2003, ces machines restent soumises à la simple réglementation des bruits de voisinage (article R 1336-8 et R 1336-9 du code de la santé publique, arrêté du 10 mai 1995 relatif aux modalités de mesure de ces bruits [2]), si bien que les procédures administratives, qui doivent être actuellement suivies pour obtenir le permis de construire une éolienne, n'imposent pas d'éloignement minimal des habitations. Dans certains cas, ces dernières se trouvent à moins de cinq cents mètres de ces engins.

Il est paradoxal de constater que jusqu'à présent les éoliennes, engins mécano électriques générateurs de taxes professionnelles pour les communes, n'aient jamais été considérées comme des installations industrielles : l'implantation de ces dernières est soumise à une réglementation spécifique destinée à prévenir les risques que leur fonctionnement peut induire, et notamment les conséquences des nuisances sonores infligées au voisinage.

Précisons enfin que la réglementation concernant la mesure des nuisances sonores des éoliennes varie d'un pays à l'autre. L'Union Européenne commence à s'intéresser à cette disparité et vient depuis peu d'uniformiser[1] les méthodes de mesure du bruit induit au voisinage d'une éolienne en fonctionnement. Mais, actuellement, cette réglementation européenne n'implique pas de mesures effectuées sur des périodes longues de plusieurs semaines.

3- Les plaintes, concernant leur santé, formulées par certaines personnes vivant à proximités des éoliennes.

Leur catalogue est difficile à établir, car les études exhaustives cliniques dépourvues de tout biais méthodologique sont rares dans la littérature scientifique.

Le bruit est la doléance la plus fréquente. Il est décrit comme lancinant, préoccupant, perpétuellement surprenant parce qu'il est irrégulier en intensité, mais comporte aussi des sonorités grinçantes et incongrues, qui détournent l'attention ou perturbent le repos. La survenue inopinée la

[1] Il s'agit de la directive IEC 61400-11. <http://www.awea.org/standards/iec_stds.html#WG5>

nuit de ces bruits perturbe le sommeil, réveillant brusquement le sujet dès que le vent se lève, ou l'empêchant de se rendormir.
Les éoliennes ont été rendues responsables d'autres troubles ressentis par les personnes habitant dans leur proximité. Ils sont moins précis, moins bien décrits et consistent en manifestations subjectives (céphalées, fatigues, sensations d'ébriété passagères, nausées) parfois objectives (vomissements, insomnies, palpitations).
Signalons que les mouvements de l'ombre des pales en rotation ont été rendus responsables de distractions susceptibles d'entraîner des d'accidents de voiture, voire d'épilepsie.

4- Les modifications physiques de l'environnement dues au fonctionnement des éoliennes.

A- La **taille des éoliennes**, dont la hauteur atteint aujourd'hui souvent plus de cent mètres, et leur situation dans des sites fréquemment ventés, c'est-à-dire dégagés et/ou élevés, peuvent les rendre visibles à plusieurs kilomètres.

B- Cette modification de l'environnement est encore plus évidente lorsque s'y ajoute **le mouvement rotatoire des pales**, dont le diamètre à lui seul approche la centaine de mètres. Cette rotation des pales, qui a été accusée d'être dangereuse pour l'homme, peut blesser les oiseaux; la réglementation actuelle a pris ce risque en compte, afin que les zones de nidification ou de migration ne soient pas perturbées par l'implantation de ces engins.

C- Mais la modification de l'environnement la plus importante est sûrement, comme toute installation industrielle, la création de **vibrations du milieu ambiant**.

Que ces vibrations soient solidiennes ou aériennes, elles sont responsables, lorsqu'elles sont audibles, d'un **bruit**, dont les caractéristiques physiques n'ont de particulier que la variabilité de ses paramètres, et notamment de leur seuil d'audibilité par l'homme.
Ce bruit [3] est dû à la rotation des engrenages de la machinerie qui assure l'adéquation au vent de l'axe des pales, et de la dynamo qui produit l'électricité. Il est dû aussi au frottement du vent sur les pales et sur le bâti de l'éolienne. Ce bruit est variable et intermittent ; par temps calme les éoliennes sont au repos, ou peu bruyantes; mais, qu'il forcisse ou reste modéré, le vent le mieux installé est toujours irrégulier. Cette variabilité du bruit explique les controverses relatives à son intensité. Elle majore son impact sur l'homme en entraînant une mise en éveil répétitive et imprévisible.
Les caractères du bruit éolien n'ont été étudiés que tout récemment, peut-être en raison des doléances exprimées par les Associations. Ce bruit a été analysé dans le périmètre aérien immédiat de ces machines, ou plus à distance en milieu liquidien [4] dans les parcs d'éoliennes implantées dans la mer. De même les modalités de sa propagation à distance sont maintenant bien connues [5] : celle-ci dépend des conditions climatiques (température, humidité, orientation et vitesse du vent, etc), mais tout autant de la topographie et de l'environnement propre à chaque site. Un vallonnement, par exemple, peut faire écho et amplifier (ou masquer) ce bruit en certains endroits de manière très localisée. Inversement, les occupants d'habitations situées sur le bord de mer n'entendent pas des éoliennes pourtant toutes proches, parce qu'ils sont soumis, sans en être gênés, au bruit constant des vagues, du ressac et du vent du large. Cette variabilité est aussi illustrée par les récentes mesures de bruit effectuées avec une instrumentation moderne près des habitations.

entreprises à la demande des populations incommodées. Dans l'une d'entre elles, par exemple [6], les enregistrements furent effectués sur 9 sites différents ; ils objectivèrent 6 valeurs sans dépassement du bruit autorisé, et 3 valeurs hors normes; parmi les 6 premières, certaines éoliennes étaient à moins de 500 mètres des habitations, tandis que pour les 3 autres, l'éolienne responsable était à plus d'un kilomètre de l'habitation où était placé l'instrument de mesure ; ces différences étaient dues uniquement à la topographie des lieux. Pour les futurs projets, il serait souhaitable que pour chaque site envisagé, des simulations sonores artificielles, et leur enregistrement au niveau des habitations concernées, soient effectuées préalablement à toute construction. Il est nécessaire pour cela que ces simulations soient désormais intégrées dans l'étude d'impact de ces parcs d'éoliennes.

En France, la mesure du bruit de voisinage, notamment celui produit par les éoliennes, était soumise, depuis 1995, à la norme NF S 31-110, qui exigeait que les mesures de bruit soient effectuées avec des vents inférieurs à 20 km/h [7], car pour des vitesses supérieures "les sonomètres pourraient enregistrer des bruits parasites".. [1]. Cette situation réglementaire était d'autant plus étonnante que, d'une part techniquement il était facile déjà à cette époque de contourner cette difficulté, et d'autre part ce sont des vitesses de vent bien supérieures qui mettent habituellement en jeu ces machines. Son application explique sans doute la plupart des doléances exprimées aujourd'hui à leur propos.

La modification de cette norme est annoncée. Mais, dans les documents ministériels [8], la prévision des nuisances fait bien plus appel à des modélisations par logiciel, qu'à des mesures sur le terrain tenant compte sur une longue période de la variabilité du spectre des bruits, et des variations saisonnières de la vitesse et de l'orientation des vents. Elle risque donc d'être inefficace.

Tout cela conduit encore plus à déplorer que, lors de la rédaction de l'article 98 dévolu aux éoliennes dans la loi du 2 juillet 2003, ces engins électromécaniques, manifestement bruyants, n'aient pas d'emblée été considérés comme des établissements industriels. Certes, ils sont soumis à l'obligation d'un permis de construire à partir d'une certaine hauteur, et, au-delà d'une certaine puissance, ils sont soumis à une "étude d'impact". Mais celle-ci ne tient pas du tout compte de la spécificité du bruit de ces machines, qui continuent, en matière de bruit, à relever de la réglementation appliquée aux habitations ordinaires. En réalité, pour les éoliennes, une distance minimum de sécurité acoustique doit être définie, même si cette distance est propre à chaque implantation. Cette mesure est seule capable d'éviter toute nuisance sonore. Ce paramètre de bon sens a jusqu'ici été ignoré, au point qu'actuellement, ni les installateurs, ni les pouvoirs publics, ne peuvent fournir de statistique indiquant, pour chaque éolienne (ou parc d'éoliennes), privée ou publique, la distance séparant chaque engin de l'habitation la plus proche.

Les infrasons se définissent comme la zone la plus grave de l'environnement sonore (aérien, liquidien ou solidien), audible ou non par l'homme, dont la limite supérieure assez floue est aux environs de 20 Hz. Ils nécessitent une intensité considérable pour être audibles, et par conséquent ne doivent pas être inclus, sous peine de confusion, dans le plus vaste domaine des sons de basses fréquences largement représentées dans la perception des voyelles et de la musique auxquelles l'oreille humaine est sensible. Bien qu'inaudibles, les infrasons sont présents dans notre environnement le plus quotidien (voir Annexe B). Ils existent dans tout l'environnement industriel. A des intensités énormes, on les retrouve aussi dans les explosions, le tonnerre, les tremblements de terre. L'étude expérimentale de leur audibilité et de leurs effets sur l'homme ou l'animal exige des laboratoires très sophistiqués, en raison de leur grande longueur d'onde et de l'énormité des intensités qui doivent être générées pour qu'ils soient perceptibles.

D- Les effets physiopathologiques du bruit

La nature de leurs effets dépend de l'intensité [9].

Tous les bruits audibles, lorsqu'ils sont ***très intenses***, peuvent entraîner plus ou moins vite des troubles fonctionnels, puis des lésions de l'oreille bien connues. Mais de telles intensités ne se rencontrent qu'à quelques mètres d'une éolienne en fonctionnement, auprès de laquelle aucun sujet n'habite ni ne travaille en permanence.

A des ***intensités modérées***, les bruits chroniques n'entraînent pas de lésions de l'oreille. Mais leur perception peut provoquer des réactions de stress, dans la mesure où ils sont irréguliers et surtout mal vécus. Ce stress induit peut être responsable de différentes affections bien connues, détaillées plus loin. Leur prévention est théoriquement assurée grâce aux précautions mises en œuvre, par exemple, dans à la construction des autoroutes ou des aéroports. La pathogénie des nuisances entraînées par le bruit généré dans les fréquences audibles par le fonctionnement intermittent des éoliennes sont de la même nature.

Les infrasons

Aux intensités auxquelles on les retrouve dans les sites industriels les plus bruyants, les infrasons, à peine audibles, n'ont aucun impact pathologique prouvé sur l'homme, au contraire des fréquences plus élevées du spectre auditif. Ce n'est que dans les explosions, naturelles ou générées par l'homme, qu'ils peuvent avoir une part de responsabilité dans les lésions souvent létales observées

Au-delà de quelques mètres de ces engins, les infrasons du bruit des éoliennes sont très vite inaudibles. Ils n'ont aucun impact sur la santé de l'homme.

La nature fallacieuse de l'origine dite scientifique des rumeurs propagées à leur propos est détaillée [10] en Annexe B.

5- Les éoliennes sont-elles dangereuses pour l'homme ?

Dangers et risques sont bien connus et font déjà l'objet de mesures de prévention efficaces. Les autres sont moins bien définis, polymorphes, inconstants, et leur recensement clinique actuel soufre de biais méthodologiques.

A- Les premiers dangers comportent:

1. Tous les accidents de personnes dus à la préparation des sites, à l'installation (ou au démontage) des parcs d'éoliennes, puis à leur entretien. Ce sont des accidents du travail dont la réglementation actuelle, pourvu qu'elle soit appliquée, est suffisante pour en assurer la prévention.
2. Le fonctionnement des éoliennes comporte un danger de traumatismes dus aux projections à distance de pièces plus ou moins volumineuses se détachant accidentellement de ces engins à la suite d'une avarie matérielle. Leur prévention relève de la création d'un *no man's land* suffisant, dont il existe des estimations en fonction de la taille des engins, mais qui n'est pas défini dans la réglementation actuelle. Notons que cette mesure de précaution, quand elle est prise, est souvent enfreinte ou contestée par les propriétaires des terrains.

3 Les mêmes dangers persistent pendant des décennies dans certains cimetières d'éoliennes anciennes, devenues obsolètes et abandonnées sans avoir été démontées pour des raisons financières.

La prévention de tous ces dangers est prévue de manière explicite par la réglementation récente, notamment celle qui concerne ces sites à l'abandon.

B- Les risques hypothétiques des éoliennes

On retrouve souvent cité parmi les doléances, le retentissement psychique, voire neurologique, de **l'effet stroboscopique** entraîné par l'observation soutenue de la rotation des pales, notamment si elle se fait dans la direction d'un soleil bas sur l'horizon. La crainte d'un effet épileptogène des éoliennes a été souvent évoquée. Cependant, si dans d'autres circonstances le rôle épileptogène d'une stimulation lumineuse répétitive est bien démontré, nous n'avons retrouvé dans la littérature aucune observation incriminant les éoliennes dans cette pathologie: cette crainte n'est étayée par aucun cas probant. Notons, de plus, qu'il faudrait que les globes oculaires du sujet soient exceptionnellement fixes, et pendant suffisamment longtemps, pour qu'ils puissent transmettre aux centres cérébraux les variations d'un faisceau lumineux aussi étroit et lointain que celui fourni par la rotation d'une éolienne.

C- Le vrai risque des éoliennes : le bruit.

Qu'il soit très intense, ou qu'il représente une pollution sonore plus modérée, le bruit est le grief le plus fréquemment formulé à propos des éoliennes [11]. Il peut avoir un impact réel, et jusqu'ici méconnu, sur la santé de l'homme (voir Annexe B).

Rappelons que le traumatisme sonore est dangereux de deux manières. Il peut entraîner des lésions de l'oreille interne si l'intensité et la durée de l'exposition au bruit atteignent des valeurs élevées. Mais ces intensités n'ont jamais été observées au niveau des habitations proches des éoliennes.

A des intensités modérées, le bruit peut entraîner des réactions de stress, perturber le sommeil et retentir sur l'état général. Il est démontré qu'une agression sonore permanente ou intermittente, telle celle qu'on peut rencontrer dans certains ateliers, ou au voisinage des aéroports ou des autoroutes, augmente le risque d'hypertension artérielle [12] et d'infarctus du myocarde [13]. De même des troubles neuroendocriniens [14] ont été décrits, avec une augmentation de la sécrétion noradrénergique, d'ACTH, et d'hormone somatotrope. Enfin, les troubles du sommeil sont particulièrement fréquents dans les zones d'habitation situées près des grands moyens de communication, en sachant que les aéroports, par l'aspect intermittent du bruit qu'ils engendrent, sont les plus redoutables. On admet que le sommeil est perturbé [15] si le bruit ambiant dépasse 45 dB pour la Communauté européenne, mais seulement 35 dB pour l'Organisation mondiale de la santé.

Il a semblé licite à certaines Associations d'extrapoler aux éoliennes ces risques observés au voisinage de certains aéroports, bien qu'il n'existe aucune étude comparable ayant porté sur les populations proches de parcs éoliens. Mais, malgré les difficultés méthodologiques qu'une telle enquête devrait surmonter, une étude épidémiologique sérieuse est indispensable, car éoliennes et aéroports constituent deux sources sonores très différentes.

L'agression sonore est majorée lorsque le bruit présente d'importantes irrégularités stimulant l'attention de l'individu. A contrario, ce bruit est mieux supporté s'il est continu [16]. Cependant, même si l'habituation à ces irrégularités peut diminuer leur impact, cette habituation est d'autant plus difficile à s'installer que le sujet se sent la victime de ce bruit. Le stress et ses conséquences dépendent du vécu du bruit. Dans le cas des éoliennes, l'impact de cette nuisance pourrait dépendre de la manière dont elle est infligée au sujet. S'il en tire un intérêt immédiat, qui le plus souvent est matériel, les risques d'en être importuné seront vraisemblablement plus faibles.

De toutes manières, la prévention de ces risques repose sur le simple éloignement de la source sonore. Mais, il est théoriquement difficile de définir a priori une distance minimale des habitations, qui serait commune à tous les parcs, car la propagation du son, c'est-à-dire l'étendue de cette zone de nuisance, dépend des éléments topographiques et environnementaux propres à chaque site.

Cependant, tant que l'étude épidémiologique de ces nuisances sonores n'a pas été réalisée, et compte tenu des résultats des récentes mesures de bruit effectuées avec des moyens modernes, il serait souhaitable, par précaution, que soit suspendue la construction des éoliennes d'une puissance supérieure à 2.5 MW situées à moins de 1500 mètres des habitations. Une distance de 1500 mètres pourrait être dès maintenant proposée à titre conservatoire

6- Discussion des mécanismes permettant d'expliquer les troubles ressentis

1- La plupart des troubles fonctionnels objet de doléance peuvent être interprétés comme des conséquences générales du bruit chronique évoqué plus haut.

2- Mais d'autres ont été mis sur le compte des infrasons, en arguant qu'ils pourraient être générés par les éoliennes à une intensité suffisante pour entraîner des manifestations de nature vestibulaire (fatigabilité, nausées, céphalées). Cette interprétation doit être discutée, en rappelant :

- Les niveaux très faibles d'intensité des infrasons mesurés au proche voisinage des éoliennes
- Les niveaux d'intensité plus de mille fois plus élevés que devraient présenter ces infrasons pour être seulement audibles, et encore plus de mille fois plus élevées pour qu'apparaissent les discrètes et transitoires réactions vestibulaires parfois observées expérimentalement. Cette crainte des infrasons produit par les éoliennes est donc sans fondement.

7- Conclusions

Le Groupe de Travail réuni à cet effet a étudié, parmi les réticences suscitées par l'installation des éoliennes, celles qui intéressent la santé de l'homme

Il estime :

1. que la production d'infrasons par les éoliennes est, à leur voisinage immédiat, bien analysée et très modérée : elle est sans danger pour l'homme ;
2. qu'il n'y a pas de risques avérés de stimulation visuelle stroboscopique par la rotation des pales des éoliennes ;
3. que les risques traumatiques liés à l'installation, au fonctionnement et au démontage de ces engins sont prévus et prévenus par la réglementation en vigueur pour les sites industriels, qui s'applique à cette phase de l'installation et de la démolition des sites éoliens devenus obsolètes.

Il constate:

4. que les vrais risques du fonctionnement des éoliennes sont liés à l'éventualité d'un traumatisme sonore chronique, dont les paramètres physiopathologiques de survenue sont bien connus, et dont l'impact dépend directement de la distance séparant l'éolienne des lieux de vie, ou de travail, des populations riveraines.

Il observe

5. que la réglementation actuelle, relative à l'impact sur la santé du bruit induit par ces engins [17], ne tient pas compte :

- ni de leur nature industrielle,
- ni de la grande irrégularité des signaux sonores émis par ces machines ;
- des progrès techniques dans la simulation et l'enregistrement au long cours des impacts sonores.

6. que ni les installateurs d'éoliennes, ni les pouvoirs publics, ni les Associations n'ont établi de statistique indiquant, pour chaque éolienne (ou parc d'éoliennes), privée ou publiques, la distance séparant chaque engin de l'habitation la plus proche ;

8- Recommandations

Pour faire la preuve de l'éventuelle nocivité du bruit éolien pour l'homme, l'Académie estime indispensable que soient entreprises deux types d'études comportant:

- la mise au point d'une procédure réalisant l'enregistrement, sur une période longue de plusieurs semaines, du bruit induit par les éoliennes dans les habitations, puis son analyse à différentes échelles temporelles, afin d'appliquer cette expertise aux populations intéressées.
- une enquête épidémiologique sur les conséquences sanitaires éventuelles de ce bruit éolien sur les populations, qui seront corrélées avec la distance d'implantation de ces engins, et les résultats des mesures proposées ci-dessus.

En attendant les résultats de ces études, l'Académie recommande aux pouvoirs publics que, dès maintenant :

- à titre conservatoire soit suspendue la construction des éoliennes d'une puissance supérieure à 2,5 MW situées à moins de 1500 mètres des habitations.
- l'article 98 de la loi du 2 juillet 2003 soit modifié comme il se doit, pour que les éoliennes, dès qu'elles dépassent une certaine puissance, soient considérées comme des installations industrielles, et que leur implantation soit désormais soumise à une réglementation spécifique tenant compte des nuisances sonores très particulières qu'elles induisent.

Annexe A

Les éoliennes : éléments techniques et économiques

Production d'énergie éolienne dans le monde

Au niveau mondial, les énergies renouvelables se développent (+1,4 % par an), mais leur part dans la production d'électricité diminue : 18,1 % en 2002 contre 20,5 en 1993, car la consommation augmente tous les ans.

L'hydraulique reste la filière prépondérante (90,4 %), mais sa croissance est très faible, de l'ordre de 1% par an. Par contre, si l'éolien ne représente dans le monde que 0,33 % de la production d'électricité, sa croissance est devenue très vive. Dans l'Union Européenne, où elle a progressé de 37,8 % depuis 1993, 1,5 % de l'électricité est aujourd'hui produite par des éoliennes.

Production d'énergie éolienne en France

En France, 14 % de l'électricité est d'origine « renouvelable ». Bien qu'en augmentation très rapide (+ 59 % par an) en raison d'incitations financières très attractives, la production éolienne reste globalement marginale avec un peu plus de 200 MW installés[2].

Théoriquement, les possibilités de la France sont importantes : elle dispose du deuxième gisement éolien européen après le Royaume Uni. Il est situé sur le littoral ouest (de la Mer du Nord à La Rochelle), dans le couloir rhodanien et en Languedoc-Roussillon. Les trois parcs éoliens réalisés en 2004 ont une puissance totale de 43 MW.

L'ambition française affichée est de 10 000 MW éoliens en 2010[3].

Les éoliennes installées en France ont une puissance variable. Par exemple, et parmi les plus grandes et les plus récentes, les 8 éoliennes du Parc de Bouin en Vendée, installées en 2003, ont une puissance de 2,5 MW chacune. Elles mesurent 102 m de haut (pales de 40 m comprises), soit la hauteur d'un immeuble de 30 étages. Leur production globale est estimée à 40 GWh (40 millions de kilowatt heure) soit une « disponibilité » d'environ 25 %. Cette production représente la consommation électrique hors chauffage de 20 000 foyers et rapporte 200 000 euros de taxes professionnelles par an à la commune de Bouin.

Avantages de l'énergie éolienne

L'énergie électrique éolienne est naturellement renouvelable, non polluante et ne génère pas de gaz à effet de serre (hors processus de construction)

En France, utilisée en base, l'énergie éolienne permet de diminuer le recours aux centrales nucléaires et donc de réduire le volume des déchets nucléaires[4]

Elle permet une production délocalisée de l'électricité convenant très bien à des zones sans infrastructures de transport de l'électricité, en particulier dans les pays en voie de développement.

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[2] -Par comparaison, chacun des 58 réacteurs nucléaires a une puissance de 900 à 1300 MW.

[3] -Compte tenu des oppositions locales que rencontrent les projets de fermes éoliennes, cet objectif, qui nécessiterait d'implanter près de 4000 éoliennes, paraît très optimiste.

[4] -Si 10 000 MW éoliens étaient installés, la réduction des déchets serait d'environ 5 %

Inconvénients de l'énergie éolienne

Par rapport aux autres formes de production de l'énergie électrique (hydraulique, thermique à flamme ou nucléaire) l'énergie éolienne est nettement plus onéreuse. Le « combustible » est gratuit, mais une éolienne de 2,5 MW coûte environ 3 millions d'euros pour une puissance électrique moyenne réelle de 0,6 MW.

La production est aléatoire, très corrélée d'une éolienne à l'autre : les chutes de vent affectent toutes les installations d'une même zone[5]. Cela entraîne des instabilités du réseau de transport qui peut être déséquilibré, avec risque de panne, si la proportion d'éoliennes est trop importante. La capacité de 10 000 MW éolien est une limite pour la France.

Aussi les incitations financières à leur implantation alimentent-elles des discussions concernant le coût réel actuel de l'énergie ainsi produite, la réalité de la diminution de l'effet de serre dont elle serait responsable, voire la pollution industrielle de certaines installations anciennes abandonnées sans avoir été démontées.

Les implantations d'éoliennes sont généralement mal acceptées par les riverains et les associations de protection de la nature qui les accusent de pollution visuelle et sonore.

Ces nuisances seraient atténuées en cas d'implantation en mer, moyennant un surcoût important.

[5] -Pendant la canicule d'août 2003, par manque de vent, la disponibilité des éoliennes est descendue en moyenne à 8 % de leur capacité maximum.

Annexe B

Le bruit et les infrasons

Le bruit:

Un bruit, ensemble de vibrations apériodiques, se définit par son spectre fréquentiel, et l'éventail des intensités portées par chacune des fréquences. Rappelons ici que l'anatomie de l'oreille humaine la rend très sensible à l'éventail des fréquences 500-4000 Hz, et que c'est justement dans cette zone que l'homme a placé les fréquences les plus signifiantes de sa parole. La plupart des bruits industriels ont, à la source, des spectres assez voisins, qui diffèrent surtout par leurs intensités relatives [18], mais dans lesquels les intensités des infrasons sont souvent inférieures à celle de leur audibilité.

Il faut insister sur le fait que le spectre fréquentiel des éoliennes est, à la source, comparable à celui de n'importe quel engin industriel.

La diffusion de l'énergie sonore à partir de la source dépend de la nature du milieu dans lequel elle se propage, et de la longueur d'onde émise. La diffusion des fréquences graves est presque sphérique, alors que celle des ultrasons est pratiquement unidirectionnelle. La perte d'énergie en fonction de la distance est énorme pour les fréquences aiguës, faible pour les fréquences graves, et varie à peu près en raison inverse du carré de la distance pour les mediums. Ainsi, à plusieurs centaines de mètres d'une source de bruit intense, il n'y a plus guère de fréquences aiguës, et seules persistent les médiums et les fréquences graves. Parmi celles-ci figurent les infrasons.

Les Infrasons:

La vitesse de propagation des infrasons dans l'air est proche de celle des ondes audibles, soit de l'ordre de 330m/s. La longueur d'onde d'un son étant inversement proportionnelle à sa fréquence, celle d'un infrason de 20 Hz est d'environ 16 mètres, c'est-à-dire très supérieure à la taille de la plupart des êtres vivants, notamment de l'homme.

Lorsqu'un corps, objet ou être vivant, est soumis à des infrasons parvenus par propagation aérienne, ce corps se trouve immergé dans un champ acoustique dont à chaque instant la phase est identique; dans cette condition, plus de 90% de l'énergie mécanique reçue se réfléchit sur le corps; ce n'est pas le cas si ce corps contient des organes remplis d'air, ne communiquant pas avec l'extérieur (c'est-à-dire, chez l'homme, la caisse du tympan, le tractus digestif, l'arbre respiratoire lorsque la glotte est fermée). Lorsque la propagation se fait en plus par voie solidienne, entraînant par exemple la vibration des murs d'une cavité aérienne, l'énergie absorbée par le corps, lorsqu'il touche une de ces parois, peut-être beaucoup plus importante.

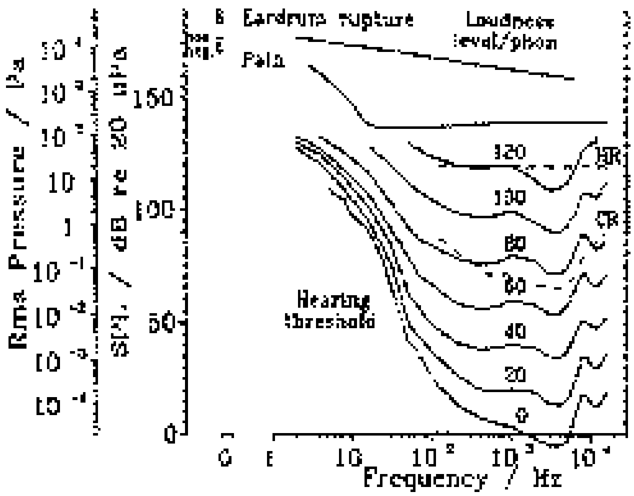

FIGURE 1 (d'après J. Dancer)

Courbes isosoniques de Fechner et Munson. Chaque point correspond à un son pur (fréquence en abscisse et intensité sonore en ordonnées, en coordonnées logarithmiques). Chaque courbe, appelée « isosone » relie les points qui correspondent à des sons qui donnent la même impression subjective d'intensité. La zone la plus basse de chaque courbe correspond au maximum de sensibilité de l'oreille (500 - 4000 Hz). La courbe 0 phone correspond aux plus faibles sons audibles; la courbe 120 phones au seuil de la douleur.

Ces caractéristiques obligent, pour réaliser les études physiologiques, à recourir à des chambres closes, dont deux panneaux opposés sont percés d'une fenêtre obturée par une membrane du type haut-parleur. Ainsi obtient-on assez facilement, s'il s'agit de corps peu volumineux, des variations de pression locale que l'on peut transmettre de façon efficace à des petits animaux; mais l'application à l'homme de ces signaux exige des installations beaucoup plus complexes. De plus, la détection et la mesure des infrasons se fait avec des appareils différents de ceux utilisés pour les ondes sonores, obligeant à recourir à des transducteurs comparables à des baromètres variables selon les fréquences.

Par ailleurs, la directivité des ondes sonores diminue avec la fréquence. Un émetteur d'ultrasons rayonne pratiquement dans une seule direction. Au contraire, les ondes émises par un générateur d'infrasons sont pratiquement sphériques et rayonnent de tous côtés. Au dessus de 150 dB, c'est-à-dire juste au-dessus de leur seuil liminaire d'audibilité, il devient vite impossible de produire, de manière contrôlée et répétitive, des niveaux d'ondes infrasonores se propageant en espace libre.

La propagation des infrasons, pourvu que leur énergie de leur source soit suffisamment importante, peut donc se faire sur des distances considérables. Par suite de leur réflexion sur les hautes couches de l'atmosphère, les infrasons aériens émis par une explosion nucléaire peuvent faire plusieurs fois le tour du globe terrestre, ce qui permet de détecter ces explosions à grande distance. De plus, les basses fréquences se propagent mieux en milieu solide qu'en milieu aérien; les infrasons solidiens sont moins amortis que les infrasons aériens.

Les infrasons naturels (vent, tonnerre, etc) font partie de l'environnement naturel de l'homme. Même s'ils sont inaudibles parce que d'intensité trop faibles, ils sont produits par de nombreuses activités quotidiennes :

7. jogging - 90 dB à 2 H;
8. nage = 140 dB à 0,5 Hz;

9. voyage en voiture vitres ouvertes = 115 dB à 15 Hz;

10. au cours de certaines manœuvres de grattage du conduit auditif externe = 160 dB à 2 Hz;

salle des machines (d'un paquebot par exemple) = 130-140 dB à 5-20 Hz.

Type de source	8 Hz	16 Hz	32 Hz	63 Hz	125 Hz
Véhicule léger à 100 km/h	95	90	88	82	78
Camion à 80 km/h	103	105	102	92	88
Train, vitres ouvertes à 80 km/h	97	101	101		
Éolienne 1 MW à 100 m	58		74	83	90
Seuil d'audibilité	**105**	**95**	**66**	**45**	**29**

TABLEAU I (d'après J. Rolland)
Seuil d'audibilité en dBA des basses fréquences et de quelques infrasons détectables instrumentalement dans les circonstances de la vie courante.

A mesure que la fréquence d'un son baisse en dessous de la zone des fréquences conversationnelles, l'énergie nécessaire pour qu'il soit perçu par l'oreille humaine croît rapidement. De plus, dans ces gammes des basses fréquences, si, à de hautes intensités, l'oreille peut, jusqu'à 20 Hz, reconnaître une tonalité, en dessous de cette zone elle ne perçoit plus que des phénomènes distincts décrits comme des battements. Cette particularité contribue à la définition des infrasons. Mais 20 Hz est une limite floue, car la non linéarité de l'oreille moyenne entraîne des distorsions responsables d'une perception sonore parasite variable.

Aux intensités inférieures à 160 dB les effets physiopathologiques des infrasons sont bien répertoriés, même si leur étude chez l'homme implique des installations volumineuses, qui n'existent que dans des laboratoires très spécialisés.

Le seuil d'audibilité des infrasons chez l'homme est de 105 dB pour 8 Hz, de 95 dB pour 16 Hz, 66 dB pour 32 Hz, 45 dB pour 63Hz et de 29 dB pour 29 Hz. Le seuil de douleur se situe entre 140 dB à 20 Hz et 162 dB à 3 Hz. On n'observe pas de fatigue auditive, aussi bien pour 140 dB à 14 Hz pendant 30 minutes, que pour 170 dB entre 1 et 10 Hz pendant 30 secondes.

Mais il s'agit là d'énergies énormes, qu'on ne retrouve (hors laboratoire) que dans des explosions.

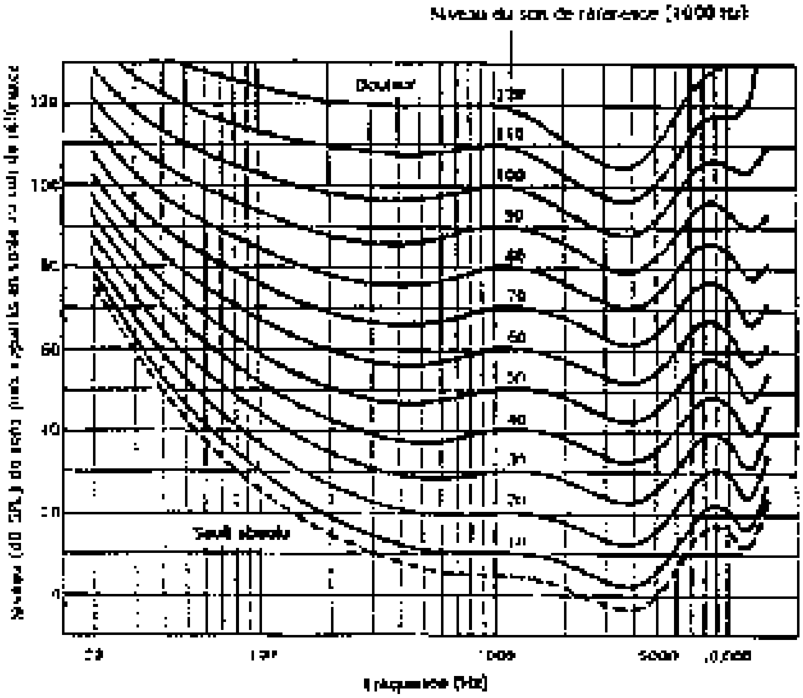

FIGURE 2 (d'après A. Dancer)

Energie nécessaire (en abscisse) pour obtenir le seuil liminaire et les seuils de sensation d'intensité équivalente, par rapport à un son de 1000 Hz servant de référence, pour différentes fréquences (en ordonnée). Les infrasons (en haut et à gauche de la figure) nécessitent une très forte intensité pour être perçus, et une intensité tout à fait hors norme pour approcher le seuil douloureux.

Les infrasons, comme les sons audibles, peuvent, eux aussi, donner naissance à des phénomènes de résonance; la poitrine résonne entre 40 et 60 Hz, et l'abdomen faiblement entre 4 et 8 Hz. L'ouverture de la glotte permet au contenu aérien thoracique d'entrer en résonance à 1 Hz, si bien qu'aux alentours de 165 dB on peut observer une respiration passive modulée par l'infrason.

L'oreille moyenne est la première à pâtir à mesure qu'augmente l'intensité des infrasons, parce que la membrane élastique du tympan est sensible aux variations de pression et absorbe bien mieux l'énergie que le reste du corps. On peut ainsi observer à partir de 130 dB une hyperhémie tympanique transitoire disparaissant à l'arrêt de la stimulation
Les niveaux supérieurs à 160 dB, qui pourraient entraîner des lésions cochléaires, nécessiteraient des générateurs d'une puissance et d'un encombrement totalement irréalistes en champ libre.
L'atteinte vestibulaire représente l'essentiel des phénomènes déclenchés dans l'oreille interne par les infrasons. Ces troubles reflètent la diffusion au vestibule de l'énergie délivrée, par l'étrier, aux liquides labyrinthiques. Lors d'une tympanométrie, geste de routine en audiométrie clinique, on applique une pression statique dans le conduit auditif externe, qui réalise une pression monaurale et peut entraîner un léger vertige. Toutefois, chez l'animal, l'exposition de 169 dB à 10 Hz ou de 158 dB à 30 Hz, n'induit pas de nystagmus. Chez l'homme soumis à des niveaux variant entre 142 et 150 dB, on n'observe pas non plus de nystagmus, que la stimulation soit monaurale ou bilatérale, ou soit en phase ou en opposition de phase. Cependant, des bouffées de bruit (*tone bursts*) ou des sons modulés en amplitude peuvent, en application monaurale ou dissymétrique de 125 dB, au rythme de trois par seconde, produire des mouvements oculaires rapides ou un déséquilibre transitoire.

Par ailleurs, en se rapprochant des fréquences conversationnelles, de la toux et une « sensation d'étouffement » ont été rapportées pendant l'exposition à des bruits de sirènes de 150 à 154 dB dans la gamme 50 à 100 Hz. Une gêne ne s'observe qu'avec des stimuli comportant à un spectre sonore ayant de fortes pentes aux basses fréquences (8 dB/oct), et à une intensité supérieure à celle du seuil de perception sonore. Des effets dits "psychologiques", avec manque de concentration peuvent apparaitre au-dessus de 110 dB, chez le sujet sain expérimentalement soumis aux infrasons.

Dans le cas particulier des éoliennes, notons que :
- à 100 mètres d'une éolienne de 1 MW, on trouve 58 dB à la fréquence 8Hz, 74 dB à la fréquence 32 Hz, 83 dB à la fréquence 63 Hz, 90 dB à la fréquence 125 Hz ,
- les basses fréquences mesurées à 100 mètres des éoliennes se situent donc à au moins 40 dB en dessous du seuil d'audibilité.

A cette distance, l'intensité des infrasons est si faible [19] que ces engins ne peuvent provoquer ni cette gêne, ni cette somnolence liées à une action des infrasons sur la partie vestibulaire de l'oreille interne, que l'on ne peut observer qu'aux plus fortes intensités expérimentalement réalisables.

Les phantasmes nés des infrasons

Pour une certaine partie de la population, et contrairement aux ondes sonores que chacun peut percevoir, les basses fréquences se situent dans un monde mystérieux qui fait peur. Les raisons invoquées sont les suivantes :

- elles accompagnent des événements maléfiques : tonnerre, explosions, notamment nucléaires, etc.
- ces ondes se propagent très loin,
- il est très difficile de se protéger contre les ondes infrasonores qui, de l'extérieur, pénètrent très facilement à l'intérieur des bâtiments.
- les phénomènes physiologiques qu'elles peuvent engendrer aux très fortes intensités sont redoutés.

On remarquera que le grand public ignore que ces hautes intensités dont l'ingéniosité de l'homme peut être responsable (explosions d'origine diverse, bang supersonique, etc), n'ont rien à voir avec l'intensité des infrasons produits par le reste de son activité industrielle, notamment celle engendrée par les éoliennes.

Cette peur des infrasons est entretenue, notamment sur Internet, par la référence à une publication [20] datant de 1966. Ce travail ancien vient d'être analysé par G Leventhall [21] ; il en a repris tous les éléments, en en faisant méthodiquement la critique. Il a pu montrer que la méthodologie employée était inadmissible et ses conclusions inacceptables, au regard des exigences actuelles d'un travail scientifique.

Bibliographie

La bibliographie scientifique concernant la pathologie induite chez l'homme par les éoliennes est limitée.

Cette rareté est encore plus nette si on n'envisage que **l'étude d'impact des infrasons sur l'homme** : courant 2005, Medline ne recensait à ce propos que 179 articles, cette action n'étant le plus souvent qu'évoquée au sein d'une étude plus générale des effets d'une stimulation sonore. Aussi, notre enquête s'est-elle spécialement penchée sur l'état actuel des connaissances concernant les infrasons, en recevant, lors de ses différentes auditions, deux spécialistes de ces phénomènes physiques :

11. Monsieur Jacques ROLLAND, Directeur du Centre Scientifique et Technique du Bâtiment à GRENOBLE [6]
12. le Docteur Armand DANCER, Directeur de Recherches à l'Institut de Recherches Franco-Allemand de Saint-Louis [7]

Insistons aussi, parce qu'elles sont très récentes, sur les publications originales du **First International Conference on Wind Turbine Noise: Perspectives for Control**. Elles ne sont pas encore publiées ni disponibles sur le Net, mais peuvent être consultées à la Bibliothèque de l'Académie.

Malgré le manque de rigueur scientifique de la plupart des sites sur internet qui traitent des relations entre infrasons et éoliennes, ils ne peuvent être ignorés, tant leur influence sur les populations intéressées peut être grande. A ce propos, on citera le travail paru en 2002, lisible sur http://crrm.u-3mrs.fr/ile-rousse/2002/IleRousse2002.pdf : « Les infrasons entre science et mythe : la bibliométrie peut-elle contribuer à clarifier une vérité scientifique controversée ? ». L'auteur, Bertrand Goujard, ingénieur, y fait une étude de la bibliographie sur Internet concernant les infrasons, qui mérite d'être lue.

[1] Manuel préliminaire de l'étude d'impact des parcs éoliens. *Agence de l'Environnement et de la Maîtrise de l'Energie* (Ademe), Ministère de l'Ecologie et du Développement Durable, février 2001, p 117.

[2] Guide de l'étude d'impact sur l'environnement des parcs éoliens. *Agence de l'Environnement et de la Maîtrise de l'Energie* (Ademe), Ministère de l'Ecologie et du Développement Durable, Fév 2005, p 75-83

[3] KLUG H. - A review of wind turbine noise. *First International Conference on Wind Turbine Noise: Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 11 p.

[4] HENRIKSEN O.D., DEGN U., MILLER L., TOUGAARD J. - Low frequency underwater noise from offshore wind turbines: detection ranges and potential implications for marine mammals. *First International Conference on Wind Turbine Noise: Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 9 p.

[5] GAMBA R., GARRIGUES S., SENAT C. - Maping of upwind and downwind airborne noise propagation. *First International Conference on Wind Turbine Noise: Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 14 p.

[6] C.S.T.B - 24, rue Joseph Fourier - 38 401 Saint Martin

[7] French-German Research Institute - ISL - 68301 Saint-Louis France

[6] Direction départementale des Affaires Sanitaires et sociales de Charente-Maritime, Santé-Environnement, Rapport de Synthèse des campagnes de mesures acoustiques réalisées autour du parc éolien de Saint-Crépin, La Rochelle, 19 janvier 2006.

[7] Manuel préliminaire de l'Etude d'impact sur l'environnement des parcs éoliens *Agence de l'Environnement et de la Maîtrise de l'Energie* (Ademe), Ministère de l'Ecologie et du Développement Durable, février 2001, p 117.

[8] Guide de l'étude d'impact sur l'environnement des parcs éoliens. *Agence de l'Environnement et de la Maîtrise de l'Energie* (Ademe), Ministère de l'Ecologie et du Développement Durable, Fév 2005, p 77.

[9] CHOUARD C.H., Pollution sonore de la ville. *C R Acad Sci III*, 2001 jul 324(7), 657-661

[10] LEVENTHALL G. - How the "mythology" of infrasound and low frequency noise related to wind turbine might have developed. *First International Conference on Wind Turbine Noise: Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 15 p.

[11] PEDERSEN E., WAYE K.P. - Human response to wind turbine noise : annoyance and moderating factors. *First International Conference on Wind Turbine Noise. Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 13 p.

[12] TOMEI F., FANTINI S., TOMAO E., BACCOLO T.P., ROSATI M.V. - Hypertension and chronic exposure to noise. *Arch. Environ. Health*, (2000), *55*, 319–325.

[13] BABISCH W., ISING H., GALLACHER J.E., SWEETNAM P.M., ELWOOD P.C. - Traffic noise and cardiovascular risk; the Caerphilly and Speedwell studies, third phase-10-year follow up. *Arch. Environ. Health*, 1999, *54*, 210–216

[14] SOULAIRAC A. - Le bruit : aspects neuro-endocriniens. *Bull. Acad. Natl. M*, 1992, *176*, 401–405.

[15] MOURET J., VALLET M. - Les effets du bruit sur la santé. *Ministère de l'Emploi et de la Solidarité*, 1998, Comelli, Paris.

[16] WAYE K.P. - Effects of low frequency noise on sleep. *Noise and health*, 2004, 6, 23, 87-91.

[17] Guide de l'Etude d'impact sur l'environnement des parcs éoliens. - *Agence de l'Environnement et de la Maîtrise de l'Energie* (Ademe), Ministère de l'Ecologie et du Développement Durable, 2005, p 75.

[18] BERGLUND B., HASSMEN P. - Sources and effects of low-frequency noise. *J. Acoustic. Soc. Am.*, 1996, 99 (5), 2985-3002.

[19] Low Frequency Noise and Wind . British wind energy association, feb 2005, Turbineshttp://www.bwea.com/ref/lowfrequencynoise.html

[20] GAVREAU V. CONDAT R. AND SAUL H. - Infrasons. générateur, détecteurs, propriétés physiques, effets biologiques, *Acustica*, 1966, *17*, 1-10.

[21] LEVENTHALL G. - How the "mythology" of infrasound and low frequency noise related to wind turbine might have developed. *First International Conference on Wind Turbine Noise: Perspectives for Control proceedings*, Berlin 17-18 oct 2005, 15 p.

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L'Académie, saisie dans sa séance du mardi 14 mars 2006, a adopté le texte de ce rapport à l'unanimité.

Pour copie certifiée conforme,
Le Secrétaire perpétuel,

Professeur Jacques-Louis BINET

EOLIENNES, SONS ET INFRASONS:

EFFETS DE L'EOLIEN INDUSTRIEL SUR LA SANTE DES HOMMES

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et de la communication,

Spécialiste de l'Information Scientifique et Technique (IST)

décembre 2004

éoliennes, en les éloignant des habitations non de 500 m comme ils le suggèrent

minimum à 5 km en tenant compte des infrasons..

En conclusion, il faut refuser les éoliennes situées à moins de 5 km de toute habitation à cause des risques provoqués par les infrasons.

Introduction

Du point de vue physique, le son est un phénomène produit par la mise en vibration des molécules de l'air ambiant à l'aide d'un émetteur sonore.
Du point de vue physiologique, le son est une sensation auditive subjective qui dépend de celui qui l'entend. Il y a donc une part subjective dans la perception du bruit.

Les sons se caractérisent par
- l'amplitude ou niveau de pression sonore, exprimée en décibel (dB), et pondérée en dB(A) pour reproduire la sensibilité de l'oreille. Elle est donnée à un endroit précis par rapport à l'observateur
On la mesure à l'aide d'un microphone
- et par leur fréquence, exprimée en Hertz (Hz) qui est la période de vibration (ex : 10 Hz= 10 périodes de vibrations par seconde)
Dans l'échelle des fréquences, on trouve:
- les infrasons non audibles, (au dessous de 16 Hz ou 20 Hz) qui sont des vibrations acoustiques de très basse fréquence,
- les sons audibles (fréquence entre 16-20 et 16 000-20 000 Hz),
- et au-delà les ultrasons (sons aigus, non audibles chez l'homme, mais perçus par les chiens et les chauves-souris)[1]
Ainsi le son est une onde, qui n'est pas forcément sonore et audible.(entendue)

Définissons le bruit. C'est un son indésirable, qui dérange ou crée des dommages aux récepteurs.

[1] [illegible]

I- Sons audibles et éoliennes

Les éoliennes émettent 2 sortes de bruits:

I-1. le bruit mécanique

Grâce à une technologie améliorée, le bruit mécanique lié à la transmission et à l'alternateur a été réduit de manière significative par le biais d'une insonorisation améliorée de la nacelle et d'autres mesures comme la modification ou la suppression des engrenages, sur certains modèles où les arbres de transmission sont montés sur des coussinets amortisseurs.
Il reste des incertitudes tant que l'on ne sait pas quel modèle (avec année de construction) sera choisi par le promoteur éolien, ce qui est le cas de figure pour certains projets.

Les pales font tout de même 1500 révolutions / mn grâce à un multiplicateur de vitesse pour entraîner le générateur. Le bruit produit par une éolienne atteint 120 dB au niveau de la nacelle (bruit d'une discothèque), et selon les constructeurs, 45 dB à 300m (bruit dans un bureau). Évidemment ensuite il faut considérer le nombre d'éoliennes, (ex.. 10 éoliennes= 55 dB) et d'autres facteurs comme la topographie, le bruit ambiant, etc..

Les progrès technologiques permettant de réduire le bruit des éoliennes sont malheureusement contrebalancés par le fait que les machines sont de plus en plus puissantes.
Elles sont aussi de plus en plus hautes, (80, puis 115 m) or les sons se propagent plus facilement si leur source est plus élevée, puisqu'en hauteur il y a moins d'obstacles à leur propagation.

I-2. le bruit aérodynamique,

Il est causé par les irrégularités de flux d'air autour des pales, autour de la tour, et par les changements de vitesse du vent[1]
Le bruit aérodynamique est actuellement le plus important, on ne peut pas l'éradiquer.

Jusqu'à 15m/s, les pales fendent l'air comme les ailes d'un planeur et émettent le même bruissement (appelé swish en anglais)…Au delà, des turbulences sur le bord de fuite de la pale génèrent des bourdonnements.

A chaque passage dans l'alignement du pylône, les pales émettent un "swish" qui ressemblent à un jappement.

[1] "Wind turbine noise issues" Renewable energy research laboratory, center of energy efficiency, A. L. Rogers, PhD, University of Massachusetts at Amherst, March 2001

I-3. Les aléas sonores

L'impact sonore d'un parc éolien est mesuré avant l'arrivée des machines par simulation informatique: on compare le niveau sonore près des habitations riveraines, avec (bruit ambiant) et sans le bruit prévu du parc éolien (bruit résiduel). La différence ou émergence ne doit pas dépasser 5 dB le jour et 3 dB la nuit, selon la réglementation française.

Les modèles de bruit des éoliennes ne tiennent en général pas compte des éléments suivants [3]

- la topographie
- les obstacles importants dans la trajectoire du vent
- la réfraction du bruit due aux effets atmosphériques (inversions de température)
- tous changements dans la propagation des sons qui modifient la fréquence (par exemple il peut se produire des *harmoniques* , augmentation par dizaines de Hz)

Turbulences

Il est vrai d'affirmer que les bruits dus au vent dans les arbres augmentent très vite avec la vitesse et peuvent dépasser 60 dB à 15m/s, ce qui peut couvrir le bruit émis par les éoliennes.

Pour un vent constant, la signature acoustique des éoliennes est constante.

Malheureusement, dans les régions où les vents sont plutôt turbulents, le bruit varie avec les mouvements des rotors ,et si les machines sont situées sur une petite crête avec des reliefs alentours, les rafles de vent créent des bulles sonores désagréables.

Topographie

Les sons audibles émis par les éoliennes ne se propagent pas de façon rectiligne mais suivent des trajectoires propres à la topographie.

Les sons se propagent plus facilement si vous habitez sous les vents dominants.

Le cas le plus prégnant de propagation du son se trouve dans le cas où le vent est suffisamment fort et bruyant en altitude pour faire tourner les éoliennes, et où il est très faible dans les vallées environnantes protégées du vent donc calmes. Dans ce cas les machines sont entendues nettement à 1000m.[4]

Jour et nuit

L'extrapolation des vitesses de vent faite à partir des relevés des mâts de mesure est fausse la nuit : la nuit la propagation du bruit est différente (et plus élevée) que le jour (Étude de l'Université de Groningen Pays-Bas[5])

Ces considérations: turbulence, topographie, et amplitude donc expliquent pourquoi des mesures acoustiques théoriques des promoteurs peuvent être rassurantes, et la réalité ensuite décevante..

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[3] http://www.[illegible]

[4] Expérience faite par l'auteur et un témoin en contrebas des éoliennes de Canaures (Aveyron) , a Brusque.

[5] www.rug.nl

Ainsi le bruit des éoliennes continue à être un problème pour les populations. Le Daily Telegraph[6] rapporte que des anglais qui étaient favorables à l'implantation d'éoliennes ont changé d'avis après avoir été confrontés au bruit d'un parc éolien situé près de chez eux.

Il faut aussi considérer que les visites en groupe de sites éoliens existants ne donnent qu'un aperçu de la situation qu'on pourrait rencontrer. En effet:
- vous parlez et vous êtes distraits, vous n'écoutez pas le silence
- vous ne percevez qu'un cas de figure à un moment donné, qu'une seule situation qui ne sera pas forcément la vôtre
- si le promoteur organise la visite, il a pu réduire le bruit des éoliennes en les bridant.

I-4. Effets du bruit des éoliennes sur notre santé

le Welsh Select Affairs Committee cite au sujet des éoliennes *« Dans le cas de parcs éoliens existants, nous constatons qu'il y a des cas de personnes qui subissent un bruit presque continu lors du fonctionnement des aérogénérateurs, à des niveaux ne constituant pas une nuisance interdite par la loi ou dépassant les conditions réglementaires, mais qui sont clairement dérangeants et désagréables, et qui peuvent avoir des effets psychologiques »*)[7]

Citons les troubles rapportés par des médecins anglo-saxons suite à des consultations de riverains d'éoliennes (observations cliniques):

- fatigue auditive et nerveuse
- stress et arythmies cardiaques..
- troubles d'anxiété et déprimes
- effets sur la qualité et la quantité de sommeil.

Bruit et perturbations du sommeil

A ce sujet, dans une thèse de médecine éditée en 2004 [8], l'auteur rapporte que pendant le sommeil, malgré l'absence d'une perception consciente, certains stimuli sonores provoquent des réactions telles que l'accélération du rythme respiratoire, des tachycardies, des mouvements corporels, le micro-réveil de 9 à 15 secondes, un changement des stades du sommeil
De plus, l'impact du bruit sur le sommeil varie en fonction de
- l'âge (le seuil d'éveil est plus élevé chez les personnes âgées, et les difficultés de ré endormissement plus élevées)
- le sexe: nous les femmes tolèrent moins bien le bruit que les hommes
- le profil psychologique

[6] "Wind farms make people sick who live up to a mile away" / L. Milner- In: Daily Telegraph 25 juin 2004

[7] www.canadc.org/research/wind_pes_present.htm CANADA
www.geocities.com/argonnes

[8] BREANT Sigrid *"troubles du sommeil et de l'éveil chez les personnes âgées"* Thèse de doctorat en Médecine Paris, Cochin, 2004.

- les caractéristiques du bruit (le sommeil est plus perturbé si le bruit est intermittent (ex: l'éolienne redémarre) que continu (cas de vents réguliers)
- le stade de sommeil (ex : on se réveille plus facilement en période de sommeil paradoxal)
- la charge émotive du bruit et sa signification (si vous haïssez les éoliennes, vous serez plus perturbé par leur bruit!)

Enfin, les troubles du sommeil qu'on pourrait considérer à première vue comme non dangereux induisent des troubles de l'éveil ou somnolence dans la journée, ce qui a des incidences graves sur la santé publique (en France, 1 accident de la route sur 3 est lié à la somnolence)
Par cet exemple on peut voir que des troubles du sommeil sans vrai danger apparent peuvent induire des effets graves pour la santé publique.

Eoliennes et sensations de jour
Notre oreille est un organe extrêmement sensible, même aux bruits relativement légers des éoliennes récentes
Nous percevons de jour d'autant plus les bruits qu'ils sont répétitifs et rythmés (ce qu'on appelle les tons nets, comme la goutte d'eau qui tombe régulièrement dans l'évier, la porte qui claque plusieurs fois), et moins les bruits aléatoires (= bruits blancs, par ex. un seau d'eau renversé).
Pour en tenir compte, il faudrait ajouter des dB(A) aux valeurs obtenues par les laboratoires d'acoustique [9]

Selon des témoignages de riverains des éoliennes, les bruits sont associés à celui d'un réfrigérateur ou d'une machine à laver, ou même "on fait de ciment au dessus de ma tête" dit un riverain

"Seulement lorsqu'elles sont arrêtées, j'entends le silence, elles nous ont à l'usure, vous ne pouvez pas y échapper".[10]
Le bruit des éoliennes leur détruit la vie

Certes on trouvera des gens qui paraissent moins affectés, les gens sont différents et ne perçoivent pas tous le bruit d'une manière identique, comme ns l'avons vu

Cependant certaines personnes , même si elles sont minoritaires, sont exposées à un risque, et il faut en tenir compte de même qu'on tient compte des 5% des handicapés en France, qui font heureusement entendre leur voix par le biais des associations auprès des pouvoirs publics.

Il faut retenir des témoignages des médecins anglais que les bruits audibles des éoliennes peuvent affecter la santé des hommes au delà d'un mile (1609 m)

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[9] www.windpower.org : Association danoise de l'industrie éolienne.
[10] "Wind farms make people sick who live up to a mile away" / C. Milner- In: Daily telegraph 25 janv 2004.

II- Les infrasons

Les infrasons ou vibrations acoustiques à basse fréquence sont nettement moins connus, parce qu'ils ne sont pas audibles.

En effet, aux fréquences inférieures à 16- 20 Hz, nous n'entendons plus les sons, mais nous pouvons percevoir les vibrations (infrasons) qui enveloppent tout notre être [11] . Même à la fréquence de 1 Hertz nous les percevons si la pression sonore est suffisante.[12]

II-1. Propagation:

Les infrasons sont inaudibles mais très puissants et se propagent dans l'air plus vite que le vent (vitesse : 360m/s), et à de plus longues distances de leur source d'émission que les sons audibles.

En effet, l'atmosphère et ses différents gradients de température jouent le rôle d'un guide d'onde [13]

Ils se propagent plus librement que les sons audibles car ils perdent moins d'énergie.

Aucun obstacle ne les arrête, ni les arbres, ni le vent, ni les murs des maisons, et l'insonorisation des fenêtres est inefficace contre les infrasons.

Notons la phrase de l'ADEME qui informe le public sur les infrasons d'une drôle de manière:"*Si les basses fréquences peuvent se propager assez loin, l'intensité sonore diminue rapidement*" [14]

Cette phrase est contradictoire et prête à confusion, car si les infrasons se propagent loin, c'est bien parce qu'ils perdent moins d'énergie que les sons, donc leur intensité sonore diminue moins vite que celle des sons.

En fait, selon A Le Pichon, chercheur au CEA[15] , les infrasons émis par un parc éolien de 7 éoliennes de 100m de haut se propageraient jusqu'à 5 à 10 km à une fréquence de 10 Hz (qui peut changer en fonction des obstacles et du vent).

II-2. Détection

La détection des infrasons peut se faire par différents capteurs en fonction de leur fréquence: [16]

- F= << 1Hz (explosions nucléaires dont les durées de période dépassent, à grande distance plusieurs mn): le baromètre (*barograph* en allemand)
- F> 0,001 Hz = les microphones électrostatiques couvrent la gamme à partir de 1 Hz

Pour les niveaux infrasoniques élevés, on utilise également les microphones piezoelectriques

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[11] Laboratoire acoustique du CNRS, île de France, chapitre "infrasons"

[12] Altmann, Jürgen. Acoustic Weapons – A prospective Assessment. Universität Dortmund / Institut für Experimentalphysik III April 1999 p.16

[13] Contribution d'un modèle 3D de tracé de rayons dans un milieu complexe pour la localisation de sources infrasonores. Thèse de doctorat en géophysique en cours . CEA /Alexis le Pichon, dir. 2004

[14] ADEME « Des éoliennes dans votre environnement? 6 fiches pour mieux comprendre les enjeux » février 2002

[15] Commissariat à l'énergie atomique Paris France

[16] Encyclopedie Universalis

Pour la gamme de 0,003 à 30 Hz on utilise le microphone "solion" : les vibrations transmises à un liquide modulent le courant des ions d'une électrolyte.

II-3. Qu'est-ce qui produit des infrasons,?

LES SOURCES NATURELLES

- Les infrasons se produisent dans l'atmosphère, créés par des événements naturels comme les coups de tonnerre, les éruptions volcaniques, les avalanches, les séismes qui peuvent faire voler en éclats les vitres des fenêtres à 100 km de leur source émettrice

Les météorites entrant dans l'atmosphère [17] génèrent aussi des infrasons.

La houle océanique aussi, à des fréquences très faibles (0,2 à 0,3 Hz)

LES SOURCES ARTIFICIELLES

Le "bang" des avions supersoniques émet des infrasons.

Les explosions comme la récente explosion du gazoduc de Ath près de Bruxelles, qui a été enregistrée par les capteurs à infrasons du BRG à plus de 1000 km, dans l'est de l'Allemagne (frontière autrichienne et de la République Tchèque) , plus fortement à HUFE (nord de l'Allemagne), et aussi à Flers en Normandie. [18]

- les essais nucléaires, émettent des infrasons de si forte amplitude que leur distance de propagation fait le tour de la terre, comme les séismes. Un réseau mondial de capteurs d'infrasons permet de surveiller la planète et de détecter l'origine du moindre essai nucléaire.

Dans la vie de tous les jours, les passages rapides de camions, des motos sur les routes et les trains émettent des infrasons d'intensité nocive

Quand vous claquez la porte, vous émettez aussi des infrasons, qui sont en revanche d'un niveau insignifiant

-le basson profond d'un orgue [19] (les infrasons correspondent aux basses, alors que les ultrasons correspondent aux aigués)

Les micro-ondes produisent des fréquences très élevées, les ultrasons, mais engendrent aussi des battements à basse fréquence .

- Certains instruments: les compresseurs à piston [20] ou plus généralement des machines vibrantes : ex: climatiseurs ou ventilateurs à rotation lente émettent aussi des infrasons

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[17] Gouvernement Canada. Commission géologique.

[18] BRG: laboratoire de recherche allemand en séismologie et infrasons. www.seismologie.brg.de

[19] Cf multimédia magazine du Web

[20] Meubles Lyon

Et même quelques appareils électroménagers comme le lave-linge en cycle d'essorage

- Dans les cabines des avions, à l'intérieur des voitures, il ne reste que les composantes graves, les aigües ayant été absorbées par les silencieux et les isolants acoustiques et l'air.

Nous remarquons que les phénomènes naturels et artificiels décrits ci-dessus n'apparaissent que d'une manière ponctuelle, passagère. S'ils sont nocifs, ils ne sont subis que momentanément.

En revanche les machines lourdes rotatives [21], les bruits industriels des usines (ZI)[22], et **l'éolien industriel** produisent des vibrations infrasoniques périodiques et répétitives, ce qui, nous allons le voir, peut avoir des effets plus néfastes sur l'organisme humain.

Les aérogénérateurs émettent des infrasons, ceci n'est controversé par personne: par quel mécanisme?
Selon Dr Hartmann, spécialiste des infrasons[23] (laboratoire BGR, Allemagne), les infrasons sont causés par la rotation des pales qui crée des flux d'ondes à basse fréquence en passant devant la tour. La fréquence dépend de la vitesse de rotation de l'éolienne. Elle peut augmenter en cas d'obstacles (vents).
Il est possible aussi qu'il y ait un phénomène de résonance dans le mât car nous savons par exemple qu'un tuyau de 24 m peut servir d'émetteur d'infrasons et résonne à 2,5 Hz [24].

II-4. Impact des infrasons sur l'organisme humain

Le sujet est très complexe pour plusieurs raisons:
-La recherche recouvre une grande variété d'approches: sciences physiques (acoustique) et aussi médecine expérimentale. Disciplines cloisonnées, sans vue transversale du problème
- Leur détection est difficile, il est en effet parfois difficile de séparer l'action des infrasons de celle des sons audibles, (on a les 2 en présence jusqu'à une certaine distance), et des autres facteurs de pollution humaine.
- Le caractère psychologique de certains symptômes est difficile à saisir de manière rigoureuse
- Ils affectent certaines personnes , et pas d'autres
- Ils affectent différemment en fonction de la durée d'exposition, de la fréquence (Hz), l'amplitude (dB) des infrasons, et de la distance de la source.

[21] "Infrasound at working places in Finland In:Combined Effects of Occupational Exposures / Jauhiainen HK . In: Proceedings of the Fourth Finnish-Soviet Joint Symposium. Institute of Occupational Health, Helsinki, Finland, 1984, pp 134-139
[22] Encyclopédie Universalis
[23] hartm@sdac.hannover.bgr.de
[24] Encyclopédie Universalis

- D'une manière générale, on a prouvé que les infrasons qui peuvent se produire dans un silence total ont des effets négatifs sur la santé humaine. Je cite les symptômes:

- système nerveux central: fatigue, insomnies, troubles du sommeil et du repos.

- Psychisme : problèmes de rendement, perte de concentration , nervosité, oppression, agressivité, stress ou anxiété, et globalement changements émotionnels et cognitifs. [25]

- Système neurovégétatif: incidences sur l'équilibre, les rythmes respiratoire et cardiaque, le système digestif (nausées), ces troubles existeraient dans le cas d'exposition prolongée

Ceci est confirmé notamment par de nombreux articles du *Journal of Low Frequency Noise, Vibration and Active Control* publiés par Multi-science Publishing Co Ltd,[26] , et par un laboratoire de recherche suisse qui s'intéresse à la sécurité des travailleurs. [27]

Les risques de maladies vibro-acoustiques sont connus chez les pilotes d'avion à réaction et les cosmonautes. Par exemple, la NASA limite l'exposition aux infrasons de ses pilotes dans les engins spatiaux au seuil de 24 h à 120 dB (pour des fréquences de 1 à 16 Hz) pour que son personnel reste indemne. Il peut persister cependant des réactions visuelles et des troubles du système circulatoire à ces amplitudes, même si les sujets sont en parfaite santé [28]

Des dizaines d'études expérimentales effectuées dans le monde industriel et en laboratoire sur les hommes et les animaux mettent aussi en évidence et confirmant ces troubles de comportement, et les changements physiologiques suivants, augmentation de la pression artérielle, changement du rythme respiratoire et troubles d'équilibre, après des expositions brèves (5 à 50 min), à des niveaux de pression sonore de 90 à 120 dB (fréquences :7 à 16 Hz).

A des expositions prolongées (45, 60 jours), chez le rat, à la fréquence de 8 Hz, on observe des changements biochimiques et morphologiques des tissus. [29] Les effets observés sont plus prononcés à des fréquences plus hautes .
A des durées d'exposition plus longues (4 mois, par exemple) certains effets négatifs sur la santé sont irréversibles.

En fait de l'amplitude des infrasons dépendent la nature des troubles sur la santé. Si vous combinez forte amplitude et fréquence élevée, autour de 16 à 17 Hz ,

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[25] Wall. Military Use Of Mind Control Weapons
[26] A questionnaire survey of complaints of infrasons... / H. Moller.- In: *Journal of Low Frequency Noise, Vibration and Active Control* September 2002, vol. 21, no. 2, pp. 53-63(11)
[27] Recommandations et règles de sécurité au travail / CUSSTR commission Universitaire pour la Santé et la Sécurité au Travail Romande , décembre 2001.
[28] Encyclopédie Universalis
[29] "Infrasound. Brief review of toxicological literature infrasound Toxicological Summary. Nov. 2001 ET "Early response of the organism to low-frequency acoustic oscillations - Karpova N I. and oth. In: Noise Vib. Bull. 11(65). pp 100-103.

les infrasons deviennent même une arme acoustique redoutable, appelée "arme à infrasons", qui est testée par les laboratoires de la Défense de plusieurs pays, dont la France depuis 1960 [30] (avec le secret défense). En effet, l'arme à infrasons provoque des effets physiologiques très nets sur un être humain, déclenchant des troubles de vision, des désorientations, des nausées, voire de lésions internes. [31]
Tout cela nous fait comprendre que les infrasons ne sont pas des phénomènes anodins. ..

Enfin, il subsiste des troubles à des amplitudes et fréquences beaucoup plus faibles, qui s'apparentent plus aux infrasons émis par les éoliennes et propagés à de longues distances, en voici quelques exemples tirés de la littérature scientifique:

- Un ventilateur à rotation lente produisant des infrasons
de 6 Hz (à 90 dB) et de 8Hz (à 80 dB) dans un standard téléphonique a provoqué au personnel:
- céphalées, troubles de vigilance et problèmes de concentration
- palpitations et nausées, compression cérébrale.
Ces troubles ont disparu lorsqu'on a modifié la climatisation de sorte qu'elle ne produise plus d'infrasons [32]

Des expositions de 6 à 16 Hz à 10 dB sont corrélés à des troubles de vigilance et de sommeil.[33]

A moins de 20 dB, des sujets exposés aux infrasons souffrent de désagrément et ressentent une pression dans les tympans. Leur système cardio-vasculaire ainsi que leurs performances restent inchangés. [34]

Des infrasons à 10, 20, 40 et 60 Hz subis par des sujets pendant leur sommeil modifient l'organisation de celui-ci.[35]

En conclusion, la plupart des études expérimentales de la littérature scientifique sont faites en laboratoire, sur des périodes très courtes; on obtient dans une très forte majorité des cas des effets néfastes sur la santé, qui augmentent en fonction de la pression sonore et de la bande de fréquence des infrasons.

On sait aussi que plus l'exposition est prolongée[36], plus l'émission est nocive.

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[30] "Le son silencieux qui tue" / Gavreau.- In: Acousaqua, vol.17, 1966 et Science et Mécanique, 1968.
[31] "Les armes qui s'attaquent au cerveau"/ Serge Brosselin.- In: Le Point n°1629, 5 déc. 2003.- p 88-89
[32] Communication de CABRAL et ROSZAK. Institut de médecine du travail du Nord 24 fév. 1973.http://membres.lycos.fr/infrasons
[33] Infrasonic threshold levels of physiological effects / Landström U., Bystrom M. In J Low Noise Vib. 3 (4) , 1984. pp 167-173
[34] Physiological and psychological effects of infrasound on humans / H. Moller - In: J Low freq Noise Vib. 1984 3(1).- pp 1-16
[35] Comparative study of the effects and low frequency sounds with those of audible sounds on sleep. / A Okada, K Inaba. In Environ. Int., 1990.- 16 (4-6) - pp 483-490.

Il manque des études épidémiologiques chez l'homme effectuées sur de longues périodes d'exposition (plusieurs années), comme on le vit dans notre environnement réel, à des doses infrasoniques prolongées et répétitives. (ex/ éoliennes)
Ainsi, on n'a pas défini pour l'instant de limite acceptable de puissance et de durée pour l'exposition humaine aux infrasons .[37]

II-5. Effets des infrasons émis par les éoliennes industrielles sur la santé humaine

Les infra-affirmations de l'ADEME

L'ADEME est un organisme dont la mission est de contribuer à économiser l'énergie, mais qui la détourne en faisant systématiquement la promotion de la production d'énergie par l'éolien industriel, au bénéfice des promoteurs et sous couvert d'informer le public.

l'ADEME a la spécialité d'émettre non des infrasons, mais des infra-affirmations, sans référence aucune, ni précision sur les fréquences, amplitude, distances de propagation des infrasons.

Selon l'ADEME , les éoliennes émettent des infrasons, mais: « *Si ces vibrations basse fréquence peuvent – effectivement dans certains cas – avoir une influence sur la santé humaine, elles sont parfaitement inoffensives dans le cas des éoliennes* »[38]
Et dans une autre étude [39]: "*Les mesures réalisées en Allemagne sur les infrasons des éoliennes ne font état d'aucun effet sur la santé*"

Il nous paraît immoral de la part de cet organisme d'affirmer, sans référence aucune, que les infrasons émis par les éoliennes sont parfaitement inoffensifs, et d'autre part, de faire état de soi-disant "*mesures*", alors qu'on ne peut prouver l'impact de infrasons des éoliennes sur l'homme que par des études épidémiologiques.

Dans une autre publication, l'ADEME cite:
le "*danger des infrasons des éoliennes pour la santé ne repose sur aucune base scientifique*" [40]
Notez la subtilité de cette désinformation. L'ADEME utilise le concept de "danger" qui prête à confusion s'il n'est pas défini
Avoir des troubles de sommeil constitue-t-il un DANGER pour l'ADEME ..?

[36] Cyril M. Harris, Editor-in-Chief, Handbook of Acoustical Measurements and Noise Control, New York: McGraw-Hill, Inc., 1991.
[37] Leo L. Beranek and Istvan L. Ver. Noise and Vibration Control Engineering: Principles and Applications. New York: John Wiley & Sons, Inc , 1992.
[38] ADEME « Des éoliennes dans votre environnement? 6 fiches pour mieux comprendre les enjeux » février 2002
[39] ADEME:Une énergie dans l'air du temps: les éoliennes / ADEME mars 2004, page 19. Sources non données.
[40] ADEME www.ademe.fr/etudes/publications

Les preuves scientifiques

Voici ce qui est prouvé scientifiquement:

1- Les infrasons ont une portée beaucoup plus grande que les sons audibles

2- Les infrasons ont des effets graduels, de négatifs à dangereux sur la santé des hommes, en tenant compte de 3 paramètres : l'amplitude liée à la distance, la fréquence, et la durée d'exposition

3- Les éoliennes émettent des infrasons, que l'on peut détecter jusqu'à 5 voire 10 km.

On pourrait donc en déduire en toute logique que:

4- Les infrasons émis par les parcs éoliens peuvent avoir des effets négatifs voire dangereux sur la santé

Surtout comme dans ce cas de éoliennes où l'exposition aux infrasons est prolongée, cela accroît la sensibilité.

Des études expérimentales sont poursuivies actuellement notamment en Allemagne, en UK (Université de Salford) à la suite de plaintes de riverains des éoliennes, puis de la demande d'instances gouvernementales et même de l'Association Britannique de l'Energie Eolienne [31].

La preuve scientifique, nous l'aurons environ dans 15 ans- 20 ans. **Des études épidémiologiques** doivent être faites sur une longue durée, (comme le fluor, sur 20 ans), à des distances différentes, et sur un grand échantillon de riverains.

Des observations cliniques

Il y a cependant de plus en plus d'observations cliniques faites par des médecins-traitants, et qui les ont divulguées dans la presse nationale et médicale.

Ils relatent des symptômes suivants.

Troubles visuels, angoisse, irritabilité, nausées, diarrhées, et troubles du sommeil et du repos, acouphènes (bourdonnement d'oreilles) , déprime.

Ces témoignages ressemblent bien étrangement aux troubles dus aux infrasons en général décrits précédemment.

On peut se poser des questions. .

Au Danemark, où les éoliennes ont été introduites en masse depuis 30 ans, le gouvernement a réagi à la demande publique par précaution en arrêtant l'installation de nouvelles éoliennes terrestres, notamment à cause de risques pour la santé

Conclusion

Les sons et infrasons émis par les éoliennes ont un impact certain sur la santé de l'homme et peuvent gâcher la vie des gens..

Au stade des observations cliniques, on sait qu'il y a des risques, et des sensibilités différentes en fonction des personnes.

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[31] "Wind farms make people sick who live up to a mile away" / C. Milner- In: Daily Telegraph 25 juin 2004

Les troubles sont réels, constatés dans des pays voisins qui ont plus de recul que nous : Allemagne, GB, Suède, Irlande… et les nuisances sont déjà reconnues par le corps médical en France, je cite , un article du Concours Médical [42] compare plusieurs nuisances des éoliennes: *Certaines (nuisances) sont plus réelles, comme le bruit prolongé autant que dure le vent, les infrasons,…"*

Des plaintes ont toujours précédé les études scientifiques. Sur les infrasons des éoliennes, celles-ci commencent à l'étranger. Des instances gouvernementales en Europe et même l'association Britannique de l'Energie éolienne ont commandité des études épidémiologiques qui doivent être menées à long terme sur les riverains des éoliennes. Elles n'ont pas encore donné leurs résultats.
Ne nous laissons pas berner par des propos apaisants.

En France on a eu l'amiante… une catastrophe sanitaire:
C'est un bon isolant qu'on a utilisé partout, alors que depuis 1945, les médecins connaissaient les risques, ils savaient que l'amiante pouvait provoquer des maladies professionnelles. Plus récemment, des épidémiologiste multipliaient leurs attaques contre les industriels de l'amiante. La preuve et la réaction sont arrivées bien tard. En 2004, 100 000 victimes devraient décéder d'un cancer de la plèvre, provoqué par une exposition à l'amiante[43]
Autre exemple, le Distilbène, dont les fabricants sont condamnés pour la première fois en 2004. Cette hormone destinée à prévenir les fausses-couches a été prescrite à 160 000 femmes en France entre 1950 et 1977 alors que ce produit avait été interdit en 1971 aux États-Unis: il provoquait des cancers et des malformations génitales chez les enfants étant exposés in utéro à ce médicament. [44]
Ces deux exemples illustrent le fait qu'en France, le délai est extrêmement long entre la période de doutes sur une nuisance quelconque après maintes observations cliniques, la lutte contre les sociétés commerciales, enfin la diffusion de la vérité scientifique au public.

Le principe de précaution est maintenant dans la Constitution. Il trouverait une belle manière de s'appliquer tout de suite au sujet des infrasons émis par les éoliennes

Les promoteurs éoliens ont la responsabilité de mettre en place les mesures adéquates pour diminuer les risques d'atteinte à la santé des riverains des éoliennes, en les éloignant des habitations non de 500 m comme ils le suggèrent dans leurs publications, mais à 1600 m en tenant compte de sons, et au minimum à 5 km en tenant compte des infrasons .

En conclusion il faut refuser les éoliennes situées à moins de 5 km de toute habitation, à cause des risques produits par les infrasons.

[42] "Risques des éoliennes" In: Concours médical, hebdomadaire des praticiens n° 22, du 09-06-2004, page 1217.
[43] "Amiante 100 000 morts, pas de responsables? / P. Benkimoun -In: Le Monde, 29 nov 2004, p.15
[44] "Le fabricant de Distilbène condamné pour la première fois à indemniser la victime d'un cancer de l'utérus./ S. Blanchard.- In: Le Monde, 19-20 déc. 2004.

BIBLIOGRAPHIE

ADEME « Des éoliennes dans votre environnement? 6 fiches pour mieux comprendre les enjeux » février 2002

ADEME:Une énergie dans l'air du temps: les éoliennes / ADEME , mars 2004, page 19. Sources non données.

ALTMANN, Jürgen, AcousticWeapons -- A prospective Assessment, Universität Dortmund / Institut für Experimentalphysik III April 1999 p.16

BERANEK, L.- Ver, Noise and Vibration Control Engineering: Principles and Applications / Leo L. Beranek and Istvan L.- New York: John Wiley & Sons, Inc , 1992.

BREANT, S "troubles du sommeil et de l'éveil chez les personnes âgées"/ Sigrid Bréant - Thèse de doctorat en Médecine. Paris, Cochin, 2004.

BROSSELIN, S.- "Les armes qui s'attaquent au cerveau"/ Serge Brosselin.- In: Le Point n°1629, 5 déc. 2003.- p 88-89.

CABRAL et ROSZAK.- Institut de médecine du travail du Nord 24 fév. 1973.http://membres.lycos.fr/infrasons

CONCOURS MEDICAL "Risque des éoliennes" In: Concours médical, hebdomadaire des praticiens n° 22, du 09-06-2004, page 1247.

CUSSTR.- Recommandations et règles de sécurité au travail / CUSSTR commission Universitaire pour la Santé et la Sécurité au Travail Romande , décembre 2001.

DERIAUX, F."Amiante 100 000 morts, pas de responsables? / F. Desriaux.- In: le Monde, 29 nov. 2004. p 15.

GAVREAU "Le son silencieux qui tue" / Gavreau.- In: Acoustique, vol.17, 1966 et Science et Mécanique, 1968.

HARRIS, C.- Handbook of Acoustical Measurements and Noise Control / Cyril M. Harris, Editor-in-Chief,. New York: McGraw-Hill, Inc., 1991.

JANHUNEN, H.- "Infrasound at working places in Finland In.Combined Effects of Occupational Explosures / Janhunen HK. In: Proceedings of the Fourth Finnish-Soviet Joint Symposium Institute of Occupational Health, Helsinki, Finland, 1984 pp 134-139.

KARPOVA, N. "Infrasound. Brief review of toxicological literature infrasound Toxicological Summary. Nov. 2001. ET "Early response of the organism to low-frequency acoustic oscillations / Karpova N.I. and alii. In: Noise Vib. Bull. 11(65), pp 100-103.

LANDSTROM, U. Infrasonic threshold levels of physiological effects / Landstrom U., Bystrom M. In: J Low Noise Vib. 3 (4) , 1984 pp 167-173.

LEPICHON, A.- Contribution d'un modèle 3D de tracé de rayons dans un milieu complexe pour la localisation de sources infrasonores. Thèse de doctorat en géophysique en cours . CEA. /Alexis le Pichon

MILNER,C.- "Wind farms make people sick who live up to a mile away" / C. Milner- In: Daily telegraph 25 juin 2004

MOLLER, H.- Physiological and psychological effects of infrasound on humans / H. Moller.- In: *Journal of Low Frequency Noise, Vibration and Active Control* 1984 3(1).- pp 1-16

MOLLER, H.- A questionnaire survey of complaintes of infrasons…/ H. Moller - In. *Journal of Low Frequency Noise, Vibration and Active Control* September 2002, vol. 21, no 2, pp. 53-63(11)

OKADA, A.- Comparative study of the effects and low frequency sounds with those of audible sounds on sleep. / A Okada, R Inaba.- In: Environ. Int.. 1990.- 16 (4-6).- pp 483-490

ORFEA.- Bureau d'études spécialisé dans l'acoustique et les vibrations. www.orfea-acoustique.com

ROGER, A.- "Wind turbine noise issues / Renewable energy research laboratory center of energy efficiency/ A. L. Rogers, PhD University of Massachusetts at Amherst, March 2004.

Sites Internet:

http://www.npl.co.uk/acoustics/techguides/wtam
http://www.tng.nl.
http://www.aandc.org/research/wind_pcc_present.html CANADA
http://www.geocities.com/nigbarnes
http://www.windpower.org. Association danoise de l'industrie éolienne.
http://www.seismologie.brg.de - BRG : laboratoire de recherche allemand en seismologie et infrasons.
http://www.ademe.fr/htdocs/publications: ADEME:
http://www.cnrs.fr. Laboratoire acoustique du CNRS. Ile de France chapitre "infrasons"

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QUELQUES REFLEXIONS SUR LES CONSEQUENCES DE L'EOLIEN INDUSTRIEL SUR L'HOMME – SA SANTE ET SON MORAL…

Par le Docteur Pierre RECHER Médecin Généraliste - Diplômé d'Hygiène Industrielle et de Médecine du Travail

Au premier coup d'œil, l'intrusion dans nos campagnes de ces usines d'un type nouveau, ne peut passer inaperçue. Des tours de quarante étages défigurent le paysage et modifient l'environnement. L'homme, comme tout être vivant, se trouve agressé, perturbé dans son corps et sa tête lorsque son lieu de vie est bouleversé.

Les promoteurs en bons vendeurs, cachent les inconvénients et font apparaître les avantages … nombreux et dans tous les domaines. Ce genre de paroles apaisantes, de belles promesses sont classiques et bien connues. Elles ne sont pas fausses, mais très orientées – et comme toutes les promesses, n'engagent que ceux qui y croient. Essayons donc de voir ce qui se passe en réalité et pour cela écoutons, non des promesses de vendeurs, mais l'avis de ceux qui, depuis 10 ou 20 ans, vivent au voisinage de ces machines. La lecture de la Presse – entre autres – est un bon moyen de voir clair et de se faire une opinion. De nombreux articles – de tous bords et de toutes tendances – provenant de pays voisins en Europe, peuvent nous donner une idée des nuisances causées, en les décrivant assez bien.

La première nuisance - les bruits :

Une éolienne émet des bruits d'origine mécanique et aérodynamique :
• Mécaniques dans la nacelle, les hélices ou pales entraînent un axe lent qui… etc.
• Aérodynamiques, le vent frappe les pales sur le bord d'attaque – c'est la claque d'air – et s'échappe en bord de fuite – c'est un sifflement – chaque pale passant devant le mât provoque un choc, un bruit mat (savoir que ces pales de 40 mètres, sont plus longues que les ailes des plus gros avions).

► Ces bruits sont connus et analysés – mesurés au sonomètre – exprimés en décibel – d'innombrables courbes dessinent leur répartition dans l'entourage (hauteur, distance, saisons, nuit, jour etc.). Ce sont des moyennes mathématiques très souvent théoriques.

► Comment sont-ils perçus par l'homme : l'étude du cortex auditif est difficile en raison de sa localisation dans le cerveau, au fond d'une profonde scissure, et les renseignements, incertains.

► Comment sont-ils ressentis par l'homme : très différemment dans ce domaine, comme dans beaucoup d'autres, les hommes sont très différents. Le promoteur trouvera des témoins qui – de bonne foi – affirmeront ne pas écouter, ne pas entendre, en tous cas ne pas être dérangés par ces bruits.
D'autres soutiendront que leur vie en est gâchée…
En présence de stress, les hommes réagissent très différemment (ex. : le mal de mer – ou le vertige – certains y sont insensibles, d'autres ne peuvent le supporter).

► Comment sont-ils décrits par l'homme : lisons de nombreux articles provenant de témoins ou de médecins frappés de recevoir de plus en plus de patients décrivant leurs misères…

- Ces bruits ne sont pas très forts – assez discrets – légers mais d'autant plus obsédants et insupportables car rythmés (la goutte d'eau tombant toutes les trois secondes est plus obsédante qu'un seau d'eau tombant trois fois par jour).
- Ils vous poursuivent chez vous – portes et fenêtres closes.
- Ils vous ont à l'usure.
- On ne peut y échapper
- Ils vous emplissent le crâne.
- On les entend de bien plus loin qu'on ne le disait. Le jour on ne peut se concentrer dans le calme. La nuit ils perturbent le sommeil. L'anxiété est permanente

Si des « sondages » prétendent que 80 % des habitants voisins d'éoliennes trouvent « ça très beau et pas gênant »… sachons tenir compte des 20 % de malheureux, de malades en puissance ! (Notre société – à juste titre – a su prendre des mesures contraignantes pour faciliter la vie aux handicapés. Notons au passage que c'est grâce à l'action de leurs associations de défense, que ces handicapés ont pu faire entendre leurs voix).
Devant le nombre croissant de témoignages sur les nuisances dues à l'éolien (introduites depuis déjà 30 ans), le gouvernement Danois a réagi en arrêtant l'installation d'éoliennes sur terre. Notons que le Danemark est le pays Européen le plus pourvu en éoliennes, il est aussi le premier producteur de gaz à effet de serre (CO_2).

Les infrasons :

Sont une autre source de nuisances encore plus sournoises.
Ce sont des sons basse fréquence – des vibrations de fréquence inférieures aux fréquences audibles. L'homme est « presque sourd » et son oreille ne perçoit que le milieu du spectre émis – pas les infrasons (pas les ultrasons). Les animaux perçoivent des sons de manière différente (exemple : sifflet du chasseur pour appeler son chien – certains poissons, etc.).

L' ADEME admet que les éoliennes émettent des infrasons, mais affirme : « *Si ces vibrations basse fréquence peuvent – effectivement dans certains cas – avoir une influence sur la santé humaine, elles sont parfaitement inoffensives dans le cas des éoliennes* »[1] (Sic)

Les infrasons occupent, dans la gamme des fréquences sonores, la fraction du spectre qui véhicule la majeure partie de l'énergie – aucun obstacle ne les arrête. Ils sont détectés à très grande distance (les explosions d'essais nucléaires sont repérées sur toute la terre – après avoir fait le tour du globe terrestre, les infrasons produits par une explosion atomique, n'ont perdu que 5 % de leur puissance).

C'est surtout à partir des années 60 que le problème des infrasons – et de leurs effets sur l'homme – a été soulevé. Des études plus poussées ont été faites dans les années 80, surtout dans le domaine de l'Hygiène Industrielle. De très nombreuses publications étudient et tentent de mieux cerner ce problème (Bibliométrie).

Les infrasons provoquent chez l'homme qui les subit des vibrations – surtout sur les organes creux – on parle de maladies Vibro-Acoustiques (M.V.A.), connues chez les aviateurs et les cosmonautes.

L'impact des infrasons sur l'organisme humain est ressenti, même à faible puissance, sous forme de troubles physiques et psychiques. Ils agissent sur le système nerveux et le cerveau en altérant le cheminement de l'influx.

Il semble que de nombreux médecins Anglais ont été frappés d'entendre les plaintes de leurs patients voisins d'éoliennes. Ils ont fait des publications auprès de leur Gouvernement et dans la presse scientifique. Ils décrivent : au début, des maux de tête – puis des vertiges avec acouphènes et nausées – palpitations, troubles du sommeil – stress – anxiété, dépression. Ces troubles détériorent la qualité de la vie avec concentration difficile – irritabilité – aboulie.

Mêmes remarques qu'en ce qui concerne les bruits : les hommes sont très différemment sensibles aux infrasons. Les troubles étant subjectifs – un doute persiste toujours devant les affirmations des malades. – ils sont traités de simulateurs…(après un accident, une victime peut simuler afin d'obtenir invalidité, réparation et pension. Une victime de l'éolien va trouver un médecin pour obtenir un remède qui la soulagera : elle n'a aucun espoir de réparation)

Il existe d'autre part des preuves que les infrasons ont un effet sur l'homme : en témoigne hélas leur utilisation comme instrument de torture – l'infrasonothérapie utilisée en rhumatologie sur certaines douleurs résiduelles après fractures – enfin la recherche sur les armes acoustiques, qui « détruisent le cerveau », recherches menées par plusieurs grandes armées.

Il semble donc que l'on puisse affirmer qu'une éolienne produit des infrasons – que ces infrasons ont un effet sur le corps humain – et représentent un grand danger potentiel.

L'effet stroboscopique est une autre nuisance.

Les réflexions périodiques des rayons du soleil sur les pales en mouvement provoquent des brusques modulations d'intensité lumineuse. Ces sauts de luminosité attirent le regard – perturbent la vision et diminuent l'attention.

Inversement, les pales en mouvement coupent les rayons du soleil qui nous parviennent et les interrompent. Les effets sur la vision et l'attention sont identiques et d'autant plus dangereux, que les rayons du soleil sont plus proches de l'horizontale (matin et soir).

Le danger pour la conduite automobile est évident.

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[1] ADEME « Des éoliennes dans votre environnement – 6 fiches pour mieux comprendre les enjeux » février 2002

Outre la gêne à la vision, l'effet stroboscopique peut provoquer des troubles du rythme cardiaque. Lorsque leur fréquence est semblable à celle des battements du cœur – s'ils s'accélèrent, notre rythme cardiaque peut s'en trouver perturbé.

Certains médecins ont décrit des troubles psychiques remarqués chez leurs patients : anxiété, dépression. Mêmes remarques qu'à propos des bruits et des infrasons : les hommes y sont très différemment sensibles (comme au mal de mer ou au vertige).

Ces trois nuisances : bruits, infrasons et effet stroboscopique, s'additionnent et perturbent la santé des hommes (et des animaux). Les pays voisins ayant adopté, depuis des dizaines d'années, l'éolien industriel, le clament sur tous les tons. Ne soyons pas sourds.

Malgré ces témoignages, ces mises en garde et ces cris d'alarme, l'acharnement des pro éolien industriel se poursuit sans relâche. La force des promoteurs et des élus locaux qu'ils ont su « convaincre », vient de l'ignorance dans laquelle ils nous ont tenus.
Maintenant que nous commençons à savoir, à comprendre, disons le haut et fort. Ne laissons pas se reproduire encore une sinistre tragédie sanitaire (on savait depuis 1900 que l'amiante causait un cancer du poumon, ce qui n'a pas empêché... Vous connaissez la suite !).

Disons le haut et fort, en privé en public.
Les Associations sont un très bon moyen pour faire bouger les idées

Octobre 2004

Annexe

Sources : Articles de journaux – Témoignages – références.

C. Milner : Daily Telegraph, 25.01.2004 : « Les éoliennes ont un effet nocif sur la santé ».
Muriel Frat : Le Figaro, 13.12.2003 : « Nuisances sonores : 7 millions de victimes ».
Serge Brosselin : Le Point 05.12.2003 : « Les armes qui s'attaquent au cerveau ».
Stefan Theil : Newsweek, 19-26.04.2004 : « Toutes contre les moulins à vent ».
Denis Delbecq : Libération, 01.06.2004 : « Un sommet pour nettoyer les énergies »
Denis Boulard : J.D.D., 30.05.2004 : « Vent de discorde dans les Vosges ».
Marc Grosclaude : La Voix du Nord, 21.03.2004 : « Une éolienne de Brack s'est écroulée ».
Frédéric Folliot : La Voix du Mercredi, 24.03.2004 : « Fragiles les éoliennes ».
Christian Pialet : L'Express n° 128, 05.04.2004 : « Eoliennes : pièges mortels »
Paris Normandie, 15.04.2004, Dieppe : « Eoliennes 1ere enquête publique ».
B. Gardet : Le Monde, 5-6.10.2003, : « Les éoliennes de la discorde ».
Libération, 10.01.2004, : « Enquête au Portel après l'accident d'éolienne ».
Malika Macloufd, J.D.D., 7.03.2004, : « Autant en emporte le vent ».
Der Spiegel n°14, 29.03.2004, : « Du rêve d'une énergie respectueuse de l'environnement, à un saccage paysager fortement subventionné ».
Niel Sandoe : Jyllands Posten : 4.06.2003 : « plus d'éoliennes amènent le chaos ». (DK).

****

J.M. Chapelle : Cahier de l'Aspan (Suisse).
Manifeste de Darmstadt en Allemagne
Rapport Kelly : 07.06.2004, chercheuse au Comité sur l'Environnement (GB).
USA : ont cessé de payer le « Product Tax Credit », qui subventionnait l'éolien

****

B. Goujard – Ecole d'Ingénieurs en Génie des Systèmes Industriels (EIGSI). bertrandgoujard@eigsi.fr
Gavreau « Infrasons » (Acoustica Vol. 17, 1966) : « Le son silencieux qui tue (sciences et mécanique, 01.1968) ».
Sally Smith: Country Life, 13.05.2004 « Ces vues (de paysages en GB) peuvent-elles être préservées ? ».

****

References

[1] Handleiding meten en rekenen industrielawaai (Manual for measuring and calculating industrial noise), Den Haag, 1999 (in Dutch).

[2] TA-Lärm: Technische Anleitung zum Schutz gegen Lärm (Technical guideline for noise protection), 1998 (in German).

[3] A.J. Kerkers, Windpark Rheder Moor; prognose geluidsimmissie vanwege 17 Enercon 66 windturbines (Wind park Rheder Moor; prognosis of sound immissions from 17 Enercon 66 wind turbines), Lichtveld Buis & Partners bv raadgevende ingenieurs, 1999 (in Dutch).

[4] S. Ljunggren, expert group study on 'Recommended practices for wind turbines testing and evaluation', part 10. Measurement of noise immission from wind turbines at noise receptor locations. Department of Building Science, The Royal Institute of Technology, Sweden, 1994/1997

[5] IEC International Standard 61400-11, Wind turbine generator systems-part 11. Acoustic noise measurement techniques, IEC 61400-11:1998(E)

[6] A.A.M. Holtslag, estimate of diabatic wind speed profiles from near-surface weather observations, *Boundary Layer Meteorology* 29 (1984) 225-250.

[7] D. Kühner, Excess attenuation due to meteorological and ground impedance, *Acustica—Acta Acustica* 84(1998) 870-883.

[8] TA-Luft, Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz-Technische Anleitung zur Reinhaltung der Luft (First general directive to the federal immission protection act—Technical guideline for clean air), 1986 (in German).

[9] http://www.metdat.llnl.gov/metdat_FAQ.html#stability_class.

[10] Climatological data from Dutch stations no. 8: Frequency tables of atmospheric stability, KNMI, De Bilt, 1972 (text part in Dutch).

[11] E. Rudolphi, Wind turbine noise emission. Wind speed measurements below hub height give poor accuracy, *Proceedings of the Nordic Acoustical Meeting*, Stockholm, 1998

[12] G.P. van den Berg, R. De Graaf, Hoge molens vangen veel wind II—geluidsbelasting door windturbines in de nacht, Natuurkundewinkel RuG (High mills catch strong winds II—sound immission by wind turbines at night, Science Shop for Physics, University of Groningen), December 2002 (in Dutch, a German version is also available).

[13] G.P. van den Berg, Wind turbines at night: acoustical practice and sound research, *Proceedings Euronoise 2003*, Naples, 2003.

[14] A.J. Kerkers, A.J. Kuffeman, Beoordeling van windturbinegeluid: technische rapportage—Constant, fluctuerend of impulsachtig (Assessment of wind turbine sound: technical report—continuous, fluctuating or impulsive), Lichtveld, Buis & Partners bv, March 2002 (in Dutch).

[15] E. Pedersen, K. Persson Waye, Perception and annoyance of wind turbine noise in a flat landscape, Proceedings Internoise 2002, Detroit, 2002.

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PART I—basic kinematics

For those of you who don't want to slog through the mathematics necessary to do this calculation,

THE BOTTOM LINE IS THAT ICE, DEBRIS OR ANYTHING BREAKING OFF THE WIND TURBINE BLADES (including the blades themselves) CAN IMPACT A POINT ALMOST 1700 FEET AWAY FROM THE BASE OF THE TURBINE...

WHAT WE KNOW:

RADIUS OF BLADE: OVER 100 FEET
ROTATIONAL SPEED: UP TO 1 REVOLUTION EVERY 3 SECONDS (OR ABOUT 20 REV/MIN)

PRELIMINARY RESULTS:

ROTOR TIP SPEED:
IN ONE REVOLUTION, THE BLADE TIPS SWEEP OUT A CIRCLE WHOSE RADIUS IS OVER 100 FEET. THIS DISTANCE IS 2*PI*R OR ABOUT 628 FEET. IF IT TAKES 3 SECONDS TO MOVE THIS DISTANCE, OUR SPEED IS 628/3 FEET PER SECOND. THIS IS ABOUT 210 FEET/SECOND OR 150 MPH.

When you do the mathematics in detail, you find that launching the fragment horizontally is NOT the worst case scenario for maximum horizontal range. (LAUNCHING FROM THE TOP OF THE TURBINE (horizontally) YIELDS A RANGE OF SLIGHTLY MORE THAN 1000 FEET.) Instead, this maximum distance occurs when debris is released with the blade at a 45 degree angle from the vertical. Imagine the blade at 45 degrees from its vertical position. At this point, the projectile will be launched about 70 ft. from the horizontal position of the hub. (This is 100 times the cosine of 45 degrees). Also, it will be about 70 feet higher (vertically) than the hub. (Again, we assume that the blades are 100 ft. in length). Thus, the vertical distance it has to fall is 300 feet (hub height) plus 70 feet (vertical distance that the piece of ice, or whatever, is from the hub).
Now, the range for this projectile is:

R= v**2/g (that's "v squared divided by "g", the gravitational acceleration). This is the range to come back down to the ORIGINAL vertical height. So after this distance, it is BACK at 370 feet off the ground.

R=(210 ft/sec x 210 ft/sec)/(32ft/sec/sec). or about 1400 ft.

Now, at this position, (neglecting air resistance), its vertical velocity is the same as when it was launched (except that it's now going DOWN instead of up). So, the vertical velocity is about 140 ft/sec. (210 x .7 or v cos 45)

The extra time it takes to fall to the ground from this height is:

x= v times t + 1/2 g times t squared.

SO,
370=140 t + 16 t**2

Solving for t, we get about 2.5 seconds. In 2.5 seconds the increase in the range is:

v(horizontal) times t or 140 x 2.5 or about 350 feet.

Thus, the TOTAL range of a projectile is: 1400 + 350 = 1750 feet. From this we subtract the 70 feet that the projectile was behind the hub when it was launched, and you end up with 1680 feet for the horizontal range from the base of the hub.

PART II—comments on inclusions of drag coefficients and risk assessment

1) Friction is NOT a fundamental force. What this means in practice is that any attempt to take into account air resistance in a description of ice throw can be fraught with model dependent errors. The drag coefficient usually quoted in wind developers' "papers" of 1.0 is totally inappropriate for the study. Variability in the Reynolds number is completely ignored. They assume a perfect ice cube of size = 4 inches. Then, they assume it always tumbles. But these are chunks of ice that are forming on propeller blades! Ice that forms on propeller blades tends to be shaped like propeller blades. And they can be QUITE aerodynamic (as are the blades). Any models employing ice cubes are at best, useless, and at worst, deceptive.

Moreover, the study of "harvested" ice that is subjected to wind tunnel testing is likewise demonstrably without merit. What they do is break off chucks of ice, make molds, and then subject them to wind tunnel tests. But real ice melts. It changes shape. It becomes smoother. The "studies" ignore this, instead adopting a drag coefficient = 1.0 This is close to the drag that a half a tennis ball (say) would present if it were thrown into the wind with the open "cup" catching the wind at all times! A rather silly assumption, and one that is totally inappropriate. Ice is NOT like this. While the developers tout their results as being representative (decidedly untrue), they ignore MacQueen's 1983 study that concluded that a maximum range of 800m (about 2500 feet) was quite possible. Indeed, even a range of 2 km. (over one mile) was conceivable. They discount this because he "assumed that the ice 'fragments' were actually large flat slabs weighing perhaps 80 kg." Actually, he was modelling BLADE throw, another issue that seems to be ignored despite the fact that within the past year there has been at least one documented instance of this; an entire rotor blade broke off from the hub. (Wethersfield, N. Y.) Incidentally, as near as I can see, the MacQueen study is the ONLY peer reviewed analysis for throw possibilities. The rest are calculations done by wind company employees and/or consultants.

2) I never claim my calculation to be anything other than a maximum calculation of distance, beyond which you don't have to worry. I am not usually accused of being conservative in many ways, but when it comes to human life, I suppose I am. Why worry when you can just adopt my calculation and not be concerned at all with tragedy in the future? Moreover, any risk assessment data is useless, since the calculations are not assuming an appropriate model to begin with! I remember when de-icing airplane wings was said to be unnecessary, posing no risk to public safety, and only after tragedy struck is it now "de rigeur" to do it (and do it carefully and thoroughly). All other mumbo jumbo is exactly that unless they get the basic physics right.

3) If you are going to invoke air, and air resistance, it is the height of deception not to include the effects of lift. Frisbees fly far. Why? Because of air. If you throw a frisbee facing the direction of travel, it will travel only a few feet. The drag coefficient is probably of order unity in this situation. If you sling it in the direction of travel, it goes very far. And rime ice, of course, will likely be shed from the rotors in a similar aerodynamic fashion. The wind companies assume that the fragment will tumble; thin blades of ice may not (as a frisbee does not, when properly oriented).

4) Throughout these discussion, the wind developers have been groping for setback distances that they can live with. They started with 1.5 times the ground-tip distance: about 150m. As

near as I can tell, this was just pulled out of a hat. (In physics, we call this a "toy model".) Then, the distance was increased to 200m. in several " papers." Now, in a recent " paper", 400m is quoted. They are getting closer to my original number!

What about data? If you refer to the Atlantic Wind Test Site memo of March 27, 2002, they state:
"Summary---Following the moderate wind icing event at AWTS on March 27, 2002, fragments of ice, large enough to cause injury, have been observed being thrown from the turbine blades. Concerns over dangers of flying ice are legitimate. In 15 m/s winds, ice was observed to travel approximately 200m." Instead of recognizing this, comapnies present a figure from an utterly useless and anecdotal "questionnaire" that purports to show that ice throw is "unlikely" more than 100 meters from the site. This figure is a completely misleading representation of "data" that has been bandied about for years by developers.

5) In the beginning, the claim was that the rotor sensors would stop the blades because of ice buildup. Now, even the papers put forward by the companies admit their error here. They state: "...rime ice formation appears to occur with remarkable symmetry on all turbine blades with the result that no imbalance occurs and the turbine continues to operate." Another failure of their initial assumptions and models.

In conclusion, there are some problems with wind turbines that have unavoidable consequences. Birds will die, bats will die. In these scenarios you NEED to adopt a risk analysis study. But here, YOU CAN ELIMINATE THE ENTIRE PROBLEM, if you just adopt a conservative value for your setbacks.

REFERENCE: J. F. MacQueen, et. al, IEE Proceedings, Vol. 130, Pt. A, No. 9, pp. 574-586 (1983).

If you have any questions, just e-mail or call. It would be a lot easier to explain this if I could write it on a piece of paper, but I hope you can picture this adequately....

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Underground Stray Voltage from Wind Turbines? A Correction and Comment

Calvin Luther Martin, Ph.D.

Last November I wrote an editorial in these pages titled "The Wind Factory Next Door," describing cattle deaths in Delta, Utah. "Now those [Delta] farmers say they've figured out what's causing the deaths: electrical currents running through the ground from the Intermountain Power Plant," writes John Hollenhorst for KSL News, Salt Lake City (see http://www.100megsfree4.com/farshores/n09cd.htm).

Allow me to make a correction here: it was my understanding that the alleged culprit (Intermountain Power Plant) was a windfarm, whereas in this case it is not: the Intermountain Power Plant is a very large coal-fired power plant. Hence, the underground voltage Maria Nye and her Utah neighbors complain about is not from a windfarm, as I claimed—and I stand corrected.

That said, in Lincoln Township, Wisconsin, the underground stray voltage which has decimated the prize-winning dairy herd of Scott Smka is, almost certainly, from the 14-turbine windfarm next door (the closest turbine being 1100 feet from his barn). Mr. Smka has had this confirmed in a variety of ways, including testing by licensed electricians. His herd is a closed breeding herd and, before the turbines went in 5 years ago, his milk production ranked among the highest in the state. No more. Within the first 6 months of the turbines going on-line, he tells me, 14 of his cows died of cancer (all of this confirmed by his veterinarian, Dr. Paul Mleziva). Autopsies showed, curiously, a black liver in virtually all cases. In those first 6 months, along with the deaths, Smka was getting heifers born with no tails, no eyeballs, and at least one born with a colossal head—monstrosities he had never experienced before. As I say, his veterinarian got involved and began his own research into this bizarre phenomenon. For a long time, Smka told me, he would have 4 cows die on average per month.

Smka believes the turbines are dumping excess voltage into the ground, and when he managed to (illegally) disconnect the ground wires from the turbines, his herd miraculously became healthy again—till the utility company discovered what he'd done, reconnected the severed ground lines, and marched him into court (where it quickly dropped the charges, fearing adverse publicity over its obvious stray voltage problem).

This is not a pleasant story. Any dairy farmer contemplating living near wind turbines would do well to give Mr. Smka a call (I have his number, if you're interested) and hear him out. (Smka will tell you that, initially, he was all for the windfarm, and even helped install it.) I invite you, as well, to speak to Smka's veterinarian: Dr. Paul Mleziva at (920) 863-2184 (office). Smka tells me his neighbor, on whose land the turbines are situated, has lost 350 cows since the turbines went in. Next to the voltage crisis, the turbine noise ("a running shoe in a tumble dryer" is how he describes it) is his next significant problem.

What Scott Smka tells me about cattle mortality, miscarriages, and monster heifers—all starting with the arrival of a windfarm next door—is repeated nearly verbatim by Roger Hutzell of Meyersdale, PA, whom I also spoke to. Talking to Maria Nye (Delta, Utah) by phone the other morning, she pointed out that her farm is 10 miles from the (coal-fired) power plant—ten miles away and, yet, still getting zapped by underground voltage from a (admittedly huge) power plant. The Nyes and others are suing Intermountain Power for $100 million, so destructive has been the impact on their livestock.

Surely we in the North Country should contemplate this issue carefully. Smka strongly advises anyone living within a mile of a proposed windfarm to have his/her property measured for in-ground electricity before the turbines begin operation, to establish an ambient, baseline voltage for future litigation with the wind companies over underground voltage. In addition, he recommends that municipalities insert a clause in their windfarm ordinance, requiring a windfarm to shut down until its stray voltage problems are corrected. No one thought to write this into the Lincoln Township ordinance, he tells me—and Scott Smka and his family live to regret it.

Anne 90

From: "D & L Roberson" <irminsul@bcn.net>
To: "Irminsul" <irminsul@bcn.net>
Sent: Saturday, May 13, 2006 6:37 AM
Subject: # CA: Wind turbines send wildlife diving for cover

http://www.newscientisttech.com/article.ns?id=mg19025494.700&feedId=life_rss20

Wind turbines send wildlife diving for cover

* 03 May 2006

NOISY wind farms in California are making squirrels edgy and prone to scurrying for cover. This change in behaviour could have knock-on effects on animals that depend upon the squirrel, such as the golden eagle, which feeds on the rodent, and the red-legged frog and California tiger salamander, which live in its burrows.

Lawrence Rabin of the University of California at Davis and his colleagues compared the behaviour of two groups of Californian ground squirrels in similar environments, except that one group lives close to a wind farm.

The biologists played recordings of alarm calls to each group of squirrels. Those living near the wind turbines were more likely to dash back to their burrow when they heard an alarm call, and spent more time looking around for predators. Team member Donald Owings says that the noise of the turbines seems to make the squirrels more alert, perhaps because they need to compensate for their reduced ability to communicate through sound.

Wind turbine noise may affect wildlife communities all over the world, the researchers write in a forthcoming issue of Biological Conservation. While not suggesting that wind farms should not be built, they say that more care needs to be taken over choosing where to site them, to minimise their impact.
From issue 2549 of New Scientist magazine, 03 May 2006, page 18

91

Anne

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Friday, December 23, 2005 10:14 PM
Subject: Wind turbines noisy, says Vermont neighbor

... notice the testimony of a Vermonter in the "Heartland Institute" article, below (excerpted here):

> Garry Degray, who already has wind turbines within sight of his property, warned at the meeting about the sight and noise pollution associated with industrial wind farms.
>
> "Not only do I have a visual impact in my backyard, I'll have to listen to the industrial rumble of the windmills," said Degray at the hearing, according to the August 4 *Bennington Banner*. "Contradictory to their claims of a light swooshing noise, it's an industrial rumble. My quality of life is taking a nose dive."

But, by golly, Noble and Zilkha tell us they're totally quiet. "Go to Fenner and see for yourself!"

Calvin

THE HEARTLAND INSTITUTE
19 South LaSalle Street #903
Chicago, IL 60603
phone 312/377-4000 · fax 312/377-5000
http://www.heartland.org

Wind Farm Proposed for Vt. National Forest

Author: James M. Taylor
Published: The Heartland Institute 10/01/2005

A French-owned power company has announced plans to transform portions of Vermont's Green Mountain National Forest into an industrial wind farm if its development proposal receives the approval of the U.S. Forest Service.

The company, Deerfield Wind, cleared the first hurdle in mid-July when the Forest Service accepted a special use application for the proposed project.

Environmental activists have opposed virtually all resource development and road building in national forests. However, with environmental activists split on whether wind farms benefit or harm the environment, the French company is hoping for activists' acquiescence in developing the most pristine areas of the Green Mountain National Forest.

Mountaintop Ridges Threatened

According to the company's plan, 20 to 30 giant wind turbines—each taller than the Statue of Liberty--will be constructed on an 80-acre wind farm at the peak of some the nation's most scenic and previously unspoiled ridgelines. In justifying the development, the company argues the industrial wind complex will power up to 16,000 local homes, albeit at higher prices than current energy sources.

The Forest Service must prepare an environmental impact statement and take into consideration public comments before deciding whether to approve the proposal.

Residents Protest

Many local residents protested the proposed windmills at an August 3 community meeting held by the Forest Service in West Dover.

Garry Degray, who already has wind turbines within sight of his property, warned at the meeting about the sight and noise pollution associated with industrial wind farms.

"Not only do I have a visual impact in my backyard, I'll have to listen to the industrial rumble of the windmills," said Degray at the hearing, according to the August 4 *Bennington Banner*. "Contradictory to their claims of a light swooshing noise, it's an industrial rumble. My quality of life is taking a nose dive."

"I'm here to kill this project," added Richard Joyce of Wilmington, as reported in the *Barre Montpelier Times Argus* on August 4. "It will provide us with very little energy at a big price."

Newspaper on the Offensive

The *Burlington Free Press*, in a series of house editorials, summarized local sentiment against the industrial wind complex.

"Do we now want to see pristine ridge lines turned into pincushions with enormous white turbines whirring along the skyline?" asked a July 24 house editorial. "Most people support clean energy sources, but at what price? Is this the vision Americans had of its national forests when these wild places were set aside for our children and their children to enjoy?

"There is a place for wind power in the clean energy mix, but pristine ridge lines that are home to important wildlife and offer spectacular natural vistas are not the place for turbines," the editorial continued. "How much power will actually be generated by these towers, and is that amount worth the environmental degradation that can be expected? How visible will these towers be and at what distance? How noisy are the turbines?"

"Vermont's ridge lines, whether public or private, are the wrong place for swooping, strobe-lighted monstrosities," added a July 27 house editorial. "The mountains are this state's backbone, home to wild animals and a rare, quiet place of solitude and contemplation for its people."

Easing Energy Prices?

"It's pretty apparent the price of oil is going up, we need to look at other sources of energy," countered Wilmington resident Gordon Ritter at the community meeting, as reported in the *Bennington Banner*.

Institute for Energy Research President Rob Bradley, however, said the price of oil has little to do with the economic costs and benefits of wind power. "Oil is used primarily for automobiles, while wind turbines are used by power plants. Coal, the primary fuel for power plants, is much cheaper than wind power."

In neighboring New York, the New York State Public Service Commission this month will begin charging electricity customers a 0.1 to 2.2 percent surcharge on their bills and handing it over as a subsidy to power companies who would otherwise balk at the high price of supplying wind power.

"In addition to the significant environmental impacts of the wind farm and necessary transmission lines—all for unreliable power—the Forest Service, environmentalists, and local residents should all be aware that this scheme exports jobs to Europe and India, where the majority of the world's wind turbines are built—and not using one stick of U.S. lumber," said

Tom Tanton, a senior fellow the at Institute for Energy Research.

"Further," added Tanton, "since there isn't any oil used to generate electricity in the U.S., this scheme will not affect gasoline prices now or in the future and does nothing for our energy independence nor economic productivity."

James M. Taylor (**taylor@heartland.org**) *is managing editor of* Environment & Climate News.

For more information ...

Research and commentary on wind power is available through *PolicyBotâ„¢*, The Heartland Institute's free online research database. Point your Web browser to **http://www.heartland.org**, click on the *PolicyBotâ„¢* button, and choose the topic/subtopic combination Environment/Energy.

Also see these *Environment & News* articles:

"Wind Farm Costly for Kansans, New Study Finds," May 2005, **http://www.heartland.org/Article.cfm?artId=16909**

"States Take Widely Varying Stands on Wind Power, February 2005, **http://www.heartland.org/Article.cfm?artId=16384**

"Environmental Group Files Suit Against California Wind Farm," January 2005, **http://www.heartland.org/Article.cfm?artId=16203**

Calvin Luther Martin

From: <Skdervin@aol.com>
To: <rushton@westelcom.com>
Sent: Wednesday, March 02, 2005 8:53 PM
Subject: (no subject)

Calvin and Nina,

May I send some of the information you sent regarding the health hazards, Infrasound etc. that you have sent out to others or not. Thank you for sending us this valuable information . .and these past days/evenings...the turbines have been so loud it is quite disturbing. Take Care....Respectfully, Karen

2/21/2006

From Robert Larivee
1435 Sand Spring Rd
Meyersdale, PA 15552

To: County Commissioners

I am writing this letter to give you more information so you may make a more informed decision concerning the proposed regulations

My house is located about 3000 feet west from the new 20 wind generators located along Meadow Mountain in the Meyersdale region. I had the noise level measured by Dr. Oguz Soysal of the Department of Physics and Engineering, Frostburg State University. The readings were measured over a 48 hours period. The preliminary results of the readings showed an average reading of about 75 decibels during that time period. This is about the amount of noise coming from a washing machine or dishwasher. According to the EPA "noise levels above 45 dB (A) disturbs sleep and most people cannot sleep above the noise level of 70 dB (A). Emotional upset, irritability and other tensions, may also arise. Noise contributes to ailments like indigestion, ulcers, heartburn and gastrointestinal malfunction in the body." Granted this is preliminary data only and much more work needs to be done.

These levels are much higher than those predicted by the company. There are a number of reasons that may contribute to this. Probably the most significant factor is the topology of the area. Our area has many mountains and valleys that tend to channel the noise so the sound does not disperse as would be expected. Second, due to the mountains, we also get a lot of low-level clouds that can also act as a barrier to sound. These low level clouds tend to channels the sound so the noise level remains much higher then expected.

As managers of our county, it is your responsibility to protect the citizens that live and raise families here. As shown above, you have not done your job very well with those of us who are now forced to live with this additional noise. Please do not make the same mistake. I urge you to vote for these additional restrictions.

Finally, if our county wishes to continue to advertise itself as being a recreational area, we need to keep our noise pollution to a minimum. People don't come to our county to see and hear windmills. They come for the serenity and beauty. We need to keep it that way.

Sincerely Yours

Correction: This home is East,
not West of the wind machines

Dr. Robert Larivee
Professor of Chemistry

76-144

07 March 2006

To Interested Parties:

I would like to share the realities and impacts that are being faced and continue to be faced by living near a wind turbine facility and hope to clear up some of the misconceptions and comparisons of the "so-called" progress regarding this particular industry.

I live within less than a 1-mile range from the Meyersdale Wind Turbine Facility in Somerset County, Pennsylvania.
I would like to share, from an up-close and personal experience, I guess one could label it the "Human Experimental Factor", the multiple nuisances and issues that coincide with these particular industrial turbine utilities that affect my neighbors, my family, local adjacent property owners and residents have and continue to experience over the past two years.

Prior to the building of the facility, our neighbors and we were never made aware of the nuisances that occur with a wind turbine facility. The noises emitted from the turbines have definitely changed our style of living. The noises produced from the blades turning on the turbines create a "threshing" sound within and around our home as well as the adjacent properties residing within certain geographical ranges of this facility.

At times it is difficult to fall asleep with the "pounding" of the turbines. One is often awakened by the "droning" noise of the turbines, finding it most difficult to fall back asleep. The noise becomes so disruptive, one can concentrate on nothing else but the constant droning. During the winter months, the noise is quite unbearable at times, sounding like drums beating constantly in the background. Sometimes the sound can be correlated to constant jet aircraft flying overhead. During the summer months, we cannot have our windows open to enjoy the fresh air or listen to the sounds of nature just the noise created by the turbines. Advocates for these facilities will often compare this "threshing" noise to the "peaceful" sound of waves beating against the rocks at the seashore, but I have been to the seashore and it certainly is in no way comparable to the "calming sound" of waves. (I guess we are now just supposed to close our eyes and pretend we are at the ocean!!) We are no longer able to enjoy peaceful picnics, hikes, and overnight camping upon the hill because of the noise nuisance, flickering and strobing of lights, and ugly view shed of the turbines. How sad it is to know that some of these rural farms and properties that have been intended to be passed down from family generation to family generation have to endure these nuisances.

We should have learned from other countries mistakes regarding extensive turbine erection all over the landscapes. Upon sole opinion and opinion only-I know though, it is a "who knows who" and a "who will benefit from what (amount of money)" mentality. Hey, let's face it, if it is not in my back yard and I don't have to put up with it; I could care less about those who are being directly and indirectly affected. If it hurts bats, who cares! How sad it is that one does not fully understand the benefits of our environment and any particular species and/or plant life. There is a particular reason for all; brush up on the facts. One may also want to inquire why particular facilities do not and will not allow any on-going studies of avian species to proceed? Is there something to hide? Remember next it may be who cares about you, your family, your friends, and your neighbors. Let's not worry about whom and how it negatively effects them; let's just make some money! Quite a lot to ponder. Perhaps one may want to CAREFULLY inquire exactly how much these companies do pay in federal, state, and local taxes and how much revenue and credits they reap. Who exactly benefits and how much? It is quite astonishing!

Placement of these particular facilities is another issue that should be carefully studied before erecting them for those tax credits. From experience, computer regurgitated data cannot be taken into consideration for these particular projects. Topography is very important and has to be studied carefully in correlation to differential wind speeds, climatic conditions, and noise levels. One size does not fit all. As property owners whom have resided a numerous amount of years –some 50 plus; before this facility was built, and who have chosen to reside within a peaceful environment, we were never given the opportunity or made aware of the nuisances produced by this type of industrial facility. We were never given a chance to look at a waiver to choose if we wanted to live near this nuisance or explained the possible devaluation of property due to view-shed, noise, water run off etc.

We have experienced more power outages and surges; as well as excessive water run-off from the clear cut ridge top-Glade City was flooded with an enormous amount of water run-off from Hurricane Ivan- photographs and video footage clearly define where the water came from, disruption of portable phones within home and television reception, shadow flicker nuisances while driving on the local roadway and reported at a local Rod and Gun Club, a blinding white strobe light that was malfunctioning on one of the large turbines, and during daytime-close adjacent property owners disrupted by strobes.

One cannot understand that within larger municipalities and cities, noise nuisances and other issues created by those to others are liable for the disruptions. Shouldn't parties involved with this particular industry have to be held responsible and uphold stringent regulations and ordinances like any other industry? Just because we live in the rural countryside and have so for the majority of our lives and want our children to enjoy the peaceful countryside, why should we be the ones to suffer with such nuisances?

Employment by this particular industry is limited. Yes, local individuals may be employed while the facility is under construction, but in the end—well, look at the numbers—only a few are permanently employed. A slap in the face to a boost in the local economy. Look into the number of local individuals actually employed, the pay scale, and the amount of money the facility actually pays in taxes to the community, local, state, and federal governments. Where does the electricity go-is it utilized for local and surrounding areas with no charge? Who in particular is reaping the benefits from your local community? Exactly how much electricity do these particular facilities produce and in comparison to other sources of clean energy what percentage, the cost per kilowatt-hour, and how much maintenance do these structures require? These are just a few of the questions that need to be asked.

Ask the companies to thoroughly explain and to publicly share the clauses that are built into their legal documents between themselves and the landowners. It can be described as a "buyer beware" clause. Can be quite interesting reading, you may want to have your own legal expert with you before signing-the wording is quite creative and meanings quite crafty. I am sure those particular clauses do not want to be shared publicly. Careful, one may be giving up an abundance of rights regarding who is and who is not liable for the very nuisances and issues that these companies insist that the turbines do not create, such as noise, shadow flicker, strobe issues, right of road ways, water issues, and yes, even having the right to determine whether you are entitled to utilize your very own property as you see fit regarding varied farming, building, and recreational usage!

Stringent criteria; federal, state, and local laws, regulations and on -going long-term pre-post studies should be implemented and enforced prior to and during the operation of these industrial facilities. These industrial facilities and the parties involved who chose to have them erected should be held liable and accountable for any detrimental impacts and nuisances imposed and continue to be imposed upon humans and the environment. The facts should be carefully studied regarding this particular issue.

Remember we must work hand in hand to preserve what God has given us, to be greedy and to want to accomplish the goal of making a quick dollar at the expense of everyone and everything else is selfish. We need to take care of what we have now, not only for our future but also for the future generations that will follow.
This industry without stringent regulations can be truly labeled a "Pandora's Box". Be careful for what is opened, and be prepared for the negative impacts that have occurred and continue to occur with this industry.

Sincerely:

Karen Ervin

13 February 2005

Dear Sir:

I am writing to you in regards to living near an industrial power wind turbine facility. This facility is located in Somerset County near Meyersdale, Pennsylvania. The facility has been operating since December 2003.

Since this facility has been up and running, my family and I have experienced noise nuisance issues, specifically when trying to go to sleep at night. The noises are greater during the winter months. The noise appears to correlate to a continual droning sound. When awakened at night, there are times that is impossible to get back to sleep due to the threshing sounds produced by the wind turbines. After the first few weeks of the initial operation, I began to experience difficulty with sleeping patterns. My family physician was consulted regarding this issue with difficulties falling asleep. I was prescribed sleeping medication.

The noise nuisance issue continues to exist. February of 2003, I was in my yard running my chain saw and the drone of the wind turbines could be heard over the sound produced by the chain saw. I was never made aware of any type of noise nuisances produced by these industrial turbines prior to their construction.

My lifestyle has changed since this operating industrial facility was erected within near vicinity of my residence. I fear that my real estate value has decreased due to the noise nuisance and deterioration of the scenic mountain ridges that surround my residence.

These industrial facilities and landowners should be held accountable and liable for any all nuisances that affect local and adjacent property owners.

Sincerely:

Rodger A. Hutzell Jr.
327 Ridge Road
Meyersdale, PA
15552

Section title: Setbacks

The attached letter is very interesting. It was written October 2002 by a man named Dick Bowdler, to Sue Sliwinski in Sardinia, NY. Bowdler is president of an acoustics research firm in Scotland, called New Acoustics. He and his firm have done numerous noise tests on behalf of wind energy companies and on behalf of neighbors of windfarms—both groups. Notice where he writes the following (p. 2):

> In practice, in most rural areas, my rule of thumb is that the nearest turbine needs to be at least 1.25 miles from any house. However, these are areas where the background noise level can be 30dB(A) at night. You suggest that your background noise level could be 30-32 dB. This seems a likely figure if you have 350 houses in the area, though I suspect it could be a bit lower than this. On this basis, noise from the wind farm should not exceed 35dB(A). If the developers are suggesting that 55 decibels is acceptable, this is quite outrageous. 55 dB(A) is more than four times as loud as your background noise.

Several interesting points, here: Nina Pierpont, MD, PhD, in her study last winter (2005) also recommended a similar set-back from homes, though she recommended one slightly farther than Bowdler's: 1.5 miles (see Nina Pierpont, MD, PhD, "Health, hazard, and quality of life near wind power installations: How close is too close?" *Malone Telegram*, March 2, 2005, p. 5). That is, an acoustics expert who has done extensive work with windfarms, on both sides of the issue, recommends 1.25 miles of set-back, and a medical researcher, Nina Pierpont, recommends a 1.5 mile set-back. Bowdler & Pierpont reached this nearly identical figure entirely independently of one another. Interesting!

Second interesting point. The wind energy salesmen here in the No. Country are calling for an acceptable turbine noise level of 55 dB(A), which Bowdler (and Pierpont, by the way) is calling "outrageous."

You can contact Dick Bowdler at

Dick Bowdler

E-mail Address(es): mail@newacoustics.co.uk

Tel. 013 8987 8891, Fax. 013 8989 0516

Company: New Acoustics, Scotland

Web Page: http://www.newacoustics.co.uk

Calvin Luther Martin

96

15th October 2002

34 Old Mill Road
Duntocher
Clydebank,
Dunbartonshire
G81 6BX
Scotland

Tel: (01389) 8997 8891
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email: mail@newacoustics.co.uk
web site: www.newacoustics.co.uk

Susan Sliwinski
10820 Allen Road
East Concord,
NY 14055
USA

Your Ref:
Our Ref: WCNY

Dear Ms Sliwinski,

PROPOSED WIND FARM

Thank you for your enquiry about wind farm noise. I should probably explain my background and interest in wind farms. I have been a noise and acoustic consultant for more than 30 years and most of my current work is dealing with the assessment of environmental noise as it affects residential properties. I work equally for those potentially creating noise and those affected by it. I have been a supporter of wind energy and other forms of renewable energy for some 35 years. I have carried out noise assessments for both "sides" in planning applications for wind farms and adopt the same method of assessment whoever employs me.

Firstly, I will deal with the standards adopted for new noise sources in the UK. There are some variations throughout Europe but in broad terms they are not very different. Where a new noise is to be introduced into a residential area it is normal to set a noise limit relative to the pre-existing background noise.

Typical planning conditions imposed by rural local authorities (and sometimes urban ones) require that the new noise be no more than 5dB above the pre-existing background. This is based on the procedure set out in British Standard 4142. I should note here that the existing background noise is measured using "L_{A90}", the level exceeded for 90% of the time – in other words it is close to the minimum. With wind farms it would be reasonable to make background noise measurements when wind speeds at the development site were in the range at which the turbines operate. There is an argument sometimes used that, because wind turbines only operate when it is windy, the background noise levels are high. This is not necessarily true. I recently climbed from a valley to a wind farm 1½ miles away. There was enough wind for all the turbines to be operating yet when I took noise measurements out of view of the turbines, the level was consistently 22-23dBA. dBA is A-weighted decibels which corresponds roughly to loudness. An increase in 10dBA is a doubling of loudness, an increase of 20dBA is a quadrupling of loudness and so on.

I should mention, as it may be raised by others, that in terms of one piece of British planning advice (PAN 45 in Scotland) the one exception to the method I have described is the method of assessing wind farm noise. This advice suggests, effectively, that wind turbines can be 35 to 40dBA at the nearest housing. I think this is quite wrong and there is no reason why wind farms should be differently treated. In fact, there is good reason why wind farms should be treated more stringently than other noise sources. Most noise, for example that from a biomass development which has similar importance in renewable energy development, has the potential of being controlled at source at a later date by silencing or by barriers. Wind farms, once constructed, cannot practicably have noise reduced at source or by barriers.

In practice, in most rural areas, my rule of thumb is that the nearest turbine needs to be at least 1¼ miles from any house. However, these are areas where the background noise level can be 20dBA at night. You suggest that your background noise level could be 30-32dB. This seems a likely figure if you have 330 houses in the area, though I suspect it could be a bit lower than this. On this basis, noise from the wind farm should not exceed 35dBA. If the developers are suggesting that 55 decibels is acceptable, this is quite outrageous. 55dBA is more than four times as loud as your background noise.

Most of the Scottish wind farms that have recently been approved have no housing closer than about 1 mile, except where the house belongs to the landowner of the wind farm site. There are a few applications with houses as close as about 2000 feet but these have all either been turned down or withdrawn by the developer.

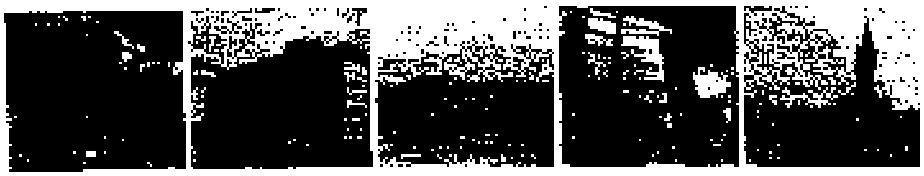
I am not familiar with the GE turbines, but I suspect that they have a sound power level of about 105dBA. In this case, the noise level would be between 45 and 50dBA at 1400 feet in neutral weather conditions and if the nearest turbines were in full view.

Pleas let me know if you would like any other information.

Yours sincerely,

Dick Bowdler

New Acoustic's sole business and that of its principals and staff is to provide a full time specialist acoustic consultancy service. Our primary field is the provision of specialist advice based on experience in noise, vibration and building acoustics. Our staff consists of the two directors with 20 and 30 years experience and an acoustic technician with 20 years experience. We work regularly throughout the UK and, in certain specialist areas, world-wide.



Our Philosophy:
We provide a complete professional service in which we will take responsibility for all aspects of the acoustic performance of a building. We adopt a pragmatic approach to our advice developed over years of working with a variety of clients. Proper professional practice is not simply the achievement of pre-determined standards, however authoritative these may be. Acoustic standards come as numbers which may have little or no meaning to a client. We will continually question, explain and demonstrate these standards so that the client and other consultants can make informed decisions.

This site was last updated on **1st September 2004** and is updated regularly so please revisit soon (maintained by Eleven Designs.) If your questions are not answered by this web site please do not hesitate to contact directors Dick Bowdler and/or Colin Frier for more information.

- home
- projects
  - building acoustics
  - environmental noise
    - transportation
    - industrial
    - windfarms
    - housing
    - planning inquiries
- conference rooms
- directors
- contact

new acoustics

We have carried out assessments for many windfarms and advised local authorities on their impact.

home
projects
directors
Dick Bowdler
Colin ...
contact

Dick Bowdler

Professional Qualifications

Bachelor of Science in Physics and Mathematics
Chartered Engineer
Member of the Institute of Physics
Fellow of the Institute of Acoustics
Fellow of the Chartered Institution of Building Services
Associate of the Chartered Institute of Arbiters

Employment

1987-Present Day	Director of New Acoustics Ltd.
1974-1987	Partner in charge of Edinburgh Office, Sandy Brown Associa
1970-1974	Consultant with Sandy Brown Associates.
1964-1970	Environmental Consultant in acoustics, ventilation and light!

Assessing and Mitigating Noise Impacts

New York State
Department of Environmental Conservation

PROGRAM POLICY	Department ID: DEP-00-1	Program ID: n/a
Issuing Authority: Environmental Conservation Law Articles 3, 8, 23, 27	**Originating Unit: Division of Environmental Permits**	
Name: Jeffrey Sama	Office/Division: Environmental Permits	
Title: Director	Unit:	
Signature: /S/ Date: 10/6/00	Phone: (518) 402-9167	
Issuance Date: October 6, 2000 Revised: June 5, 2001	Latest Review Date (Office Use):	

Abstract: Facility operations regulated by the Department of Environmental Conservation located in close proximity to other land uses can produce sound that creates significant noise impacts for proximal sound receptors. This policy and guidance presents noise impact assessment methods, examines the circumstances under which sound creates significant noise impacts, and identifies avoidance and mitigative measures to reduce or eliminate noise impacts.

Related References: See references pages 27 and 28.

I. PURPOSE[1]

This policy is intended to provide direction to the staff of the Department of Environmental Conservation for the evaluation of sound levels and characteristics (such as pitch and duration) generated from proposed or existing facilities. This guidance also serves to identify when noise levels may cause a significant environmental impact and gives methods for noise impact assessment, avoidance, and reduction measures. These methods can serve as a reference to applicants preparing environmental assessments in support of an application for a permit. Additionally, this guidance explains the Department's regulatory authority for undertaking noise evaluations and for imposing conditions for noise mitigation measures in the agency's approval

1 A Program Policy Memorandum is designed to provide guidance and clarify program issues for Division staff to ensure compliance with statutory and regulatory requirements. It provides assistance to New York State Department of Environmental Conservation (DEC) staff and the regulated community in interpreting and applying regulations and statutes to ensure that program uniformity is obtained throughout the State. Nothing set forth in a Program Policy Memorandum prevents DEC staff from varying from that guidance as specific circumstances may dictate, provided the staff's actions comply with applicable statutory and regulatory requirements. As this guidance document is not a fixed rule, it does not create any enforceable right by any party using the Program Policy Memorandum.

operates at the same noise level as the ambient, then 3 dB(A) must be added to the existing ambient noise level to obtain the future noise level. If the goal is not to raise the future noise levels the new facility would have to operate at 10 dB(A) or more lower than the ambient.(see Table A)

Table B

HUMAN REACTION TO INCREASES IN SOUND PRESSURE LEVEL

Increase in Sound Pressure (dB)	Human Reaction
Under 5	Unnoticed to tolerable
5 - 10	Intrusive
10 - 15	Very noticeable
15 - 20	Objectionable
Over 20	Very objectionable to intolerable

(Down and Stocks - 1978)

Impact assessment will vary for specific project reviews, but must consist of certain basic components for all assessments. Additional examination of sound generation and noise reception are necessary, where circumstances warrant. Sound impact evaluation is an incremental process, with four potential outcomes:

- exemption criteria are met and no noise evaluation is required;
- noise impacts are determined to be non-significant (after first-level evaluation);
- noise impacts are identified as a potential issue but can be readily mitigated (after second level evaluation); or
- noise impacts are identified as a significant issue requiring analysis of alternatives as well as mitigation (third level evaluation).

All levels of evaluation may require preparation of a noise analysis. The required scope of noise impact analysis can be rudimentary to rather sophisticated, depending on circumstances and the results obtained from initial levels of evaluation. Recommendations for each level of evaluation are presented below.

Anne

From: "Paul Coran" <pcoran@cecomet.net>
To: <rushton@westelcom.com>
Sent: Tuesday, November 30, 2004 11:52 PM
Subject: Setbacks and Request for Correction, etc./Wets Impact on Weatherpatterns

Hi Calvin-

It was a pleasure speaking with you the other week. Feel free to call anytime with your questions or if you are having difficulty viewing any of the videos, etc.

Thanks for generous gift. It wasn't necessary but sincerely appreciated.

Enclosed with this email is the contents of dialogue regarding set-backs of WT from residential areas. Fenner, NY is included in the discussion.

Additionally, you may wish to check out the following link to a thesis (2MB PDF download) concerning the impact of WTs to change weather patterns, etc. Larry McGuinn, a friend and neighbor comments below on his reading of the document. The link follows his comments and then the comments about setbacks.

Thanks again and I wish you well with you efforts to let the truth about WTs be known in your area.

God Bless,
Paul

From: "Larry & Linda McGuinn" <ldmcguin@cecomet.net>
Date: Wed, 24 Nov 2004 08:23:23 -0500
To: "Claire Quadri" <wind@cecomet.net>
Subject: Re: Another article!

it worked, read this over last nite...very interesting. If you noticed the fields were 30m or over 30 miles off shore, well out of the visual impact range and yet they had an effect on rain fall on land. You might send this to Paul and see if he would want to put on his computer and show at a meeting. The pics on the first page were impressive.
Larry
http://www.ucalgary.ca/~keith/Misc/KooijmansMesoscale.pdf

Paul J. Coran
Chautauqua County Citizens for Responsible Wind Power
P.O. Box 301, Westfield, NY 14787-0301
Hm.: 716.326.7440 Fax: 716.326.4740
pcoran@cecomet.net or wind@cecomet.net

------ Forwarded Message
From: "Cynthia Cole" <cynthiacole@usadatanet.net>
Reply-To: "Cynthia Cole" <cynthiacole@usadatanet.net>
Date: Wed, 24 Nov 2004 05:46:26 -0500
To: "John Servo" <jservo@dawnbreaker.com>
Subject: Re: Setbacks and Request for Correction

John Servo
Advocates for Prattsburgh
(585) 594-2522 (AFP)
(585) 594-9281 (work)
prattsburgh1@prattsburgh.org

------ End of Forwarded Message

before sunset. The setback requested to address this problem is 2300', which is equivalent to 10 rotor diameters for the GE 1.5s towers previously mentioned by Ecogen for this project. The setback would need to be farther for turbines with larger rotor diameters. Again, AFP is willing to accept mitigation. In this case, the shadow flicker can be mitigated by turning off the rotor during the problem periods. However, we have no confidence that the wind farm operator will do so unless stiff penalties were in place for non-compliance.

Viewshed is **very** difficult to mitigate, considering the fact that these towers will be visible up to 20 miles away. This is one of the reasons to aggregate the towers in one location – a designated or de facto industrial park – rather than spreading them across the town in-between the properties and house of non-participating landowners. AFP requested setbacks of **5 miles from historic sites**, which is consistent with State Historic Preservation Office guidelines. To my knowledge, there are at least 3 historic sites which would be affected by the project as currently structured: two in the Village of Naples (located in an adjacent Town, which will be affected by the project) and the Narcissa Prentice house in Prattsburgh.

We also requested setbacks of **a half-mile from major roads** for highway safety. To my knowledge, the only major road which would be affected is Route 53. For example, Palm Springs, CA has an ordinance requiring a half-mile setback from highways. When you get the copy of the presentation, please note the superimposition (to scale) of the 384' GE 1.5s wind towers on Knapp Hill, which rises 520' above (and directly alongside) Route 53. Imagine driving down this corridor with some of these towers near the edge of the cliffs above the road. We feel this distraction to drivers will constitute **a road hazard of colossal proportions**.

Of the setbacks mentioned at the 11/18/04 SCIDA meeting, the SHORTEST was **1536'**. This is for safety protection from **ice throw** when dealing with a tower/turbine with a total height (to the top of the blade) of 384'. 384' (80' taller than the Statue of Liberty from the top of the tide to the tip of the torch) is the total height of the specific version of the GE 1.5s windtower which Ecogen initially indicated to SCIDA and AFP that they would be using. Ecogen now appears to be keeping its options open to select a larger windtower, such as the GE 2.7. Global Winds Harvest has also mentioned using larger towers. **For these larger towers, the requested minimum setback to address ice throw (alone) would be 1800'** as stated in data from Germany for these larger (and taller) towers.

As noted above, there a number a serious health, safety, noise and viewshed concerns which can only be adequately addressed by placing these windtowers a significant distance from the property lines of non-participating landowners.

You requested a brief clarification. Here is my best effort, which you are free to excerpt.

"While the requested setback for high-frequency noise will vary (being site-specific), Advocates for Prattsburgh anticipates that noise studies following the 10/1/04 DEC Guidelines will lead to setbacks from property lines of 2200' to 3000'. This distance would also safely protected landowners from ice throw, and most probably, from shadow flicker. A half-mile setback from major roads is warranted for highway safety. Consistent with SHPO guidelines, a 5 mile setback should be honored from historic sites. A one-mile setback (or effective mitigation) can address the potentially harmful health effects from low-frequency noise."

The NYS PSC projects that we will have 1300 wind tower within the next 8 years, most of them in Western New York. There are currently NO REGULATIONS in New York to protect citizens from the inappropriate siting of these massive towers. SCIDA has the opportunity to show New York how this project can be done right, and we hope they rise to the challenge. Thanks again for your interest in what will be a critical issue for Prattsburgh, Steuben county and all of New York.

Please feel free to contact me should you need any further clarification.

Best regards,

John,
Thank you for an excellent reply.
Cynthia

----- Original Message -----

From: John Servo <mailto:jservo@dawnbreaker.com>

To: scanews@linkny.com

Sent: Tuesday, November 23, 2004 9:50 PM

Subject: Setbacks and Request for Correction

Rob Price
Steuben Courier Advocate

Dear Rob,

It was a pleasure speaking with you this afternoon about the Advocates for Prattsburgh (AFP) presentation to SCIDA on 11/18/04 and we appreciate your covering and writing about the meeting for the Steuben Courier Advocate. As we discussed, I will be sending you a hard copy of the Power Point presentation, in which we mentioned specifics regarding setbacks from the property lines of non-participating landowners. I mentioned this because **AFP did NOT specifically request a blanket 1500' setback from property lines.** What we requested and explained were various needs for setbacks which would adequately address *health, safety, noise and viewshed* issues. The minimum setback requirements are not arbitrary, as the need for setbacks varies with the nature of the problem which needs to be addressed and the siting of the towers. The setbacks are referenced to the **requirements necessary to adequately address specific problems** which will occur if **these machines are placed between the homes and properties of non-participating landowners**.

One of the most important (and easily regulated) setback is for **high-frequency noise.** We referenced the 10/1/04 letter from the DEC to SCIDA indicating how noise studies should be conducted at the **property lines** of non-participating landowners, when the leaves are off the trees, from the precise location of each tower. I will be sending you this DEC letter in a separate e-mail. As we discussed, Pastor Danley's house in Fenner is **over 2000' away** from the nearest tower, and the noise problem, at times, at her location is quite bad. Considering this and other information and data we have, AFP would NEVER request a noise setback of only 1500'. The background noise level at some of the property lines near proposed tower locations is in the range of 34-36dB(A). I can tell you this: where I have my house, it's QUIET. Because of the low background noise, it is more probable that actual noise setbacks consistent with the 10/1/04 DEC guidelines would be **in the range of 2200-3000'**, dependent of course, upon local conditions.

We also mentioned setbacks of at least **1 mile for low frequency noise,** the sub-audible noise which can make people sick. (Please see the attached article. I can provide more information should you need it.) For example, the city of Riverside, CA has an ordinance requiring a 2 mile setback for wind towers, **unless** the manufacturer can prove that the machine model in question will not produce any impulsive, tonal noise in the low frequency range. While AFP is potentially willing to accept a manufacturer's guarantee as mitigation for low frequency noise, we will first need to get the straight story from GE Wind Energy in Tahachapi, CA. As you and I discussed, when pressed for specifications the manufacturer has been non-responsive, claiming that virtually all technical information is "proprietary". Then they refer us to a cheerful person in Marketing, who thus far has acknowledged no problems resulting from the operations of these wind towers under any circumstances whatsoever. This has not been reassuring.

Shadow flicker - reflections of the sun off the blades - can turn each rotor into a giant strobe generator. Shadow flicker can cause seizures and migraines in susceptible individuals. This flicker effect occurs primarily during the first 60-90 minutes after sunrise and the first 60-90 minutes

The Press Republican - Plattsburgh, NY

ARCHIVES

[illegible]

Minor earthquake shakes up the North Country

Date: January [illegible], 2006
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH -- A Monday-morning rumble [illegible] around the North Country. [illegible] Maybe it's a passing train? Well, there's [illegible] ... in reality, a minor earthquake struck at 10:35 a.m. Monday and was felt across the North Country, [illegible] windows [illegible] to rumble... "I thought maybe [illegible], but there was no vehicle...

Small earthquake strikes along Quebec border

Date: March 4, 2005
Publication: Press Republican (Plattsburgh, NY)
Story Length: 2[illegible] words

MALONE -- A small earthquake with a magnitude of 2.5 struck in western [illegible] County [illegible] night. The National Weather Service in Burlington, Vt., said Thursday that the U.S. Geological Survey in Golden, Colo., reported the quake's epicenter was [illegible] miles [illegible] of the village of [illegible], about [illegible] miles south of the Canadian border. The quake occurred at 9:22 p.m. [illegible] Earthquakes of magnitude 2.5 generally...

Owls Head is center of 3.5 earthquake

Date: April 5, 2005
Publication: Press Republican (Plattsburgh, NY)
Story Length: 5[illegible] words

MALONE -- North Country residents were shaken by an earthquake Tuesday morning, the second one in less than a year. It measured 3.5 on the [illegible] scale and was recorded at [illegible] a.m., according to Dr. Frank Revetta, director of the Seismic Network at the Geology Department at SUNY Potsdam. "It was located about 30 miles east of Potsdam in the Adirondacks, near Lake Ozonia and Owls Head," he said. "It was felt by a lot of people in Plattsburgh.

Bi-county quake aid: $4 million

Date: January [illegible], 2004
Publication: Press-Republican (Plattsburgh, NY)
Story Length: 4[illegible] words

AU SABLE FORKS -- Last April's earthquake [illegible] the bi-county area around Au Sable Forks, resulting in $4.[illegible] million in earthquake aid [illegible] to people in Essex and Clinton counties. [illegible] from the April 20, 2002, earthquake is almost complete. Essex County Emergency Services Director Raymond Thatcher and the Federal Emergency Management Agency [illegible] million to [illegible] people for disaster housing aid in Essex County and [illegible] to [illegible] families and...

Quake of 3.0 felt on holiday

Date: December 25, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — [illegible]

Phantom quake alarms area

Date: December 5, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

LAKE PLACID — [illegible]

Holy Name being restored after quake

Date: July 19, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

AUSABLE FORKS — [illegible]

Clinton backs quake aid

Date: July 7, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

AUSABLE FORKS — [illegible]

Tremor revisits region

Date: June 28, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

LAKE PLACID — [illegible]

For the record

Date: June 21, 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

AUSABLE FORKS — [illegible]

Assess quake damage

Date: June [illegible], 2002
Publication: Press Republican (Plattsburgh, NY)
Story Length: [illegible] words

ALBANY — [illegible]

Quake disaster aid in area tops $600,000

Date: May 30, 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

ALBANY — Federal and state disaster assistance to people in Essex and Clinton counties affected by the April 20 earthquake has [illegible] more than [illegible]. Federal Coordinating Officer [illegible] C. Jackson of the Federal Emergency Management Agency [illegible] of recovery [illegible]. Since President Bush declared a major disaster on May 16, [illegible] have registered for assistance through FEMA's [illegible] More than $[illegible]...

Quake revisits area

Date: May 2[illegible], 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — North Country residents [illegible] evening. Around 7:45 [illegible] tremor shook the land. "Preliminary reports say that it was an aftershock from the April 20 [illegible]," said Essex County Emergency Services Director Raymond Thatcher. The April earthquake — a 5.1-magnitude temblor [illegible] as far away as Maine and Maryland — [illegible] damaging than Friday's [illegible] which originated...

Grants, loans available for quake victims

Date: May 2[illegible], 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

WASHINGTON — The recent disaster declaration for people in Clinton and Essex counties affected by the April 20 earthquake makes funds

available to help pay for temporary housing, emergency home repairs and other [illegible]. Grants totaling almost $[illegible] have already been awarded to [illegible] victims. Grants will be coordinated by the Federal Emergency Management Agency. Low-interest loans from the U.S. Small Business Administration also will be available to cover residential and...

Bush declares quake disaster

Date: May 17, 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — [illegible] President George W. Bush formally declared Clinton and Essex counties disaster areas Thursday in the wake of the April 20 earthquake. [illegible] The declaration opens the availability of federal and state grants and low-interest loans to pay for damage caused by the quake, which registered 5.1 on the Richter scale. [illegible] I could go outside and...

Pataki asks for federal disaster status after quake; aid at stake

Date: May 1[illegible], 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — Gov. George Pataki asked President Bush Thursday to declare Clinton and Essex counties [illegible] due to damages from the April 20 earthquake. That designation would make local governments, homeowners and businesses eligible for federal disaster assistance. The 5.1-magnitude earthquake [illegible] North Country [illegible] throughout the state and beyond. [illegible] The AuSable Forks earthquake [illegible]...

For kids, real effects may surface in future

Date: May 4, 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — The 5.1 earthquake that rocked the North Country [illegible] children a year from now. Their [illegible] by acting out [illegible] in the past 24 hours," said [illegible], coordinator of the [illegible] Network of Family Resource Centers and [illegible] Family Connections in Plattsburgh. "It can be something [illegible]...

5.1 Earthquake

Date: April 21, 2002
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

PLATTSBURGH — An earthquake rattled the North Country Saturday morning, causing [illegible] damage [illegible] reported. According to [illegible] reports from the U.S. Geological Survey, the temblor registered 5.1 on the Richter scale, [illegible] the strongest quake to hit the region since [illegible] deployed [illegible] the location and [illegible] Jim [illegible], director of [illegible] County Emergency Services, said Clinton and Essex counties [illegible]...

North Country is quake prone
Our region likes to shake, but most seismic events here are small

Date: February [illegible], 1999
Publication: Press-Republican (Plattsburgh, NY)
Story Length: [illegible] words

[illegible] — [illegible] northern New York in 19[illegible], the North Country [illegible] earthquakes, and [illegible] Richter scale, with [illegible] Santa Clara, [illegible] and [illegible]...

CNN.com / U.S.

Northeast of U.S. quivers in rare quake

April 20, 2002 Posted: 3:28 PM EDT (1928 GMT)

The quake caused this road to collapse outside Plattsburgh, New York

PLATTSBURGH, New York (CNN) -- An unusually strong earthquake was felt across the Northeast United States and parts of Canada early Saturday morning, rattling residents and buckling roads in the region of the epicenter. No injuries or deaths have been reported.

The U.S. Geological Survey confirmed the quake, setting the preliminary magnitude at 5.1 -- capable of causing considerable damage. It was centered 15 miles southwest of Plattsburgh, New York. According to the USGS, the quake happened at 6:50 a.m.

The Canadian Geological Survey reported an earthquake of magnitude 5.5. Frank Revetta, the director of the Potsdam Seismic Network at SUNY-Potsdam, said the Canadian figure may prove to be more accurate.

Jim King, director of Clinton County Emergency Services, told CNN two aftershocks have been felt -- one about 15 minutes after the initial earthquake, and a second shortly before 9 a.m.

"We're assessing the damage that's been called in," said King. "We have a couple of roads that have failed." He said State Route 9 was closed to traffic because of damage from the quake.

New York Department of Transportation workers began inspecting bridges for possible damage, and a lot of people had called in reports of damage ranging from shattered glass to cracked ceilings and chimneys. King said the county had declared an emergency. Plattsburgh reported no significant damage or injuries.

George Facteau, a resident of Plattsburgh, said statues and pictures in his apartment started to fall down, then his cat jumped up and ran out of the room.

"Actually at first it was kind of scary," Facteau said. "I wasn't quite sure what was going on."

Facteau said he lives close to several banks and a federal building. "That was my first concern, The shocks were so strong that they changed the course of the Mississippi River, church bells rang in Washington D.C. and Boston, and observers reported that the land distorted into visible rolling waves.

There were few deaths or damage because the surrounding area was mostly undeveloped at the time.

100

Northeastern Section - 40th Annual Meeting (March 14-16, 2005)

Paper No. 18-14

Presentation Time: 8:00 AM-12:00 PM

GEOGRAPHIC INFORMATION SYSTEM AS A RESEARCH AND TEACHING TOOL

[illegible] ... Geology Department ... St. Lawrence Univ ... Canton, NY ... [illegible] ... College at Potsdam, Dept. Geology, Potsdam, NY 13676

Geographic Information System (GIS) technology is used on the undergraduate level as a teaching and research tool. [illegible] New York State and Pennsylvania. [illegible] SUNY Potsdam [illegible] New York State Geological Survey [illegible] The project involved the compilation of 8500 gravity measurements and 370 earthquake epicenters in New York.

[illegible]

Northeastern Section - 40th Annual Meeting (March 14-16, 2005)
General Information for this Meeting

Session No. 18
[illegible]
[illegible]
[illegible] Tuesday, March 15, 2005

Geological Society of America Abstracts with Programs, Vol. 37, No. 1, p. [illegible]

Earthquake rattles northern New York Saturday

Press Release

Posted: 5/14/02

Press Release

An earthquake registering 5.1 on the Richter Scale was felt around northern New York and across the eastern seaboard of the United States just before 7 a.m. on Saturday, April 20, according to Dr. Frank Revetta, a professor of earth science and geophysics at SUNY Potsdam and director of the Potsdam Seismic Network.

"The earthquake was centered approximately 15 miles southwest of Plattsburgh, but people all over New York, New England and down to Maryland felt the tremors," said Dr. Revetta. "It certainly jolted me awake this morning."

According to Dr. Revetta, the earthquake that shook the area was a strong one. The United States Geological Survey (USGS) measured the earthquake at a magnitude of 5.1 on the Richter Scale. However, the Canadian Geological Survey measured the earthquake at a slightly higher magnitude - 5.5 on the Richter Scale.

"I think the Canadians might be right on this one," said Dr. Revetta. "They have a number of seismographs in the region. The earthquake definitely caused some damage in the area. I've heard reports of a portion of road collapsing near the epicenter and a roof buckling in the Parishville area.

"We don't have many earthquakes like this - typically, we only experience earthquakes of this size every 100 years," Dr. Revetta continued. "Interestingly though, we had one this size about 20 years ago in Newcomb, so it seems that the time span between major earthquakes is shortening. I'm not sure yet what this means, but it could be signaling that a bigger one is coming."

The earthquake in northern New York was stronger than others in recent history but short of the strongest earthquake recorded in New York State. That one hit Massena in 1944 and registered 5.8 on the Richter Scale and caused approximately $2 million worth of damage.

The Richter Scale, named after American Seismologist Charles F. Richter, is used to express the total amount of energy released by an earthquake. The scale ranges from one to ten.

Dr. Revetta said that today's earthquake was felt over a wide area, which is typical of earthquakes on the East Coast of the United States. "Our earthquakes are mostly shallow in this area because the crust of the earth is thinner along the East Coast. In California, the plates are deeper, so the shock waves are transmitted at a much greater depth."

Dr. Revetta's Potsdam Seismic Network monitors seismic activity throughout the North Country utilizing stations located in Potsdam, Massena, Bangor, Lake Ozonia (south of St. Regis Falls), Brasie Corners, Chipman (near Ogdensburg) and Fine. Those stations monitor activity twenty-four hours a day, and several have recorded smaller aftershocks that followed this morning's earthquake.

"I think there will be a number of aftershocks," said Dr. Revetta. "Geologists will travel to the epicenter today and tomorrow to evaluate the earthquake and its aftershocks with portable seismographs. This will help determine the exact depth and magnitude.

"I'm also hoping to conduct an intensity study with my students, beginning next week. I'd like to send surveys to people around the region through e-mail, so we can speed up the distribution and the return of results. Regardless of how we do it though, this is something we'll be working on and evaluating for quite a while."

10 Z

PressRepublican
The Online Community & News Source for Clinton, Essex and Franklin Counties of Northeastern New York

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[illegible]

[illegible]

Press-Republican (Plattsburgh, NY) [illegible]

January 17, 2006

Minor earthquake shakes up the North Country

STEPHEN BARTLETT Staff Writer

PLATTSBURGH -- A Monday-morning rumble raised some questions around the North Country: Is a giant snowplow rolling by?

Is the furnace about to explode?

Maybe it's a passing train? Wait, there are no train tracks near here.

Actually, a minor earthquake struck at 10:05 a.m. Monday and was felt across the North Country, causing dishes and windows to rattle, [illegible] to tremble and houses to rumble.

"I thought maybe it was a snowplow, but there was no vehicle traveling on the road," said [illegible], who was sitting in his Elizabethtown home with his wife, [illegible], [illegible] mail when the place rumbled.

Then he figured the furnace was on the blink. But when the longtime furnace repairman went to the basement, he found no indication of a problem.

"So it had to be an earthquake."

EPICENTER IN CANADA

The 3.7-magnitude earthquake's epicenter was the St. Lawrence Valley of Quebec, according to the U.S. Geological Survey's National Earthquake Information Center. Specifically, it originated 11 miles from Chateaugay, 15 miles from Akwesasne and 16 miles from Wolcott.

But earthquake specialist Dr. Frank Revetta of Potsdam State said the epicenter was actually closer to the New York border with Canada, about 25 kilometers east of [illegible]. The Canadians rated the magnitude at 4.2, though specialists in Vermont gave it a 3.7.

"It was a small one, but it was felt all over northern New York," Revetta said. "I was surprised at how far it was felt."

He said the "minor earthquake" was felt in Potsdam as well.

"I didn't bother to check the furnace."

Section title: Neighbors complain of turbine noise

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LATEST: Queen unveils police memorial

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CONCERN AT WIND NOISE

10:00 - 16 March 2005

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I Have been undertaking work on the problem of low frequency sound transmission from wind turbines since 1995 and I was part of the team who worked on the DTI Snow Report in 1997. It is clear to me that the downwind sounds from wind turbines have been underestimated and this is supported by the work recently undertaken by Fritz Van Den Berg, of the University of Groningen, in the Netherlands.

A very recent paper by Pedersen and Wayne in the December 2004 issue of the Journal of the Acoustic Society of America refers to sound medical dosages from wind turbines.

For a report, not to be published yet, I have computed the findings of Van Den Berg with figures of a well-known Government adviser in the UK, and have found that in the band 30 to 300Hz, the audible "swish" noise can carry for several kilometres downwind and at night time this is over the recommended limits.

My partner in the report that I am writing is Dr Amanda Harry, who lives in Cornwall, and she has many medical cases of illness - noise-related.

I am also concerned about the low frequency content of the noise and the seismic ground signals from nearby wind farms.

In 1995 to 1996 I gave evidence to planning officers of Powys Council and Leominster Council, which led to the refusal of a wind farm near Knighton.

One of the factors that the planners stated was the close proximity of the Powys Observatory, which had a sensitive seismometer.

There needs to be more work done in this field, especially if large wind farm clusters are approved.

It has often been found that standing below a turbine tower one does not detect the noise, which is often "pushed" downwind. I hold two BSc degrees, the first with first class honours (maths and physics), a London external Doctor of Philosophy degree, and I am a member of the Institution of Electrical Engineers (MIEE), a

Chartered Engineer (C Eng), a member of the Institute of Acoustics and a Fellow of the Institute of Physics (C Phys).

D M J P Manley

Stone Street

Llandovery

The following report on wind turbine noise was filed by residents of

Upper Lachlan, Australia in August 2005

by

Ian McCausland
9 August 2005

Factual Information about Wind Turbine Noise

The purpose of this presentation is to draw Councillors' attention to new scientific evidence concerning the noise made by high wind turbines of the type now being used throughout the wind generation industry, and to 'on the ground' evidence from the community near the Toora wind farm in South Gippsland, Victoria. This information is particularly relevant in view of the imminent wind farm DCP for Upper Lachlan and the Australian Wind Energy Association's submission that residences could be as close as 350 metres [1100 feet] from turbines.

My request to Councillors is to become fully acquainted with the reality of night time noise from wind farms so that the problems experienced at Toora and elsewhere can be avoided in Upper Lachlan. While it is recognised that the State Government is now the approval authority for larger wind farms, I believe our elected Council is potentially the most effective and appropriate influence on the Minister in protecting neighbours who will otherwise be adversely affected.

The Toora Experience

At Toora where there are just 12 turbines, all of a similar height to those proposed in Upper Lachlan, the following are examples of 'on the ground' evidence found with just a couple of phone calls:

- Sam Bitta, a dairy farmer of 30 years' residence who lives 1km [0.6 miles] from the nearest turbine, is disturbed by the noise for more than 3 nights in most weeks despite being assured by the wind farm developers that noise would not be a problem. His 9 year old son cannot sleep on these nights; even the dogs and cows are disturbed by the noise. He would be happy to receive a delegation from Upper Lachlan Council, or to receive phone calls at 03 56862035.

- Councillor David Lewis reports that the 'thumping' noise, heard on still nights when the turbines are still turning, is heard by those living in many directions from the turbines, and not just those who live down wind. He says that while the Council approved the Toora wind farm with a clear majority in 2001, it is now totally against further wind farm developments because the noise and other effects are now properly understood. While the community was about 75% in support of wind farms at the time of the Toora approval, it is now about 75% against. Councillor Lewis is prepared to speak to any Upper Lachlan Councillor by phoning the Council office on 03 56629200 and would be happy to try and arrange a meeting with his Council.

- Both Sam Bitta and David Lewis said that the turbine noise issue is frequently underestimated because it is often not heard during the daytime, particularly when close to the turbines, or when wind speed is quite high. It is the night time noise, heard in the absence of any background noise, that drives people to distraction. Sam

Bitta described the thumping noise as more of a physical sensation, like heavy heartbeats, than a clear sound. Others liken it to a distant pile driver.

- The Victorian Government, which generally supports wind farms, uses a system of Ministerially selected panels to advise on each wind farm proposal. The panel for the proposed Bald Hills development went to Toora to see and hear for themselves. The panel's report stated that on a windy day turbine noise was clearly audible 1km [0.6 miles] downwind, and, on a second visit during a relatively still period at night, they were able to detect turbine noise at 1.5km [nearly 1 mile], even when there was 'considerable topographical intervention'. It further reported ' *Whilst the Panel cannot claim to have experienced any of the alleged low frequency or infrasound effects complained of, it must record some surprise at the noise emissions observed at Toora. It could understand that nearby residents would be annoyed'*

New Scientific Findings

The new scientific evidence was published in the international *Journal of Sound and Vibration* late last year. It is an exhaustive European study of wind turbine noise which is the subject of complaints from residents living up to 1900 metres [1.18 miles] away. A series of actual noise measurements were made over a period of 4 months at distances of 400 [quarter mile] and 1500 [nearly 1 mile] metres from the turbines. It found several causes of night time noise level being higher than predicted by normal sound estimations required for development of wind farms. These were:

- Wind speed at night was over twice that predicted at tower height, based on a 10 metre [33 feet] reference level, and, as a result, turbine noise at ground level was up to 15 dB higher than predicted. The difference in night time wind level at tower height against that predicted was attributed to radiation cooling of the surface air which diverts wind upwards, leaving ground level conditions still and quiet. Under these conditions the turbines can be clearly heard and cause considerable annoyance to residents.

- At night the sound from the wind turbines contained repetitive 'pulses', and the investigators found this to be due to two or more turbines operating nearly synchronously. This pulsing produces a 'thumping' sound as much as 5 dB louder than estimations made by sound modelling.

These finding are particularly relevant to the Upper Lachlan because radiation cooling of surface air with wind diversion upward (surface temperature inversion) is known to be common and more prevalent on the tablelands than in areas close to the coast (Ken Batt, Officer in Charge, Canberra Meteorology Office) In coastal areas, such as the wind farm at Toora, residents living as far as 1.2 km [3/4 of a mile] away are disturbed by the night time noise, which has been likened to a dripping tap in its relentlessness. In Upper Lachlan, the noise can be expected to travel further because of the greater effect of surface temperature inversion, when the wind is diverted upwards so that turbines continue to turn and generate noise which can be clearly heard in the still conditions at ground level. Ken Batt says temperature inversion can occur daily in the tablelands in winter, and less commonly in summer.

Finally, I suggest Councillors make contact with South Gippsland Council, either through David Lewis or the Shire CEO (Joseph Cullen, 03 56629204) to become fully acquainted with the continuing difficulties turbine noise is causing for Toora residents and the Council itself. Joseph will be happy to arrange a meeting with his Councillors.

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Problems associated with wind turbines

Arlin Monfils, Chairman
Lincoln Town Board
Kewaunee County, Wisconsin

February 1, 2000

[This letter was written by Mr. Monfils, Lincoln Town Board Chairman, about living near wind turbines in Kewaunee County, Wisconsin. He wrote it hoping that it will help other communities facing wind power plant proposals.]

To Whom It May Concern:

One lesson learned from our experience with the process of the request for locating wind turbines in the Town of Lincoln in Kewaunee County, was never to assume that what the Utilities or their private supporters tell you about the project is accurate. They put out information, which was beneficial to them and the project and downright wrong.

When dealing with the utilities or private companies, try to deal with one or two persons in charge. This avoids having to repeat your concerns and helps to avoid problems about who said what and who promised this or that about your concerns about the project. Get their promises in writing with guarantees about what they are promising. If their promises are not met, written penalties of appropriate, but substantial size must be provided and enforced. Written conditions and penalties are mandatory if you plan to accept the wind farm project.

Problems that are of strong concern, and problems that we had warned the utilities about but were assured that they would not occur are as follows: interference with T V reception, Microwave reception interference, depreciating property values, flashing red lights (FAA) interfering with nearby homes, wind turbine NOISE which interferes with neighbors sleep and their mental health, increased traffic, road damage, cattle being scared from rotating shadows cascading from the blades in a setting sun, rotating shadows in nearby homes, concerns about stray voltage, concerns about increased lightening strikes, environmental damage to birds, etc. etc. etc. But the proponents for wind energy will dismiss all of these concerns and tell you that they will not occur. THEY ARE WRONG. Ask the neighbors who are not property owners reimbursed by the utilities through lease agreements on their

(over)

property or people who want to lease in the future. They will verify these problems.

If a town has zoning, establish written conditions with penalties to ensure that the utilities and companies follow the regulations of the local town zoning. Also, look into the establishment of a moratorium on the project so more time can be used to collect or research information about the concerns voiced in areas like Kewaunee County. These concerns are about the public health and safety of our residents and this grand idea of "sticking" these huge towers in near by residents is not a proven success story. It's a trial by ERROR! Only time will tell what the effects of this "EXPERIMENT" will be. This is especially true with the issues of noise, its effect on the neighbors, their mental health related to the noise and its disturbance, the effect of stray voltage on the nearby cattle, as well as other safety issues. Other concerns like the distractions of drivers from the rotating blades, increased lightening strikes in the areas of the towers (not to the towers directly because they are grounded), and other public health and safety issues need to be analyzed on into the future.

Once again, let me stress the importance of taking your time and asking the questions and researching the answers. Forget about deadlines, don't be intimidated by the attorneys of the utilities, their deadlines are their problem and don't make them yours. Once the turbines are up and operating the wind turbine noise will be there. It will not be constant and it may not be above the decibel level that they establish as a maximum, but it will be irritating, at any time of day or night and will vary in its intensity with the wind direction and speed. It violates the very basis of what a zoning ordinance is meant to protect - the welfare of the people who already live in that community. The responsibility of your zoning board and your town board is to protect the residents of your community. Further, these elected or appointed people are supposed to represent the will of the people. You the electorate must demand no less than that, and the town board and the zoning board must vote accordingly.

Sincerely,

Arlin Monfils
Chairperson, Lincoln Town
Kewaunee County, Wisconsin

AGRICULTURAL RESOURCE CENTER

University of Wisconsin-River Falls, 410 S. 3rd Street, River Falls, WI 54022-5001
(715) 425-0640 • FAX (715) 425-4479

UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY
This survey summary completed Thursday, May 16, 2001,
by David E. Kabes and Crystal Smith.

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

1. Are any of the following wind turbine issues currently causing problems in your household?

d. Noise

Question # 1d

1 Sometimes so loud it makes it seem like we live in an industrial park. The noise dominates the "sound scape". It's very unsettling/disturbing especially since it had been so peaceful here. It is an ongoing source of irritation. Can be heard throughout our house even with all the windows and doors closed.

2 The noise generated by the turbines can be felt and heard inside as well as outside the house. Since most wind is from the west, northwest, and southwest we are usually down wind from the turbines.

3 When there is a strong south wind and you are sitting on the deck you can here the swish of the blades.

4 Wind from south, constant droning sound

5 They are very loud when it is calm outside.

6 It is the annoyance of never having a quiet evening outdoors. When the blades occasionally stop its like pressure being removed from my ears. You actually hear the quiet, which is a relief.

7 At night I have a hard time sleeping because I can hear them.

8 Depending which way the wind is we hear a slight noise.

9 Only when I'm outside and it's quiet. It's a big whoosh sound

Does not affect us.

We don't live close

10 Sounds like a gravel pit crushing rock nearby.

11 Sometimes depends which way the winds are blowing.

12 Sometimes

We can hear a mild hum in ideal conditions and if we pay attention to hear it.

13 Here when you go to bed and try to sleep at night or when you're outside working you hear what is like a constantly running silo and humming and swoosh sound from blades.

14 A loud whooshing noise.

At times we can hear them.

A faint sound

15 Can here them at night!

16 Occasional noise

17 Very noisy, very annoying when conditions are right.

18 When high winds

19 Very annoying if we have the windows open at night.

20 When the wind if from the northwest, we can hear the turbines. It sounds like a threshing machine running. It is annoying.

21 Loud swooshing comes through walls and bothers sleep and serenity of country living.

22 North winds and cold wind you can hear noise.

23 Can hear on some days even 2+ miles away. I'd hate to live near them.

24 Very noisy when wind is out of the southwest, west, south and east. At times we can hear them with the windows shut. There are very few days we don't hear them.

25 People that say they don't make noise. They probably say that you can't see them either. "RIGHT"

26 When I'm down wind from the turbines I hear a swishing noise, when directions are right.

27 Very audible in the spring, summer and fall when our windows are open. Sounds like the pounding of heavy machinery. Very nerve racking when subject to this.

I hear the wind towers once in a while.

28 Depending which way the wind blows and the time of the each wind a swooshing sound can be heard and it is very annoying. Several make the noise constant.

If outside for extended periods of time the mind registers the whooshing sound and I "hear" it even if I really don't. Windows remain closed in summer during the evenings.

29 The noise can make it impossible to fall asleep. It makes an uneven pitch not like the white noise of a fan. Can be heard through closed windows making it hard to fall asleep anytime of the year.

30 You can hear them at times as far as two miles away.

31 Summer, spring, and fall when windows are open the swooshing of the blades.

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"The noise was incredible"

Paula Stahl

April 4, 2004

[This is a letter written by Paula Stahl of St. George, West Virginia, about her experiences living in the neighborhood of the 66 MW Mountaineer Wind Energy Center. Formerly known as the Backbone Mountain Wind Farm, the 4,400-acre site has 44 turbines, 1.5 MW each, stretched along miles of ridgeline in Tucker and Preston counties. Ms. Stahl submitted the letter to the *Berkshire Eagle* and *North Adams Transcript*, neither of which has printed it.]

I live in rural West Virginia, far and away from technology and the modern rat race of life. And that is how I like it. That is why I live here. I am of Native American descent, and chose this way of life and my location carefully, as did many other people who live in the area. Several years ago, large trucks carrying large pieces of something started showing up. Before long, several Wind Turbines were erected on the top ridge of the Mountain. ("The mountain" is what the local folks call Backbone Mountain Ridge, here in Tucker County.)

More and more trucks came and, in time, the whole ridge of the mountain skyline was lined with Wind Turbines. A wide path of timber was cut to make room for them, and the debris from this was just tossed over the hill, leaving large piles of brush, and the workers' trash underneath.

I did not know much about wind turbines, and so, I reserved my judgment. At first I learned that the community and the county were all for them, and excited about the arrival, for they said that there would be financial gains, and jobs created in the area from the project.

I walked on my normal walk in the woods one day, and looked up to the top of the mountain. Just several months before it had been a picturesque view of wilderness Beauty...the kind that attracts tourists, and creates much of the state's income. Now, it was lined with these tall mechanical monsters, towering over the trees of an old forest. I am not talking about the quaint and charming windmills of Holland here, we are talking about metal, and flashing lights, and a size that miniaturizes the grand forest beneath it.

I remember that day, for I stood there, and felt just as my ancestors must have felt when they watched the railroad coming across the country into their land, and into their life...and there was nothing, absolutely nothing they could do to stop it once it began. I had a gut feeling. Instinct reaction. My mind whispered..."they are coming".

Still, I tried to keep an open mind, and learn more. Perhaps, if they are environmentally safe...if they provide jobs, and revenue...perhaps for the good of all they are worth the eye sore. So, I took a walk up the mountain, the four miles they are from my home in the little valley below, and stood beneath the machines.

The noise was incredible. It surprised me. It sounded like airplanes or helicopters. And it traveled. Sometimes you could not hear the sound standing right under one, but you heard it 3,000 yards down the hill, where the wind carried the sound. My good friend, who lives right near them, says she can hear them with the doors to her house closed sometimes.

I looked around me, to a place where months before had been prime country for deer, wild turkey, and yes, black bear, to see positively no sign of any of the animals about at all. This alarmed me, so I scouted in the woods that afternoon. I am accustomed to these woods, and know them and the signs of animals well. All afternoon, I found no sign, sight, or peek of any animal about.

I did notice, in the next few months, that the animals were more abundant down here in the valley, in the farmers' fields and such. Places that they had steered away from before, they now were in, and causing trouble for man, and, in turn, getting shot. I saw more bear and bob cats in the populated areas than I had ever seen. I went up to the windmills several times to check, and it seemed that the animals had moved away from that area. There were no sight of them, no prints, no sign.

I also noticed more flooding in the valley below. Each and every rain storm seems to make the creeks rise out of their banks, and cause damage to fields, and roads, and all the things we humans depend upon. I have tried to inquire as to any studies being done on the effects of water runoff from disturbing the top of the mountain to this degree, and the erosion, and impact of leaving the timber lay, but I am answered with blank stares, and minds that have already decided that the Wind Turbine Project is good, and will stay.

In fact, I am seen as a trouble maker, a tree hugger, and a "granola" for being concerned. It seems as if one is not really allowed to ask questions, once the monsters start their invasion.

All the while, I look up to the top of the hills my Father, GrandFather, and Great Great Grandfather called home...and watch more monsters come.

The value of property here is directly related to it being a scenic area. This is not the scenery I would travel to go see if I were a tourist. Are we cutting out our state's main revenue of tourism to try to gain a little revenue from the monsters?

Will it work? Is there a true gain in jobs? In revenue? Is it environmentally safe?

"I live in Tucker County [West Virginia], approximately 1.5 miles from the Backbone Mountain wind turbines, and have tried everything to get used to them. A brief visit to one of the viewing areas certainly gives no true impression of what it is like to be forced to live with them.

We have now suffered for three long years under their hideous shadows. They have taken over the entire landscape and are in our sight no matter where we go, day or night, 24 hours a day, 365 days a year.

The movement is impossible to ignore, no matter how hard we try, and the noise they make travels miles and miles, down the mountains and hollows, disturbing people who cannot even see them from their homes. I compare the noise to Chinese water torture, or fingernails on a chalkboard, or water dripping in a pan. Even on the calmest nights, the endless drumming goes on; windows closed, pillows over the head, it is still inescapable.

While we were led to believe this would be a clean, quiet, pristine, and environmentally-friendly way to address energy problems and give a huge boost to our ailing economy, I feel we have been tricked. There appears to be no recourse or plan to compensate us for property value losses, erosion of our quality of life, or mental anguish.

Besides these 44 wind turbines, thousands more are in the pipeline! God help!"

-- from, "Activist Shares Wind Power Concerns – Linda Cooper, Citizens for Responsible Wind Power," *The Pendleton Times (Franklin, W. Va.)*, March 3, 2005, p. 4.

Section title: Noise studies & reports

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Calvin Luther Martin

From: "Angela Kelly" <amk@clara.co.uk>
To: "Angela Kelly" <amk@clara.co.uk>
Sent: Saturday, November 05, 2005 4:07 AM
Attach: NOISE NZ .doc
Subject: AK Re: IMPORTANT - NOISE - Wind turbine setback: 1.5 miles, saysphysician

RR

Information sent March 2005 courtesy of our co-campaigners in France

AK) Resent for the benefit of the many newcomers to this RR List

Please find the new information just published concerning health problems about French St Crepin Windfarm located in the southwest in
"Charentes maritime Department"
The results of an offlcidal public opinion poll concerning the 280 residents (sent to 200 adults over 18 year old)

Participation 83%

58% consider noise as disturbing

10% complain about noise by day

27% consider noise as intolerable by night

distance from the nearest windmill:

16% less than 500 m	1640 ft.	0.31 mile
23% 750 m	2460 ft.	0.47 mile
45% 1000 m	3280 ft.	0.62 mile
12% 1250 m	4100 ft.	0.78 mile

All survey participants were within 3/4 mile, 84% within 2/3 mile, 39% within 1/2 mile of turbines

An official protest asking the "Prefect" to stop the windfarm every night from 20 pm to 7 am

Can you pass information internationally and also to Dr Pierpont with my thanks for his report.

Cordialy
J.L. Butré
http://ventdubocage

<http://ventdubocage/> *SAINT CREPIN LA CENTRALE EOLIENNE DOIT IMPERATIVEMENT S'ARRÊTER LA NUIT*
LA SANTE DES HABITANTS EN DANGER
Vent de Colère en Pays d'Aunis demande :
L'arret du parc éolien toutes les nuits de 20 heures a 7 heures du matin .
St Crépin est un petit village de 280 habitants ,
Un questionnaire a été adressé par le Maire aux 200 adultes de plus de 18 ans (80 résidents secondaires + absents +enfants)
Résultat : 83 % de participation
Distances des habitations par rapport a l'éolienne la plus proche :
- 500 mètres et - 16 %
- 750 mètres 23 %
- 1000 mètres 45 %
- 1250 mètres 16 %
Se plaignent du bruit : 58 %

Trouvent le bruit gênant et insupportable :
de nuit : 27 %
de jour : 10 %
Demandent un aménagement Horaire : 40%

Assessing and Mitigating Noise Impacts

New York State
Department of Environmental Conservation

PROGRAM POLICY	Department ID: DEP-00-1	Program ID: n/a
Issuing Authority: Environmental Conservation Law Articles 3, 8, 23, 27	Originating Unit: Division of Environmental Permits	
Name: Jeffrey Sama	Office/Division: Environmental Permits	
Title: Director	Unit:	
Signature: /S/ Date: 10/6/00	Phone: (518) 402-9167	
Issuance Date: October 6, 2000 Revised: February 2, 2001	Latest Review Date (Office Use):	

Abstract: Facility operations regulated by the Department of Environmental Conservation located in close proximity to other land uses can produce sound that creates significant noise impacts for proximal sound receptors. This policy and guidance presents noise impact assessment methods, examines the circumstances under which sound creates significant noise impacts, and identifies avoidance and mitigative measures to reduce or eliminate noise impacts.

Related References: See references pages 27 and 28.

I. PURPOSE[1]

This policy is intended to provide direction to the staff of the Department of Environmental Conservation for the evaluation of sound levels and characteristics (such as pitch and duration) generated from proposed or existing facilities. This guidance also serves to identify when noise levels may cause a significant environmental impact and gives methods for noise impact assessment, avoidance, and reduction measures. These methods can serve as a reference to applicants preparing environmental assessments in support of an application for a permit. Additionally, this guidance explains the Department's regulatory authority for undertaking noise evaluations and for imposing conditions for noise mitigation measures in the agency's approval

[1] A Program Policy Memorandum is designed to provide guidance and clarify program issues for Division staff to ensure compliance with statutory and regulatory requirements. It provides assistance to New York State Department of Environmental Conservation (DEC) staff and the regulated community in interpreting and applying regulations and statutes to assure that program conformity is attained throughout the State. Nothing set forth in a Program Policy Memorandum prevents DEC staff from varying from that guidance as specific circumstances may dictate, provided the staff's actions comply with applicable statutory and regulatory requirements. As this guidance document is not a fixed rule, it does not create any enforceable right by any party using the Program Policy Memorandum.

of permits for various types of facilities pursuant to regulatory program regulations and the State Environmental Quality Review Act (SEQR).

II. Background

Noise is defined as any loud, discordant or disagreeable sound or sounds. More commonly, in an environmental context, noise is defined simply as unwanted sound. Certain activities inherently produce sound levels or sound characteristics that have the potential to create noise. The sound generated by proposed or existing facilities may become noise due to land use surrounding the facility. When lands adjoining an existing or proposed facility contain residential, commercial, institutional or recreational uses that are proximal to the facility, noise is likely to be a matter of concern to residents or users of adjacent lands.

A. Sources of Noise Generation

The three major categories of noise sources associated with facilities are (1) fixed equipment or process operations; (2) mobile equipment or process operations; and (3) transport movements of products, raw material or waste. The fixed plant may include a very wide range of equipment including: generators; pumps; compressors; crushers of plastics, stone or metal; grinders; screens; conveyers; storage bins; or electrical equipment. Mobile operations may include: drilling; haulage; pug mills; mobile treatment units; and service operations. Transport movements may include truck traffic within the operation, loading and unloading trucks and movement in and out of the facility. Any or all of these activities may be in operation at any one time. Singular or multiple effects of sound generation from these operations may constitute a potential source of noise.

B. Potential for Adverse Impacts

Numerous environmental factors determine the level or perceptibility of sound at a given point of reception. These factors include: distance from the source of sound to receptor; surrounding terrain; ambient sound level; time of day; wind direction; temperature gradient; and relative humidity. The characteristics of a sound are also important determining factors for considering it as noise. The amplitude (loudness), frequency (pitch), impulse patterns and duration of sound all affect the potential for a sound to be a noise. The combination of sound characteristics, environmental factors and the physical and mental sensitivity of a receptor to a sound determine whether or not a sound will be perceived as a noise. This guidance uses these factors in assessing the presence of noise and the significance of its impacts. It relies upon qualitative and quantitative sound evaluation techniques and sound pressure level impact modeling presented in accepted references on the subject.

C. Mitigation

Mitigation refers to actions that will be taken to reduce the effects of noise or the noise levels on a receptor. Adverse noise effects generated by a facility can be avoided or reduced at the point of generation thereby diminishing the effects of the noise at the point of reception. This guidance identifies various mitigation techniques and their proper application either at the source of noise generation or on a facility's property. Alternative construction or operational methods, equipment maintenance, selection of alternative equipment, physical barriers, siting of activities, set backs, and established hours of construction or operation, are among the techniques that can successfully avoid or reduce adverse noise effects.

D. Decision Making

When an assessment of the potential for adverse noise impacts indicates the need for noise mitigation, it is preferred that specifications for such measures be incorporated in a noise analysis and in the applicant's work or operational plan necessary for a complete application. Presenting a plan that incorporates effective noise mitigation provisions facilitates the Department's technical and environmental review and minimizes or negates the imposition of permit conditions by the Department. Adherence to these plans becomes a condition of a permit.

Noise avoidance and mitigation measures may also be imposed directly as conditions of permit issuance. This guidance will review the statutory authority under which the Department can require the mitigation of noise effects.

III. Policy

In the review of an application for a permit, the Department of Environmental Conservation is to evaluate the potential for adverse impacts of sound generated and emanating to receptors outside of the facility or property. When a sound level evaluation indicates that receptors may experience sound levels or characteristics that produce significant noise impacts or impairment of property use, the Department is to require the permittee or applicant to employ reasonable and necessary measures to either eliminate or mitigate adverse noise effects. Options to be used to fulfill this guidance should be implemented within the existing regulatory and environmental review framework of the agency.

Regulatory authority for assessing and controlling noise effects are contained in both SEQR and specific Department program regulations. Specific regulatory references are as follows:

Section 3-0301(1)(i) of the Environmental Conservation Law (ECL) states that the commissioner shall have the power to: "i. Provide for prevention and abatement of all water, land and air pollution including but not limited to that related to particulates, gases, dust, vapors, noise, radiation, odor, nutrients and heated liquids."

To comply with Article 8 of the ECL and 6 NYCRR Part 617, State Environmental Quality Review Act, consideration of all relevant environmental issues must be undertaken in making a determination of environmental significance. Noise impact potential is one of many potential issues for consideration in a SEQR review.

Environmental Conservation Law (ECL) Article 23, Title 27, Mined Land Reclamation Law (MLRL), requires applicants for permits to prepare and submit a mined land use plan to the Department for approval. The plan must describe, "the applicant's mining method and measures to be taken to minimize adverse environmental impacts resulting from the mining operation." The provisions to be incorporated in a Mined Land Use Plan, as specified in 6 NYCRR Section 422.2, include the control of noise as a component of the plan.

The solid waste regulations at 6 NYCRR Subdivision 360-1.14(p), establish A-weighted decibel levels that are not to be exceeded at the property line of a facility.

The Division of Air Resources has regulations in 6 NYCRR Parts 450 through 454 that regulate the allowable sound level limits on certain motor vehicles. The statutory authority for these regulations is found in the New York State Vehicle and Traffic Law, Article 10, Section 386.

This guidance does not supercede any local noise ordinances or regulations.

IV. RESPONSIBILITY

The environmental analyst, acting as project manager for the review of applications for permits or permit modifications and working in concert with the program specialist, is responsible for ensuring that sound generation and noise emanating from proposed or existing facilities are properly evaluated. For new permits or significantly modified permits, there should be a determination as to the potential for noise impacts, and establishment of the requirements for noise impact assessment to be included in the application for permit Where the Department is lead agency, the analyst is responsible for making a determination of significance pursuant to SEQR with respect to potential noise impacts and include documentation for such determination.

Where impacts are to be avoided or reduced through mitigation measures, the analyst, or where there are program requirements to address noise, the program specialist, should determine the effectiveness and feasibility of those measures and ensure that the permit conditions contain specific details for such measures. It should also be determined if additional measures to control noise are to be imposed as a condition of permitting. Appropriate permit language for the permit conditions should be developed by the program specialist and the analyst. The results of noise impact evaluations and the effectiveness of mitigation measures shall be incorporated into SEQR documents and, where necessary, permit conditions shall be placed in final permits to ensure effective noise control.

When it is determined that potential noise effects, as well as other issues, warrant evaluation of impacts and mitigation measures in a Draft Environmental Impact Statement (EIS) prepared pursuant to SEQR, the environmental analyst with the Division of Environmental Permits assumes responsibility for determining the level of evaluation needed to assess sound level generation, noise effects, and mitigation needs and feasibility.

For existing facilities, the program specialist will determine the need for additional mitigation measures to control noise effects either in response to complaints or other changes in circumstances such as new noise from existing facilities or a change in land-use proximal to the facility.

The applicant or their agent, in preparing an application for a permit and supporting documentation, is responsible for assessing the potential noise impacts on area receptors. When potential adverse noise impacts are identified, the applicant should incorporate noise avoidance and reduction measures in the construction or operating plans. The applicant's submittal should also assess the effectiveness of proposed mitigation measures in eliminating adverse noise reception. Where noise effects are determined to be a reason in support of a SEQR positive declaration, the applicant shall assess noise impacts, avoidance, and mitigation measures in a Draft EIS using methodologies acceptable to this Department.

V. PROCEDURE

The intent of this section is to: introduce terms related to noise analyses; describe some of the various methods used to determine the impacts of sound pressure levels on receptors; identify some of the various attenuators of noise; and list some of the mitigative techniques that can be used to reduce the effects of noise on a receptor. At the end of the section three levels of analysis are described. The first level determines the potential for adverse noise impacts based on noise characteristics and sound pressure increases solely on noise attenuation over distance between the source and receptor of the noise. The second level factors other considerations such as topography and noise abatement measures in determining if adverse noise impacts will occur. The third level evaluates noise abatement alternatives and their effectiveness in avoiding or reducing noise impacts.

The environmental effects of sound and human perceptions of sound can be described in terms of four characteristics:

1. Sound Pressure Level (SPL may also be designated by the symbol L_p) or perceived loudness is expressed in decibels (dB) or A-weighted decibel scale dB(A) which is weighted towards those portions of the frequency spectrum, between 20 and 20,000 Hertz, to which the human ear is most sensitive. Both measure sound pressure in the atmosphere.

2. Frequency (perceived as pitch), the rate at which a sound source vibrates or makes the air vibrate.

3. Duration i.e., recurring fluctuation in sound pressure or tone at an interval; sharp or startling noise at recurring interval; the temporal nature (continuous vs. intermittent) of sound.

4. Pure tone which is comprised of a single frequency. Pure tones are relatively rare in nature but, if they do occur, they can be extremely annoying.

Another term, related to the average of the sound energy over time, is the Equivalent Sound Level or L_{eq}. The L_{eq} integrates fluctuating sound levels over a period of time to express them as a steady state sound level. As an example, if two sounds are measured and one sound has twice the energy but lasts half as long, the two sounds would be characterized as having the same equivalent sound level. Equivalent Sound Level is considered to be directly related to the effects of sound on people since it expresses the equivalent magnitude of the sound as a function of frequency of occurrence and time. By its derivation L_{eq} does not express the maximum nor minimum SPLs that may occur in a given time period. These maximum and minimum SPLs should be given in the noise analysis. The time interval over which the L_{eq} is measured should always be given. It is generally shown as a parenthetic; $L_{eq(8)}$ would indicate that the sound had been measured for a period of eight hours.

Equivalent Sound Level (L_{eq}) correlates well and can be combined with other types of noise analyses such as Composite Noise Rating, Community Noise Equivalent Level and day-night noise levels characterized by L_{dn} where an $L_{eq(24)}$ is measured and 10 dBA is added to all noise levels measured between 10 pm and 7 am. These different types of noise analyses basically combine noise measurements into measures of cumulative noise exposure and may weight noise occurring at different times by adding decibels to the actual decibel level. Some of these analyses require more complex noise analysis than is mentioned in this guidance. They may be used in a noise analyses prepared for projects.

Designations for sound levels may also be shown as $L_{(10)}$ or $L_{(90)}$ in a noise analysis. These designations refer to the sound pressure level (SPL) that is exceeded for 10% of the time over which the sound is measured, in the case of $L_{(10)}$, and 90% of the time, in the case of $L_{(90)}$. For example, an $L_{(90)}$ of 70 dB(A) means that 70 dB(A) is exceeded for 90% the time for which the measurement was taken.

A. Environmental Setting and Effects on Noise Levels

1. Sound Level Reduction Over Distance - It is important to have an understanding of the way noise decreases with distance. The decrease in sound level from any single noise source normally follows the "inverse square law." That is, SPL changes in inverse proportion to the square of the distance from the sound source. At distances greater than 50 feet from a sound source, every doubling of the distance produces a 6 dB reduction in the sound. Therefore, a sound level of 70 dB at 50 feet would have a sound level of approximately 64 dB at 100 feet. At 200 feet sound from the same source would be perceived at a level of approximately 58 dB.

2. Additive Effects of Multiple Sound Sources - The total sound pressure created by multiple sound sources does not create a mathematical additive effect. Below Table A is given to assist you in calculating combined noise sources. For instance, two proximal noise sources that are 70 dBA each do not have a combined noise level of 140 dBA. In this case the combined noise level is 73 dBA. Since the difference between the two sound levels is 0 dB, Table A tells us to add 3 dB to the sound level to compensate for the additive effects of the sound. To find the cumulative SPL assess the SPLs starting with the two lowest readings and work up to the difference between the two highest readings. For several pieces of equipment, operating at one

time, calculate the difference first between the two lowest SPLs, check Table A and add the appropriate number of decibels to the higher of the two sound levels. Next, take the sound level that was calculated using Table A and subtract the next lowest sound level to be considered for the operation. Consult Table A again for the additive effect and add this to the higher of the two sound levels. Follow this process until all the sound levels are accounted for. As an example, let us say that an area for a new facility is being cleared. The equipment to be used is: two chainsaws, one operating at 57 dBA and one at 60 dBA; a front end loader at 80 dBA; and a truck at 78 dBA. Start with the two lowest sound levels: 60 dBA - 57 dBA = 3 dBA difference. Consulting the chart add 2 dBA to the higher sound level. The cumulative SPL of the two chainsaws is 62 dBA. Next, subtract 62 dBA from 78 dBA. 78 dBA - 62 dBA = 16 dBA. In this case, 0 dBA is added to the higher level so we end up with 78 dBA. Lastly, subtract 78 dBA from the 80 dBA. 80 dBA - 78 dBA = 2 dBA a difference of 2 dBA adds 2 dBA to the higher SPL or 82 dBA. The SPL from these four pieces of equipment operating simultaneously is 82 dBA.

Table A

Approximate Addition of Sound Levels

Difference Between Two Sound Levels	Add to the Higher of the Two Sound Levels
1 dB or less	3 dB
2 to 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or more	0 dB

(USEPA, Protective Noise Levels, 1978)

3. Temperature and Humidity - Sound energy is absorbed in the air as a function of temperature, humidity and the frequency of the sound. This attenuation can be up to 2 dB over 1,000 feet. Such attenuation is short term and, since it occurs over a great distance, should not be considered in calculations. Higher temperatures tend to increase sound velocity but does

not have an effect on the SPL. Sound waves bend towards cooler temperatures. Temperature inversions may cause temporary problems when cooler air is next to the earth allowing for more distant propagation of sound. Similarly, sound waves will bend towards water when it is cooler than the air and bounce along the highly reflective surface. Consequently large water bodies between the sound source and the receptor may affect noise attenuation over distance.

4. Time of Year - Summer time noises have the greatest potential for causing annoyance because of open windows, outside activities, etc. During the winter people tend to spend more time indoors and have the windows closed. In general, building walls and windows that are closed provide a 15 dB reduction in noise levels. Building walls with the windows open allow for only a 5 dB reduction in SPL.

5. Wind - Wind can further reduce the sound heard at a distance if the receptor is upwind of the sound. The action of the wind disperses the sound waves reducing the SPLs upwind. While it is true that sound levels upwind of a noise source will be reduced, receptors downwind of a noise source will not realize an increase in sound level over that experienced at the same distance without a wind. This dispels the common belief that sound levels are increased downwind due to wind carrying noise.

6. Land forms and structures - In certain circumstances, sound levels can be accentuated or focused by certain features to cause adverse noise impacts at specified locations. At a hard rock mine, curved quarry walls may have the potential to cause an amphitheater effect while straight cliffs and quarry walls may cause an echo. Buildings that line streets in cities can cause a canyon effect where sound can be reflected from the building surfaces similar to what might happen in a canyon. Consideration of noise impacts associated with these types of conditions may require specialized expertise to evaluate impact potential and to formulate suitable mitigation techniques.

Consideration of existing noise sources and sound receptors in proximity to a proposed activity can be important considerations even when the activity under review is not a noise source. Topography, vegetation, structures and the relative location of noise receptors and sources to these features are all aspects of the environmental setting that can influence noise impact potential. As such, land alteration may also indirectly create an adverse noise impact where natural land features or manmade features serve as a noise barrier or provide noise attenuation for existing sources of noise. i.e. highway, railroads, manufacturing activity. Removal of these features, i.e. hills, vegetation, large structures or walls, can expose receptors to increased sound pressure levels causing noise problems where none had previously existed.

B. Impact Assessment

1. Factors to Consider

Factors to consider in determining the impact of noise on humans, are as follows:

a. Evaluation of Sound Characteristics

(1) Ambient noise level - A noise can only intrude if it differs in character or SPL from the normal ambient sound. Most objective attempts to assess nuisance noise adopt the technique of comparing the noise with actual ambient sound levels or with some derived criterion.

(2) Future noise level - The ambient noise level plus the noise level from the new or proposed source.

(3) Increase In Sound Pressure Level - A significant factor in determining the annoyance of a noise is Sound Pressure Level (SPL). SPLs are measured in decibels.

(4) Sharp and Startling Noise - These high frequency and high intensity noises can be extremely annoying. When initially evaluating the effects

of noise from an operation, pay particular attention to noises that can be particularly annoying. One such noise is the back-up beepers required to be used on machinery. They definitely catch one's attention as they were meant to do. Continual beeping by machinery can be mitigated (see Section V.C. Mitigation - Best Management Practices). Another impulse noise source that can be very annoying is the exhaust from compressed air machinery. This exhaust is usually released in loud bursts. Compressed air exhaust can also be mitigated if it causes a noise problem by using readily available mufflers or specifically designed enclosures.

(5) Frequency and Tone - Frequency is the rate at which a sound source vibrates or makes the air vibrate. Frequency is measured in Hertz (Hz). Frequency can also be classified as high ("sharp"), low ("dull"), and moderate. Pure tones are rare in nature. Tonal sounds usually consist of pure tones at several frequencies. Pure tones and tonal sounds are discerned more readily by the human ear. Pure tones and tonal sounds are compensated for in sound studies by adding a calculated number of dB(A) to the measured sound pressure.

(6) Percentile of Sound Levels - Fluctuations of SPLs can be expressed as a percentile level designated as $L_{(n)}$ where a given decibel level is exceeded *n* % of the time. A designation of $L_{(10)}$ = 70 dBA means the measured SPLs exceeded 70 dBA 10% of the time. A designation of $L_{(90)}$ = 70 dBA means the measured SPLs were exceeded 90% of the time. $L_{(90)}$ is often used to designate the background noise level.

(7) Expression of Overall Sound - Part of the overall assessment of sound is the *Equivalent Sound Level* (L_{eq}) which assigns a single value of sound level for a period of time in which varying levels of sound are experienced over that time period. The L_{eq} value provides an indication of the effects of sound on people. It is also useful in establishing the ambient sound levels at a potential noise source.

In order to evaluate the above factors in the appropriate context, one must identify the following: 1) appropriate receptor locations for sound level calculation or measurement; 2) ambient sound levels and characteristics at these receptor locations; and 3) the sound pressure increase and characteristics of the sound that represents a significant noise effect at a receptor location.

b. Receptor Locations

Appropriate receptor locations may be either at the property line of the parcel on which the facility is located or at the location of use or inhabitance on adjacent property. The solid waste regulations require the measurements of sound levels be at the property line. The most conservative approach utilizes the property line. The property line should be the point of reference when adjacent land use is proximal to the property line. Reference points at other locations on adjacent properties can be chosen after determining that existing property usage between the property line and the reference point would not be impaired by noise, i.e., property uses are relatively remote from the property line. The location of the facility should be shown on a map in relation to each potential receptor. Any future expansion should be described in a narrative as well as depicted on a map. The map and narrative should also include the distance of the operation to each point of reception including the distance at the point in time when an expanding operation will be closest to the receptors.

c. Thresholds for Significant Sound Pressure Level (SPL) Increase

The goal for any permitted operation should be to minimize increases in sound pressure level above ambient levels at the chosen point of sound reception. Increases ranging from 0-3 dB should have no appreciable effect on receptors. Increases from 3-6 dB may have potential for adverse noise impact only in cases where the most sensitive of receptors are present. Sound pressure increases of more than 6 dB may require a closer analysis of impact potential depending on existing SPLs and the character of surrounding land use and receptors. SPL increases approaching 10 dB result in a perceived doubling of SPL. The perceived doubling of the SPL results from the fact that SPLs are measured on a logarithmic scale. An increase of 10 dB(A) deserves consideration of avoidance and mitigation measures in most cases. The above thresholds as indicators of impact potential should be viewed as guidelines subject to adjustment as appropriate for the specific circumstances one encounters.

Establishing a maximum SPL at the point of reception can be an appropriate approach to addressing potential adverse noise impacts. Noise thresholds are established for solid waste management facilities in the Department's Solid Waste regulations, 6 NYCRR Part 360. Most humans find a sound level of 60 - 70 dB(A) as beginning to create a condition of significant noise effect (EPA 550/9-79-100, November 1978). In general, the EPA's "Protective Noise Levels" guidance found that ambient noise levels • 55 dBA $L_{(dn)}$ was sufficient to protect public health and welfare and, in most cases, did not create an annoyance (EPA 550/9-79-100, November 1978). In non-industrial settings the SPL should probably not exceed ambient noise by more than 6 dB(A) at the receptor. An increase of 6 dB(A) may cause complaints. There may be occasions where an increase in SPLs of greater than 6 dB(A) might be acceptable. The addition of any noise source, in a non-industrial setting, should not raise the ambient noise level above a maximum of 65 dB(A). This would be considered the "upper end" limit since 65 dB(A) allows for undisturbed speech at a distance of approximately three feet. Some outdoor activities can be conducted at a SPL of 65 dB(A). Still lower ambient noise levels may be necessary if there are sensitive receptors nearby. These goals can be attained by using the mitigative techniques outlined in this guidance.

Ambient noise SPLs in industrial or commercial areas may exceed 65 dB(A) with a high end of approximately 79 dB(A) (EPA 550/9-79-100, November 1979). In these instances mitigative measures utilizing best management practices should be used in an effort to ensure that a facility's generated sound levels are at a minimum. The goal in an industrial/commercial area, where ambient SPLs are already at a high level, should be not to exceed the ambient SPL. Remember, if a new source operates at the same noise level as the ambient, then 3 dB(A) must be added to the existing ambient noise level to obtain the future noise level. If the goal is not to raise the future noise levels the new facility would have to operate at 10 dB(A) or more lower than the ambient.(see Table A)

Table B

HUMAN REACTION TO INCREASES IN SOUND PRESSURE LEVEL

Increase in Sound Pressure (dB)	Human Reaction
Under 5	Unnoticed to tolerable
5 - 10	Intrusive
10 - 15	Very noticeable
15 - 20	Objectionable
Over 20	Very objectionable to intolerable

(Down and Stocks - 1978)

Impact assessment will vary for specific project reviews, but must consist of certain basic components for all assessments. Additional examination of sound generation and noise reception are necessary, where circumstances warrant. Sound impact evaluation is an incremental process, with four potential outcomes:

- exemption criteria are met and no noise evaluation is required;
- noise impacts are determined to be non-significant (after first-level evaluation);
- noise impacts are identified as a potential issue but can be readily mitigated (after second level evaluation); or
- noise impacts are identified as a significant issue requiring analysis of alternatives as well as mitigation (third level evaluation).

All levels of evaluation may require preparation of a noise analysis. The required scope of noise impact analysis can be rudimentary to rather sophisticated, depending on circumstances and the results obtained from initial levels of evaluation. Recommendations for each level of evaluation are presented below.

2. Situations in Which No Noise Evaluation is Necessary

When certain criteria are satisfied, the need for undertaking a noise impact analysis at any level is eliminated. These criteria are as follows:

a. The site is contained within an area in which local zoning provides for the intended use as a "right of use". It does not apply to activities that are permissible only after an applicant is granted a special use permit by the local government; and

b. The applicant's operational plan incorporates appropriate best management practices (BMPs [see Section V.C. Mitigation - Best Management Practices]) for noise control for all facets of the operation

Where activities may be undertaken as a "right of use", it is presumed that noise has been addressed in establishing the zoning. Any residual noise that is present following BMP implementation should be considered an inherent component of the activity that has been found acceptable in consideration of the zoning designation of the site.

3. First Level Noise Impact Evaluation

The initial evaluation for most facilities should determine the maximum amount of sound created at a single point in time by multiple activities for the proposed project. All facets of the construction and operation that produce noise should be included such as land clearing activities (chain saw and equipment operation), drilling, equipment operation for excavating, hauling or conveying materials, pile driving, steel work, material processing, product storage and removal. Land clearing and construction may be only temporary noise at the site whereas the ongoing operation of a facility would be considered permanent noise. An analysis may be required for various phases of the construction and operation of the project to assure that adverse noise effects do not occur at any phase.

To calculate the sound generated by equipment operation, one can consult the manufacturers' specifications for sound generation, available for various types of equipment. Another option for calculating the sound to be generated by equipment is to make actual measurements of sound generated by existing similar equipment, elsewhere.

Tables C and D summarize noise measurements from some common equipment used in construction and mining. Table E summarizes the noise level, in decibels (dB[A]), from some common sources. This information can be used to assist Department staff in relating potential noise impacts to sound levels produced by commercial and industrial activities. Use of these tables in the first level of analysis will help determine whether or not noise will be an issue and whether actual measurements should be made to confirm noise levels.

Table C

PROJECTED NOISE LEVELS

Noise Source	Measurements	1,000 feet	2,000 feet	3,000 feet
Primary and secondary crusher	89 dB(A) at 100 ft	69.0 dB(A)	63.0 dB(A)	59.5 dB(A)
Hitachi 501 shovel loading	92 dB(A) at 50 ft	66.0 dB(A)	60.0 dB(A)	56.5 dB(A)
Euclid R 50 pit truck loaded	90 dB(A) at 50 ft	64.0 dB(A)	58.0 dB(A)	54.4 dB(A)
Caterpillar 988 loader	80 dB(A) at 300 ft	69.5 dB(A)	63.5 dB(A)	60.0 dB(A)

(The Aggregate Handbook, 1991)

Table D

Common Equipment Sound Levels

EQUIPMENT	DECIBEL LEVEL	DISTANCE in feet
Augered earth drill	80	50
Backhoe	83-86	50
Cement mixer	63-71	50
Chain saw cutting trees	75-81	50
Compressor	67	50
Garbage Truck	71-83	50
Jackhammer	82	50
Paving breaker	82	50
Wood Chipper	89	50
Bulldozer	80	50
Grader	85	50
Truck	91	50
Generator	78	50
Rock drill	98	50

(excerpt and derived from Cowan, 1994)

Table E

Sound Source	dB(A)*	Response Criteria
	150	
Carrier Deck Jet Operation	140	
	130	Painfully Loud Limit Amplified Speech
Jet Takeoff (200 feet) Discotheque Auto Horn (3 feet) Riveting Machine	120	
	110	Maximum Vocal Effort
Jet Takeoff (2000 feet) Shout (0.5 feet)	100	
N.Y. Subway Station Heavy Truck (50 feet)	90	Very Annoying Hearing Damage (8 hours, continuous exposure)
Pneumatic Drill (50 feet)	80	Annoying
Freight Train (50 feet) Freeway Traffic (50 feet)	70	Telephone Use Difficult Intrusive
Air Conditioning Unit (20 feet)	60	
Light Auto Traffic (50 feet)	50	Quiet
Living Room Bedroom	40	
Library Soft Whisper (15 feet)	30	Very Quiet
Broadcasting Studio	20	
	10	Just Audible
	0	Threshold of Hearing

(The Aggregate Handbook, 1991)

The sound level at receptor locations should be calculated using the inverse square rule whereby sound is attenuated over distance. Again, each doubling of the distance from the source of a noise decreases the SPL by 6 dB(A) at distances greater than 50 feet. This calculation should first consider the straight line distance between the point of noise generation and the point of noise reception with the presumption that no natural or manmade features exist along the transect between the two points that would further attenuate sound level. Calculations should be performed for each point of reception in all directions being careful to evaluate the worst case noise impact potential by considering activities at the point where they would be closest to a receptor. The sound level calculated for the point of reception should be related to ambient sound levels. Ambient sound levels can be either measured or assumed based on established references for the environmental setting and land use at the point of reception. For estimation purposes, ambient SPLs will vary from approximately 35 dB(A) in a wilderness area to approximately 87 dB(A) in a highly industrial setting. A quiet seemingly serene setting such as rural farm land will be at the lower end of the scale at about 45 dB(A), whereas an urban industrial area will be at the high end of this scale at around 79 dB(A) (EPA 550/9-79-100, November 1978). If there is any concern that levels based on reference values do not accurately reflect ambient SPL, field measurements should be undertaken to determine ambient SPLs.

Where this evaluation indicates that sound levels at the point of reception will not be perceptible, similar to or only slightly elevated as compared to ambient conditions, no further evaluation is required. When there is an indication from this initial analysis that marginal or significant noise impact may occur, further evaluation is required. In determining the potential for an adverse noise impact, consider not only ambient noise levels, but also the existing land use, and whether or not an increased noise level or the introduction of a discernable sound, that is out of character with existing sounds, will be considered annoying or obtrusive. (see B 1 a Evaluation of Sound Characteristics)

4. Second Level Noise Impact Evaluation

Further refine the evaluation of noise impact potential by factoring in any additional noise attenuation that will be provided by existing natural topography, fabricated structures such as buildings, walls or berms or vegetation located between the point of noise generation and noise reception. This analysis may require consideration of future conditions and the loss of natural noise buffers over time.

Dense vegetation that is at least 100 feet in depth will reduce the sound levels by 3 to 7 dB(A). Evergreens provide a better vegetative screen than deciduous trees. Keep in mind that if a vegetative screen does not currently exist, planting a vegetative screen may require 15 or more years of growth before it becomes effective.

The degree to which topography attenuates noise depends on how close the feature is located to the source or the receptor of the noise. Topography can act as a natural screen. The closer a hill or other barrier is to the noise source or the receptor, the larger the sound shadow will be on the side opposite the noise source. Certain operations such as mining and landfills may be able to use topography to maintain a screen between the operation and receptors as they progress. Mining operations may be able to create screens by opening a mine in the center of the site using and maintaining the pit walls as barriers against sound (Aggregate Handbook, 1991).

If after taking into account all the attenuating features the potential still exists for adverse noise impact, other types of noise analyses or modeling should be used to characterize the source. An Equivalent Sound Level (L_{eq}) analysis or a related type of noise analysis may better define activities or sources that require more mitigation or isolation so that noise emanating from these sources will not cause an adverse impact.

Where it is demonstrated that noise absorbing or deflecting features further attenuate sound reception to a level of no significant increase, no further analysis is necessary. Where it is determined that noise level or the character of the noise may have a significant adverse effect on receptors, other noise mitigation measures should be evaluated in an expanded noise analysis.

5. Third Level - Mitigation Measures

When the above analyses indicate significant noise effects may or will occur, the applicant should evaluate options for implementation of mitigation measures that avoid, or diminish significant noise effects to acceptable levels (see Section V.C. Mitigation - Best Management Practices). Adequate details concerning mitigation measures and an evaluation of the effectiveness of the mitigative measures through additional sound level calculations should be provided in a noise analysis. These calculations are to factor in the noise reduction or avoidance capabilities of the mitigation measures. In circumstances where noise effects cannot readily be reduced to a level of no significance by project design or operational features in the application, the applicant must evaluate alternatives and mitigation measures in an environmental impact statement to avoid or reduce impacts to the maximum extent practicable per the requirements of the State Environmental Quality Review Act (SEQR).

The noise analysis should be part of the application or a supplement to it, and will be part of the SEQR environmental assessment by reference. Duplicative noise analysis information is not required for the permit application and the assessment of impacts under SEQR. A proper analysis can satisfy information needs for both purposes.

C. Mitigation - Best Management Practices (BMP) for Reducing Noise

Various noise abatement techniques are available for reducing frequency of sound, duration of sound or SPLs at receptor locations. The mitigation techniques given below are listed according to what sound characteristic they mitigate.

1. Reduce noise frequency and impulse noise at the source of generation by:

   a. Replacing back-up beepers on machinery with strobe lights (subject to other requirements, e.g., OSHA and Mine Safety and Health Administration, as applicable). This eliminates the most annoying impulse beeping;

   b. Using appropriate mufflers to reduce the frequency of sound on machinery that pulses, such as diesel engines and compressed air machinery;

   c. Changing equipment: using electric motors instead of compressed air driven machinery; using low speed fans in place of high speed fans;

   d. Modifying machinery to reduce noise by using plastic liners, flexible noise control covers, and dampening plates and pads on large sheet metal surfaces, and

2. Reduce noise duration by:

   a. Limiting the number of days of operation, restricting the hours of operation and specifying the time of day and hours of access and egress can abate noise impacts.

   b. Limiting noisier operations to normal work day hours may reduce or eliminate complaints.

   Limiting hours of construction or operation can be an effective tool in reducing potential adverse impacts of noise. The impacts of noise on receptors can be significantly reduced by effectively managing the hours at which the loudest of the operations can take place.

Implementation of hours of operation does not reduce the SPL emanating from a facility. Determining whether or not hours of operation will be effective mitigation requires consideration of: public safety, for example road construction at night may reduce traffic concerns and facilitate work; duration of the activity, is it a one time event necessary to meet a short term goal or will the activity become an ongoing operation; and surrounding land use, consider what type(s) of land use is proximal to the activity and at what time(s) might a reduction of noise levels be necessary. There may be other factors to consider due to the uniqueness of a given activity or the type of land use adjacent to the activity. Hours of operation should also consider weekend activities and legal holidays that may change the types of land use adjacent to the permitted activity or increase traffic levels in an area.

The best results from using hours of operation as a mitigative measure will be obtained if the hours are negotiated with the owner or operator of the facility. The less noisy aspects of an operation may not have to be subject to the requirements of hours of operation such as preparing, greasing and maintaining machinery for the upcoming day's operation. The more noisy operations can be scheduled to begin when people in the receptor area are less likely to be adversely effected. Hours of operation should be included in the operation plans for a facility that becomes part of the permit, or in the event that there is no operation plan, can be included as a permit condition.

3. Reduce Noise sound pressure levels by:

   a. Increasing the setback distance.
   b. Moving processing equipment during operation further from receptors
   c. Substituting quieter equipment (<u>example</u> - replacing compressed air fan with an electric fan could result in a 20 dB reduction of noise level).

d. Using mufflers selected to match the type of equipment and air or gas flow on mechanical equipment.

e. Ensuring that equipment is regularly maintained.

f. Enclosing processing equipment in buildings (example - enclosing noisy equipment could result in an 8-10 dB noise level reduction, a 9 inch brick wall can reduce SPL by 45-50 dB).

g. Erecting sound barriers such as screens or berms around the noise generating equipment or near the point of reception. The angle of deflection also increases as the height of a screen or barrier increases. Screens or barriers should be located as close to the noise source or the receptor as possible. The closer the barrier is located to the source or the receptor, the greater the angle of deflection of the sound waves will be creating a larger "sound shadow" on the side opposite the barrier. Stockpiles of raw material or finished product can be an effective sound barrier if strategically placed.

h. phasing operations to preserve natural barriers as long as possible.

i. altering the direction, size, proximity of expanding operations.

j. Designing enclosed facilities to prevent or minimize an SPL increases above ambient levels. This would require a noise analysis and building designed by a qualified engineer that includes adequate ventilation with noise abatement systems on the ventilation system.

Public notification of upcoming loud events can also be used as a form of mitigation although it doesn't fit easily into the categories above. People are less likely to get upset if they know of an upcoming event and know that it will be temporary.

The applicant should demonstrate that the specific mitigation measures proposed will be effective in preventing adverse noise effects on receptors.

D. Decision Making - Conditioning Permits to Limit Noise Impacts

Preferably, the mitigation measures as outlined in the construction and operational plans should be relied upon to mitigate the effects of noise on receptors. The permit should state that the activity will be conducted in accordance with the approved plan. Otherwise, mitigation measures and BMP's can be imposed within specific permit conditions.

It is not the intention of this guidance to require decibel limits to be established for operations where such limits are not required by regulation. There are, however, instances when a decibel limit may be established for an operation to ensure activities do not create unacceptable noise effects, as follows:

1. The review of a draft and final environmental impact statement demonstrates the need for imposition of a decibel limit;
2. A decibel limit is established by the Commissioner's findings after a public hearing has been held on an application;
3. The applicant asks to have a decibel limit to demonstrate the ability to comply; or
4. A program division seeks to establish a decibel limit as a permit condition, when necessary to demonstrate avoidance of unacceptable noise impact.

Ultimately, the final decision must incorporate appropriate measures to minimize or avoid significant noise impacts, as required under SEQR. Any unavoidable adverse effects must be weighed along with other social and economic considerations in deciding whether to approve or deny a permit.

REFERENCES

1) Cowan, James P., Handbook of Environmental Acoustics, Van Nostrand Reinhold, 1994.

2) Down, C.G. and Stocks, J.; Environmental Impact of Mining, Applied Science Publishers Ltd., ISBN 0853347166, 1978.

3) U.S. Dept of Transportation - Federal Highway Administration Office of Research and Development; Highway Noise-A Manual for Highway Noise and Land Use, Nov. 1974.

4) New York State Motor Vehicle Law, Chapter IV, Subchapter E, 450.2, Part 450, "Noise From Heavy Motor Vehicles," 200 701 CN, February 28, 1997.

5) Beranek, L.A. ed., Noise and Vibration Control. Cambridge, MA: Institute of Noise Control Engineering, 1971, pp. 164-174 and 182-191.

6) Barksdale, R.D., editor, 1991. The Aggregate Handbook: National Stone Association (Washington, DC), 1.V.

7) Norman, David K., Wampler , Peter J., Throop, Allen H., Schnitzer, E. Frank, and Roloff, J., 1996. "Best Management Practices for Reclaiming Surface Mines in Washington and Oregon." Oregon Dept. of Geology and Mineral Industries, Open File Report 0-96-2

8) United States Environmental Protection Agency, Protective Noise Levels, Condensed Version of EPA Levels document, EPA 550/9-79-100, November 1978, Office of Noise Abatement & Control, Washington, D.C.

9) United States Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA 550/9-74-004, March 1974, Office of Noise Abatement and Control, Washington, D.C.

10) City of Davis General Plan, Appendix E Background Information on Environmental Acoustics, November 1996.

11) The Australian National University, "Physics and Psychophysics of Music", ACAT 1003, David Worrall, http://www.anu.edu.au/ITA/ACAT/drw/PPofM/Intensity2.html, 1998.

12) Danish Wind Turbine Manufacturers Association, Measuring and Calculating Sound Levels, November 18, 1997

Additional Reading

a. Beranek, Leo L. and Istavan L. Ver, Noise and Vibration Control Engineering, John Wiley & Sons, Inc. New York, 1992.

b. Beranek, Leo L., Noise and Vibration Control, Institute of Noise Control Engineering, Revised Edition, Washington, C.C., 1988.

c. Diehl, George, M., Machinery Acoustics, John Wiley & Sons, New York, 1973.

d. Erwin, J.D., Graf, E. R., Industrial Noise and Vibration Control, Prentice Hall, Englewood Cliffs, New Jersey, 1979

e. Jensen, Paul, et al, Industrial Noise Control Manual, U.S. Department of Health, Education and Welfare, Public Health Service, Cincinnati, 1978.

CASELLA STANGER

Report

Low Frequency Noise

Technical Research Support for DEFRA Noise Programme

This contract is managed by DEFRA on behalf of

DEFRA
Department of the Environment, Northern Ireland
Scottish Executive
National Assembly for Wales

DEFRA
Department for Environment, Food & Rural Affairs

The information contained in this report is intended as guidance and gives only an indication of the range of topics addressed under the contract. It should not be taken as definitive guidance and reference should always be made to the original documents.

Although the work reported here has been carried out under a DEFRA contract it represents the views of the authors and is not necessarily the view of the Department.

Casella Stanger
Low Frequency Noise Update

1 Introduction

1.1 This document has been produced by Casella Stanger under contract to DEFRA with the objective of providing

- an update of the current information available concerning low frequency noise; and
- help for those involved in low frequency noise issues.

It has been designed only to provide some general information on the subject. It should not be regarded as formal guidance from DEFRA.

1.2 Possible causes and possible effects of low frequency noise are described, and a procedure for investigating complaints concerning low frequency noise is set out. Some general advice is given regarding the measurement of low frequency noise, but a detailed measurement procedure is not given. A further detailed report on the subject of the measurement of low frequency noise may be produced in due course.

1.3 In the field of low frequency noise and its perception, there are still a number of factors that make it difficult to derive specific, quantitative guidelines by which to judge the acceptability or otherwise of a given level of noise at low frequency. This document, therefore, tries to offer suggestions which may be helpful in explaining some of the factors most commonly affecting the outcome of investigations.

2 Background

2.1 Low frequency noise is not clearly defined but is generally taken to mean noise below a frequency of about 100 to 150 Hz. Noise at frequencies below about 20 Hz is sometimes referred to as infrasound and this type of noise presents even greater difficulties in its measurement and assessment. At these particularly low frequencies complainants often have difficulty in describing the source of their complaint, sometimes referring to "feeling the noise" or to "pressure sensations"

2.2 The Report of the Noise Review Working Party 1990 published by the Department of the Environment (the Batho report) commented on low frequency noise. It said

> *"Low frequency noise does not give rise to the same level of concern as neighbourhood noise but it can have a serious effect on the quality of life of those affected by it. On average just over 500 cases of low frequency noise disturbance are reported each year compared to 67,000 cases of neighbourhood noise. It is often difficult to check on low frequency noise complaints because the sensitivity of individuals to such noise varies greatly. The noise may be inaudible to the EHO (Environmental Health Officer) and its measurement often requires sophisticated monitoring*

techniques. In some cases the noise complained of may have no external source but be a result of a medical condition.

The Working Party was told that low frequency noise problems could occur anywhere in the range 10 – 150 Hz but were usually associated with noise in the 40 – 60 Hz range. The commonest cause of such noise is industry but there can be many other causes, some of them domestic (refrigerators, oil-fired boilers, and washing machines) and some associated with road vehicles. Sometimes low frequency noise seems more like vibration than noise and it can cause structural vibration. It has also been postulated that non-acoustic sources such as high intensity electromagnetic fields or radar microwaves may create for some people the illusion of low frequency noise.

It will be apparent that low frequency noise presents particular problems for those who have to deal with complaints about it. It is in any case likely that the business of identifying the source of low frequency noise will be laborious and may not always be conclusive.

We accept that this problem, though it generates comparatively few complaints, is a real one. Much remains to be done to extend understanding of the nature of low frequency noise and how best to detect and deal with it."

2.3 Much of the above continues to apply today, although statistics relating specifically to low frequency noise are still not gathered on a routine basis.

2.4 There are several factors relevant to low frequency noise propagation and its perception which need to be borne in mind:

- Mid and high frequency noise is attenuated by propagation through the atmosphere and also by attenuation due to its passage over acoustically soft ground such as grass land. Low frequency noise does not benefit to the same extent from either of these effects. This means that as a sound travels, its frequency content alters making the low frequencies more prominent at greater distances.
- For people inside buildings with windows closed, this effect is exacerbated by the sound insulation properties of the building envelope. Again mid and high frequencies are attenuated to a much greater extent than low frequencies. Thus the frequency content again alters emphasising still further the low frequency content.
- Resonance can be set up inside a room with nodes (quiet points) and anti-nodes (loud points). The number and position of these nodes and anti-nodes will depend on the specific room dimensions and the frequency of the noise. The consequence is that the room resonances can cause elevated levels of low frequency noise at points within a room.
- People's hearing tends to deteriorate with age, but not equally across the frequency spectrum. Hearing deteriorates more rapidly at the mid and higher frequencies than at the lower frequencies which means that

older people's hearing tends to be proportionately more acute at low frequencies.

- It has been postulated that some people exhibit discrete peaks in their hearing threshold. This means that a sound could appear tonal to one person but not to another.

2.5 The human ear, for the majority of people, is not very sensitive at low frequencies. At low levels of noise, the human ear attenuates sound by about 25 dB at 100 Hz, 40 dB at 50 Hz and 70 dB at 20 Hz (an attenuation of 70 dB is less than 1/100th as loud), compared with the level at 1000 Hz. At higher levels, the effect is not so marked with the attenuation being about 5 dB at 100 Hz, 10 dB at 50 Hz and just under 25 dB at 20 Hz (i.e. less than 1/5th as loud). This means that frequencies in the region of 20 Hz may not be audible unless the level exceeds about 70 dB. The A-weighting network found on most sound level meters is intended to reflect this response.

2.6 There are no British Standards that specifically refer to the assessment of Low Frequency Noise. There is an international standard,

"*ISO 7196:1995(E) Acoustics – Frequency-weighting characteristic for infrasound measurements*",

which defines a G-weighting network specifically intended for the measurement of noise in the 1 to 20 Hz frequency range. Whilst this standard is used in some countries it is not in common use in the UK.

2.7 There is also a German Standard:

DIN 45680 : 1997 (Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft)

which provides guidance on the measurement and assessment of low frequency noise. It suggests that measurements should be made at the position identified by the complainant as the worst location in the room. It goes on to note that the measurement time interval will depend on the fluctuation of the noise but that the measurement should include at least one or more representative cycle. As a preliminary investigation it recommends that if the difference between the A-weighted and C-weighted L_{eq} values is greater than 20 dB then a low frequency noise problem should be suspected (the Batho report, see Para 2.2 above, made a similar observation but with a difference of 30 dB). It also provides useful guidance on assessing whether tones are present by comparing adjacent 1/3 octave bands. If noise in one band is more than 5 dB above the level in the immediately adjacent bands then the noise is judged to be tonal.

3 Possible Sources

3.1 Possible sources of low frequency noise are many and varied but are often industry related. The following is a list of common sources:

Pumps	Fans
Boilers	Ventilation plant
Heavy industry	Blasting
Electrical installations	Road, rail, sea and air traffic
Amplified music	Cooling towers
Wind farms	

3.2 It can be seen that the sources are generally industrial/commercial noise sources and are mostly located externally. However, low frequency noise can also be generated from internal domestic sources such as refrigerators. In addition to man-made sources there are some natural sources of low frequency sound such as the wind, the sea, thunder and vibration from low level ground movements.

4 Possible Effects

4.1 As with any noise, reported effects include annoyance, stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep.

4.2 As people's hearing sensitivity varies from one individual to another it is often the case that a low frequency noise can be heard by one person and not by another. Consequently it may annoy one person but not the other. This feature can sometimes mean that the person who is annoyed can also feel isolated.

4.3 Low frequency noise is sometimes confused with vibration. This is mainly due to the fact that certain parts of the human body can resonate at various low frequencies. For example the chest wall can resonate at frequencies of about 50 to 100 Hz and the head at 20 to 30 Hz.

4.4 In addition low frequency noise can cause lightweight elements of a building structure to vibrate causing a secondary source of noise. This vibration is generally superficial and should not be confused with vibration of the whole building.

5 Measurement and Assessment

5.1 There are a number of factors that make measuring and assessing low frequency noise difficult, especially at frequencies below 20 Hz. Among these are the following.

- Individuals appear to vary considerably in the sensitivity of their hearing at low frequencies.
- It may be difficult to measure with conventional sound measuring equipment. Not all local authorities, who are generally the first to be asked to investigate, will have ready access to suitable equipment.
- Even when identified, the nature of low frequency noise is such that it is often very difficult to locate the source, which could be quite distant from the receiver.

5.2 As the A-weighting network attenuates low frequencies by a large amount, any measurements made of the noise should be with the instrumentation set to linear. For a preliminary analysis, measurements should be made in 1/3rd octave frequency bands. More detailed analysis would need the use of narrower frequency bands or even an FFT (Fast Fourier Transform) analyser. In any event, it is preferable to use real time analysis so that instantaneous variations in level and frequency can be observed as they happen. Care should be taken to be aware of the lower limiting frequency of the measuring instrumentation.

5.3 Simple techniques can be employed by the investigator as a preliminary screening exercise. This could include placing their ear to the wall to try to detect the noise in the structure. As indicated in the German standard (see Para 2.7) another method is to observe the difference between A-weighted and C-weighted noise measurements. A difference of 20 dB could indicate high levels of low frequency sound. These simple screening methods should not, however, be used as a substitute for a full investigation.

5.4 As mentioned previously (para 2.4), resonance can occur in a room, which can mean large variations in measured sound levels at different points within the room. It is advisable, therefore, to measure at the location regarded by the complainant as being where the noise is loudest. This is most likely to be at the head position when standing or seated or when in bed. A measurement position in a room corner (approximately 15cm from the corner) is likely to be at an antinode and hence detect all resonant peaks. This can be useful as a reference measurement, particularly if comparable measurements will have to be made on a later occasion.

5.5 When trying to locate a source of low frequency noise, look first for the source within the building itself. This may require electrical items within the building to be turned off, e.g. electric clocks, refrigerators, extract fans, etc., or even temporarily turning off the electrical supply to the home. If this does not identify the source, then consideration should be given to external sources or sources in adjacent buildings. It must be remembered that low frequency noise can travel large distances, consequently the source could be quite distant. Experience has shown that sources could be as varied as a fish tank in the next room to a faulty bearing in a factory some 300 metres away.

5.6 Information on the source can often be gleaned from the spectral content of the noise. As a general rule electrical sources will generate noise at the mains frequency of 50 Hz, but harmonics may also be present, i.e. at 100 Hz and other multiples. Due to the way transformers operate, their fundamental frequency is double the mains frequency at 100 Hz. For rotating sources, such as fans, specific frequencies are often generated which relate to the number of blades and the speed of rotation. This is known as the blade pass frequency. In very general terms the lower the frequency of the noise the larger the physical size of the source is likely to be.

6 Investigation procedure

6.1 The general investigating procedure, as with any noise investigation procedure, should be to listen for the noise, measure the noise, assess the noise, locate the source and where necessary take action to resolve the problem.

6.2 Following extensive research by the Building Research Establishment and Sound Research Laboratories on behalf of the Department of the Environment a suggested Low Frequency Noise Investigation Protocol was developed. The protocol was originally published in 1994 and the following is based on that procedure.

Visit the Sufferer

6.3 The investigator's first visit should be handled with particular care and the complainant must be shown respect. The situation should be approached with an open mind in order to avoid an entrenched reaction by the complainant.

6.4 Continue to keep an open mind during the investigation. Discuss the problem with the complainant and obtain a history and background to it. The history should include the following.

- When the noise was first heard.
- Type of noise heard.
- Duration and frequency of occurrence of the noise.
- Complainant's belief about the source.
- Effects of the noise on the complainant.
- Whether other family members hear the noise.
- Whether neighbours hear the noise.
- Whether the complainant believes that he/she is particularly sensitive to other sources of noise.

6.5 Listen for the noise. Ensure that the complainant can clearly hear the noise at the time of the investigation. This may mean having to investigate the noise at different times e.g. during the day, evening or night. If the noise can be heard by the investigator then attempt to find the source. Use measurements (as described below) to assist in the source identification. If the investigator cannot hear the noise and yet the complainant can hear it, then measurements should be made. Bear in mind that if other members of the complainant's family or their neighbours have heard the noise then there is probably a noise to be detected.

Measurements

6.6 As mentioned above it is preferable to use a narrow band or FFT real time analyser. Look for characteristics that relate to the noise experienced by the complainant, i.e. increases, decreases, the loudest place in the dwelling, etc. Try to quantify the level and frequency that appear to correlate with what the complainant is hearing.

If Nothing is Found

6.7 If no noise is heard or no particular low frequency noise can be measured there are several options. If it is believed that the measurements were made when the noise was not considered by the complainant to be at its worst, then a second visit would be advisable. However, consideration should be given to the possibility that the complainant is referring to a previous source that has now been abated.

6.8 If after a second visit the investigator is convinced that there is no noise, either heard or measured, that relates to the complaint, and no other family members or neighbours have heard the noise, then the complainant should be referred to an audiological specialist. This, of course, must be done in a sensitive manner, as a common criticism of low frequency noise investigation is that the problem is blamed immediately on tinnitus or some other related problem. The complainant should be told that the investigator has not been able to hear or measure the noise that they have described and that the sufferer should be examined by an audiological specialist as their hearing system may be part of the problem.

6.9 In fact low frequency tinnitus is reported to be very rare and is very difficult to confirm, however, a hearing test can be valuable in such cases.

6.10 A Decision Flow Chart to assist in the investigation process, based on the above procedure, is appended.

7 Contact Organisations

7.1 There are various organisations that may be able to assist those affected by low frequency noise and, in particular, may be able to facilitate contact with others in similar situations. The addresses of two such organisations are provided below. If there are other organisations that exist to help, please contact DEFRA, Zone 4/G16, Ashdown House, 123 Victoria Street, London, SW1E 6DE or email noise@defra.gsi.gov.uk

Low Frequency Noise Suffers Association
Laundry Cottage
Home Farm
Leicester Road
Thornhaugh
Peterborough
PE8 6NL

British Tinnitus Association
4th Floor White Building
Fitzalan Square
Sheffield
S1 2AZ

This document has been prepared by Casella Stanger on behalf of DEFRA. It has been designed only to provide some general information on the subject. It should not be regarded as formal guidance from DEFRA.

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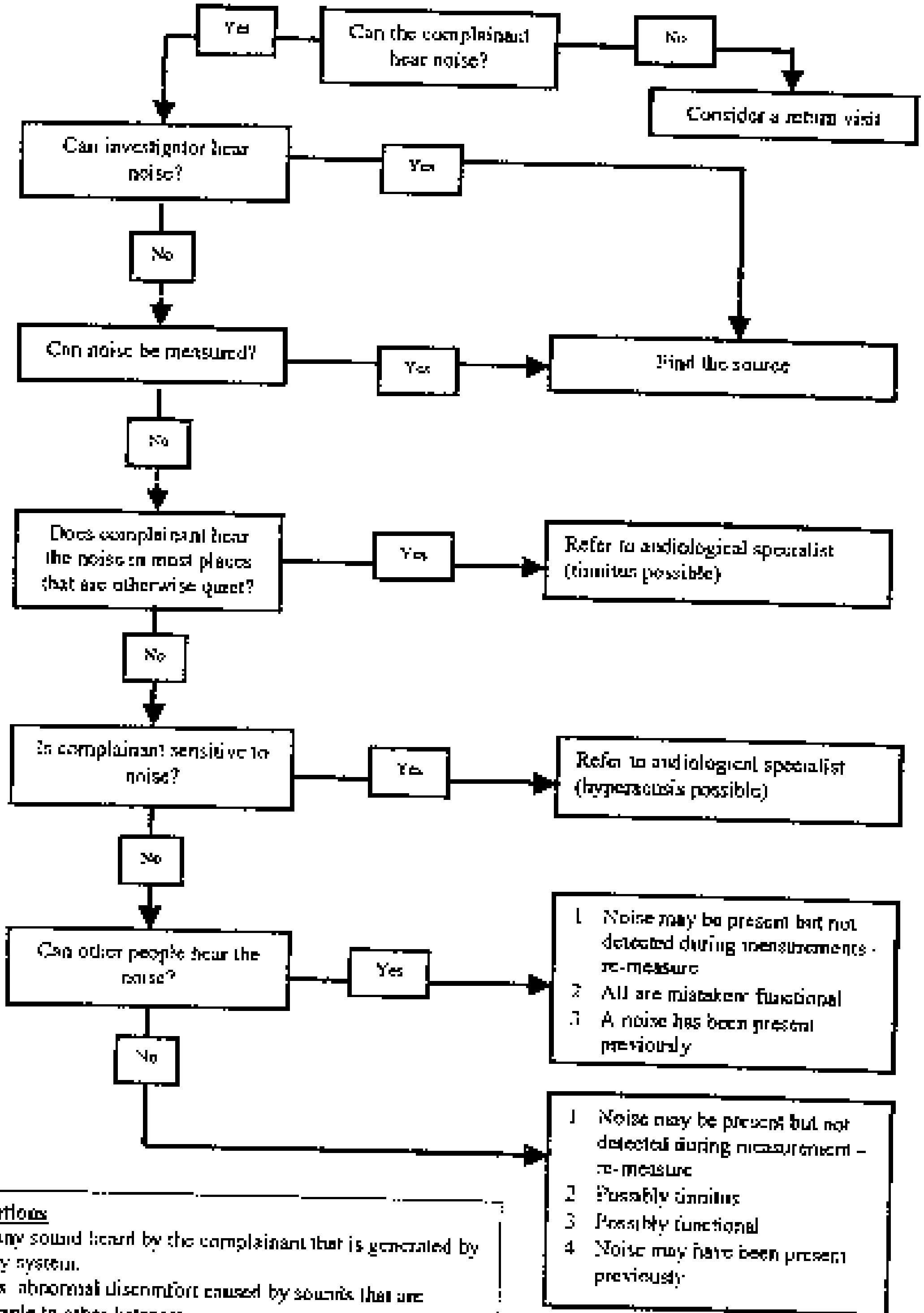
Decision Flow Chart

To assist in Low Frequency Noise Investigation



Brief Definitions

Tinnitus – any sound heard by the complainant that is generated by their auditory system.

Hyperacusis abnormal discomfort caused by sounds that are usually tolerable to other listeners.

Functional A complainant has become convinced of the presence of the noise when it is not in fact present

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GUIDELINES

FOR

COMMUNITY NOISE

Edited by

Birgitta Berglund
Thomas Lindvall
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This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO- expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and *Karolinska* Institute.

World Health Organization, Geneva
Cluster of Sustainable Development and Healthy Environment (SDE)
Department of the Protection of the Human Environment (PHE)
Occupational and Environmental Health (OEH)

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Foreword

Noise has always been an important environmental problem for man. In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the Romans. In Medieval Europe, horse carriages and horse back riding were not allowed during night time in certain cities to ensure a peaceful sleep for the inhabitants. However, the noise problems of the past are incomparable with those of modern society. An immense number of cars regularly cross our cities and the countryside. There are heavily laden lorries with diesel engines, badly silenced both for engine and exhaust noise, in cities and on highways day and night. Aircraft and trains add to the environmental noise scenario. In industry, machinery emits high noise levels and amusement centres and pleasure vehicles distract leisure time relaxation.

In comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on humans and of dose-response relationships as well as a lack of defined criteria. While it has been suggested that noise pollution is primarily a "luxury" problem for developed countries, one cannot ignore that the exposure is often higher in developing countries, due to bad planning and poor construction of buildings. The effects of the noise are just as widespread and the long term consequences for health are the same. In this perspective, practical action to limit and control the exposure to environmental noise are essential. Such action must be based upon proper scientific evaluation of available data on effects, and particularly dose-response relationships. The basis for this is the

process of risk assessment and risk management.

The extent of the noise problem is large. In the European Union countries about 40 % of the population are exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime and 20 % are exposed to levels exceeding 65 dB(A). Taking all exposure to transportation noise together about half of the European Union citizens are estimated to live in zones which do not ensure acoustical comfort to residents. More than 30 % are exposed at night to equivalent sound pressure levels exceeding 55 dB(A) which are disturbing to sleep. The noise pollution problem is also severe in cities of developing countries and caused mainly by traffic. Data collected alongside densely travelled roads were found to have equivalent sound pressure levels for 24 hours of 75 to 80 dB(A).

The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professional trying to protect people from the harmful effects of noise in non-industrial environments. Guidance on the health effects of noise exposure of the population has already been given in an early publication of the series of Environmental Health Criteria. The health risk to humans from exposure to environmental noise was evaluated and guidelines values derived. The issue of noise control and health protection was briefly addressed.

At a WHO/EURO Task Force Meeting in Düsseldorf, Germany, in 1992, the health criteria and guideline values were revised and it was agreed upon updated guidelines in consensus. The essentials of the deliberations of the Task Force were published by Stockholm University and Karolinska Institute in 1995. In a recent Expert Task Force Meeting convened in April 1999 in London, United Kingdom, the Guidelines for Community Noise were extended to provide global coverage and applicability, and the issues of noise assessment and control were addressed in more detail. This document is the outcome of the consensus deliberations of the WHO Expert Task Force.

Dr Richard Helmer
Director, Department of Protection of the Human Environment
Cluster Sustainable Development and Healthy Environments

Preface

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. The main indoor sources of noise are ventilation systems, office machines, home appliances and neighbours. Typical neighbourhood noise comes from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.); from live or recorded music; sport events including motor sports; playgrounds; car parks; and domestic animals such as barking dogs. Many countries have regulated community noise from road and rail traffic, construction machines and industrial plants by applying emission standards, and by regulating the acoustical properties of buildings. In contrast, few countries have regulations on community noise from the neighbourhood, probably due to the lack of methods to define and measure it, and to the difficulty of controlling it. In large cities throughout the world, the general population is increasingly exposed to community due to the sources mentioned above and the health effects of these exposures are considered to be a more and more important public health problem. Specific effects to be considered when setting community noise guidelines include: interference with communication; noise-induced hearing loss; sleep disturbance effects, cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses, and effects on social behaviour.

Since 1980, the World Health Organization (WHO) has addressed the problem of community noise. Health-based guidelines on community noise can serve as the basis for deriving noise standards within a framework of noise management. Key issues of noise management include abatement options; models for forecasting and for assessing source control action, setting noise emission standards for existing and planned sources; noise exposure assessment; and testing the compliance of noise exposure with noise immission standards. In 1992, the WHO Regional Office for Europe convened a task force meeting which set up guidelines for community noise. A preliminary publication of the Karolinska Institute, Stockholm, on behalf of WHO, appeared in 1995. This publication served as the basis for the globally applicable *Guidelines for Community Noise* presented in this document. An expert task force meeting was convened by WHO in March 1999 in London, United Kingdom, to finalize the guidelines.

The *Guidelines for Community Noise* have been prepared as a practical response to the need for action on community noise at the local level, as well as the need for improved legislation, management and guidance at the national and regional levels. WHO will be pleased to see that these guidelines are used widely. Continuing efforts will be made to improve its content and structure. It would be appreciated if the users of the *Guidelines* provide feedback from its use and their own experiences. Please send your comments and suggestions on the WHO *Guidelines for Community Noise – Guideline document* to the Department of the Protection of the Human Environment, Occupational and Environmental Health, World Health Organization, Geneva, Switzerland (Fax: +41 22-791 4123, e-mail: schwelad@who.int).

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The World Health Organization thanks all who have contributed to the preparation of this document, *Guidelines for Community Noise*. The international, multidisciplinary group of contributors to, and reviewers of, the *Guidelines* are listed in the "Participant list" in Annex 6. Special thanks are due to the chairpersons and workgroups of the WHO expert task force meeting held in London, United Kingdom, in March 1999: Professor Thomas Lindvall, who acted as the chairperson of the meeting, Professor Birgitta Berglund, Dr John Bradley and Professor Gerd Jansen, who chaired the three workgroups. Special contributions from those who provided the background papers and who contributed to the success of the WHO expert meeting are gratefully acknowledged:

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Executive Summary

1. Introduction

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic; industries; construction and public work; and the neighbourhood. The main indoor noise sources are ventilation systems, office machines, home appliances and neighbours.

In the European Union about 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime, and 20% are exposed to levels exceeding 65 dB(A). When all transportation noise is considered, more than half of all European Union citizens is estimated to live in zones that do not ensure acoustical comfort to residents. At night, more than 30% are exposed to equivalent sound pressure levels exceeding 55 dB(A), which are disturbing to sleep. Noise pollution is also severe in cities of developing countries. It is caused mainly by traffic and alongside densely-travelled roads equivalent sound pressure levels for 24 hours can reach 75–80 dB(A).

In contrast to many other environmental problems, noise pollution continues to grow and it is accompanied by an increasing number of complaints from people exposed to the noise. The growth in noise pollution is unsustainable because it involves direct, as well as cumulative, adverse health effects. It also adversely affects future generations, and has socio-cultural, esthetic and economic effects.

2. Noise sources and measurement

Physically, there is no distinction between sound and noise. Sound is a sensory perception and the complex pattern of sound waves is labeled noise, music, speech etc. Noise is thus defined as unwanted sound.

Most environmental noises can be approximately described by several simple measures. All measures consider the frequency content of the sounds, the overall sound pressure levels and the variation of these levels with time. Sound pressure is a basic measure of the vibrations of air that make up sound. Because the range of sound pressures that human listeners can detect is very wide, these levels are measured on a logarithmic scale with units of decibels. Consequently, sound pressure levels cannot be added or averaged arithmetically. Also, the sound levels of most noises vary with time, and when sound pressure levels are calculated, the instantaneous pressure fluctuations must be integrated over some time interval.

Most environmental sounds are made up of a complex mix of many different frequencies. Frequency refers to the number of vibrations per second of the air in which the sound is propagating and it is measured in Hertz (Hz). The audible frequency range is normally considered to be 20–20 000 Hz for younger listeners with unimpaired hearing. However, our hearing systems are not equally sensitive to all sound frequencies, and to compensate for this various types of filters or frequency weighting have been used to determine the relative strengths of frequency components making up a particular environmental noise. The A-weighting is most commonly used and weights lower frequencies as less important than mid- and higher-frequencies. It is intended to approximate the frequency response of our hearing system.

The effect of a combination of noise events is related to the combined sound energy of those events (the equal energy principle). The sum of the total energy over some time period gives a level equivalent to the average sound energy over that period. Thus, LAeq,T is the energy average equivalent level of the A-weighted sound over a period T. LAeq,T should be used to measure continuing sounds, such as road traffic noise or types of more-or-less continuous industrial noises. However, when there are distinct events to the noise, as with aircraft or railway noise, measures of individual events such as the maximum noise level (LAmax), or the weighted sound exposure level (SEL), should also be obtained in addition to LAeq,T. Time-varying environmental sound levels have also been described in terms of percentile levels.

Currently, the recommended practice is to assume that the equal energy principle is approximately valid for most types of noise and that a simple LAeq,T measure will indicate the expected effects of the noise reasonably well. When the noise consists of a small number of discrete events, the A-weighted maximum level (LAmax) is a better indicator of the disturbance to sleep and other activities. In most cases, however, the A-weighted sound exposure level (SEL) provides a more consistent measure of single-noise events because it is based on integration over the complete noise event. In combining day and night LAeq,T values, night-time weightings are often added. Night-time weightings are intended to reflect the expected increased sensitivity to annoyance at night, but they do not protect people from sleep disturbance.

Where there are no clear reasons for using other measures, it is recommended that LAeq,T be used to evaluate more-or-less continuous environmental noises. Where the noise is principally composed of a small number of discrete events, the additional use of LAmax or SEL is recommended. There are definite limitations to these simple measures, but there are also many practical advantages, including economy and the benefits of a standardized approach.

3. Adverse health effects of noise

The health significance of noise pollution is given in chapter 3 of the *Guidelines* under separate headings according to the specific effects: noise-induced hearing impairment; interference with speech communication; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behaviour and annoyance; and interference with intended activities. This chapter also considers vulnerable groups and the combined effects of mixed noise sources.

Hearing impairment is typically defined as an increase in the threshold of hearing. Hearing deficits may be accompanied by tinnitus (ringing in the ears). Noise-induced hearing impairment occurs predominantly in the higher frequency range of 3 000–6 000 Hz, with the largest effect at 4 000 Hz. But with increasing LAeq,8h and increasing exposure time, noise-induced hearing impairment occurs even at frequencies as low as 2 000 Hz. However, hearing impairment is not expected to occur at LAeq,8h levels of 75 dB(A) or below, even for prolonged occupational noise exposure.

Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard and it is estimated that 120 million people worldwide have disabling hearing difficulties. In developing countries, not only occupational noise but also environmental noise is an increasing risk factor for hearing impairment. Hearing damage can also be caused by certain diseases, some industrial chemicals, ototoxic drugs, blows to the head, accidents and hereditary origins. Hearing deterioration is also associated with the ageing process itself (presbyacusis).

The extent of hearing impairment in populations exposed to occupational noise depends on the value of LAeq,8h, the number of noise-exposed years, and on individual susceptibility. Men and women are equally at risk for noise-induced hearing impairment. It is expected that environmental and leisure-time noise with a LAeq,24h of 70 dB(A) or below will not cause hearing impairment in the large majority of people, even after a lifetime exposure. For adults exposed to impulse noise at the workplace, the noise limit is set at peak sound pressure levels of 140 dB, and the same limit is assumed to be appropriate for environmental and leisure-time noise. In the case of children, however, taking into account their habits while playing with noisy toys, the peak sound pressure should never exceed 120 dB. For shooting noise with LAeq,24h levels greater than 80 dB(A), there may be an increased risk for noise-induced hearing impairment.

The main social consequence of hearing impairment is the inability to understand speech in daily living conditions, and this is considered to be a severe social handicap. Even small values of hearing impairment (10 dB averaged over 2 000 and 4 000 Hz and over both ears) may adversely affect speech comprehension.

Speech intelligibility is adversely affected by noise. Most of the acoustical energy of speech is in the frequency range of 100–6 000 Hz, with the most important cue-bearing energy being between 300–3 000 Hz. Speech interference is basically a masking process, in which simultaneous interfering noise renders speech incapable of being understood. Environmental noise may also mask other acoustical signals that are important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music.

Speech intelligibility in everyday living conditions is influenced by speech level; speech pronunciation; talker-to-listener distance; sound level and other characteristics of the interfering noise; hearing acuity; and by the level of attention. Indoors, speech communication is also affected by the reverberation characteristics of the room. Reverberation times over 1 s produce loss in speech discrimination and make speech perception more difficult and straining. For full sentence intelligibility in listeners with normal hearing, the signal-to-noise ratio (i.e. the difference between the speech level and the sound level of the interfering noise) should be at least 15 dB(A). Since the sound pressure level of normal speech is about 50 dB(A), noise with sound levels of 35 dB(A) or more interferes with the intelligibility of speech in smaller rooms. For vulnerable groups even lower background levels are needed, and a reverberation time below 0.6 s is desirable for adequate speech intelligibility, even in a quiet environment.

The inability to understand speech results in a large number of personal handicaps and behavioural changes. Particularly vulnerable are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language.

Sleep disturbance is a major effect of environmental noise. It may cause primary effects during sleep, and secondary effects that can be assessed the day after night-time noise exposure. Uninterrupted sleep is a prerequisite for good physiological and mental functioning, and the primary effects of sleep disturbance are: difficulty in falling asleep; awakenings and alterations of sleep stages or depth; increased blood pressure, heart rate and finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and increased body movements. The difference between the sound levels of a noise event and background sound levels, rather than the absolute noise level, may determine the reaction probability. The probability of being awakened increases with the number of noise events per night. The secondary, or after-effects, the following morning or day(s) are: reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance.

For a good night's sleep, the equivalent sound level should not exceed 30 dB(A) for continuous background noise, and individual noise events exceeding 45 dB(A) should be avoided. In setting limits for single night-time noise exposures, the intermittent character of the noise has to be taken into account. This can be achieved, for example, by measuring the number of noise events, as well as the difference between the maximum sound level and the background sound level. Special attention should also be given to: noise sources in an environment with low background sound levels; combinations of noise and vibrations; and to noise sources with low-frequency components.

Physiological Functions. In workers exposed to noise, and in people living near airports, industries and noisy streets, noise exposure may have a large temporary, as well as permanent, impact on physiological functions. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposure to high sound levels. The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviours and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset.

Workers exposed to high levels of industrial noise for 5–30 years may show increased blood pressure and an increased risk for hypertension. Cardiovascular effects have also been demonstrated after long-term exposure to air- and road-traffic with LAeq,24h values of 65–70 dB(A). Although the associations are weak, the effect is somewhat stronger for ischaemic heart disease than for hypertension. Still, these small risk increments are important because a large number of people are exposed.

Mental Illness. Environmental noise is not believed to cause mental illness directly, but it is assumed that it can accelerate and intensify the development of latent mental disorders. Exposure to high levels of occupational noise has been associated with development of neurosis, but the findings on environmental noise and mental-health effects are inconclusive. Nevertheless, studies on the use of drugs such as tranquillizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates, suggest that community noise may have adverse effects on mental health.

Performance. It has been shown, mainly in workers and children, that noise can adversely affect performance of cognitive tasks. Although noise-induced arousal may produce better performance in simple tasks in the short term, cognitive performance substantially deteriorates for more complex tasks. Reading, attention, problem solving and memorization are among the cognitive effects most strongly affected by noise. Noise can also act as a distracting stimulus and impulsive noise events may produce disruptive effects as a result of startle responses.

Noise exposure may also produce after-effects that negatively affect performance. In schools around airports, children chronically exposed to aircraft noise under-perform in proof reading, in persistence on challenging puzzles, in tests of reading acquisition and in motivational capabilities. It is crucial to recognize that some of the adaptation strategies to aircraft noise, and the effort necessary to maintain task performance, come at a price. Children from noisier areas have heightened sympathetic arousal, as indicated by increased stress hormone levels, and elevated resting blood pressure. Noise may also produce impairments and increase in errors at work, and some accidents may be an indicator of performance deficits.

Social and Behavioural Effects of Noise; Annoyance. Noise can produce a number of social and behavioural effects as well as annoyance. These effects are often complex, subtle and indirect and many effects are assumed to result from the interaction of a number of non-auditory variables. The effect of community noise on annoyance can be evaluated by questionnaires or by assessing the disturbance of specific activities. However, it should be recognized that equal levels of different traffic and industrial noises cause different magnitudes of annoyance. This is because annoyance in populations varies not only with the characteristics of the noise, including the noise source, but also depends to a large degree on many non-acoustical factors of a social, psychological, or economic nature. The correlation between noise exposure and general annoyance is much higher at group level than at individual level. Noise above 80 dB(A) may also reduce helping behaviour and increase aggressive behaviour. There is particular concern that high-level continuous noise exposures may increase the susceptibility of schoolchildren to feelings of helplessness.

Stronger reactions have been observed when noise is accompanied by vibrations and contains low-frequency components, or when the noise contains impulses, such as with shooting noise. Temporary, stronger reactions occur when the noise exposure increases over time, compared to a constant noise exposure. In most cases, LAeq,24h and L_{dn} are acceptable approximations of noise exposure related to annoyance. However, there is growing concern that all the component parameters should be individually assessed in noise exposure investigations, at least in the complex cases. There is no consensus on a model for total annoyance due to a combination of environmental noise sources.

Combined Effects on Health of Noise from Mixed Sources. Many acoustical environments consist of sounds from more than one source, i.e. there are mixed sources, and some combinations of effects are common. For example, noise may interfere with speech in the day and create sleep disturbance at night.

These conditions certainly apply to residential areas heavily polluted with noise. Therefore, it is important that the total adverse health load of noise be considered over 24 hours, and that the precautionary principle for sustainable development be applied.

Vulnerable Subgroups. Vulnerable subgroups of the general population should be considered when recommending noise protection or noise regulations. The types of noise effects, specific environments and specific lifestyles are all factors that should be addressed for these subgroups. Examples of vulnerable subgroups are: people with particular diseases or medical problems (e.g. high blood pressure); people in hospitals or rehabilitating at home; people dealing with complex cognitive tasks; the blind, people with hearing impairment; fetuses, babies and young children; and the elderly in general. People with impaired hearing are the most adversely affected with respect to speech intelligibility. Even slight hearing impairments in the high-frequency sound range may cause problems with speech perception in a noisy environment. A majority of the population belongs to the subgroup that is vulnerable to speech interference.

4. Guideline values

In chapter 4, guideline values are given for specific health effects of noise and for specific environments

Specific health effects.

Interference with Speech Perception. A majority of the population is susceptible to speech interference by noise and belongs to a vulnerable subgroup. Most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, the ability of people to interpret difficult, spoken messages with low linguistic redundancy is impaired compared to people 20–30 years old. It has also been shown that high noise levels and long reverberation times have more adverse effects in children, who have not completed language acquisition, than in young adults.

When listening to complicated messages (at school, foreign languages, telephone conversation) the signal-to-noise ratio should be at least 15 dB with a voice level of 50 dB(A). This sound level corresponds on average to a casual voice level in both women and men at 1 m distance. Consequently, for clear speech perception the background noise level should not exceed 35 dB(A). In classrooms or conference rooms, where speech perception is of paramount importance, or for sensitive groups, background noise levels should be as low as possible. Reverberation times below 1 s are also necessary for good speech intelligibility in smaller rooms. For sensitive groups, such as the elderly, a reverberation time below 0.6 s is desirable for adequate speech intelligibility even in a quiet environment.

Hearing Impairment. Noise that gives rise to hearing impairment is by no means restricted to occupational situations. High noise levels can also occur in open air concerts, discotheques, motor sports, shooting ranges, in dwellings from loudspeakers, or from leisure activities. Other important sources of loud noise are headphones, as well as toys and fireworks which can emit impulse noise. The ISO standard 1999 gives a method for estimating noise-induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, impulse) during working hours. However, the evidence strongly suggests that this method should also be used to calculate hearing impairment due to noise exposure from environmental and leisure time activities. The ISO standard 1999 implies that long-term exposure to $L_{Aeq,24h}$ noise levels of up to 70 dB(A) will not result in hearing impairment. To avoid hearing loss from impulse noise exposure, peak sound pressures should never exceed 140 dB for adults, and 120 dB for children.

Sleep Disturbance. Measurable effects of noise on sleep begin at LAeq levels of about 30 dB. However, the more intense the background noise, the more disturbing is its effect on sleep. Sensitive groups mainly include the elderly, shift workers, people with physical or mental disorders and other individuals who have difficulty sleeping.

Sleep disturbance from intermittent noise events increases with the maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep. Therefore, to avoid sleep disturbance, guidelines for community noise should be expressed in terms of the equivalent sound level of the noise, as well as in terms of maximum noise levels and the number of noise events. It should be noted that low-frequency noise, for example, from ventilation systems, can disturb rest and sleep even at low sound pressure levels.

When noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided. For noise with a large proportion of low-frequency sound a still lower guideline value is recommended. When the background noise is low, noise exceeding 45 dB LAmax should be limited, if possible, and for sensitive persons an even lower limit is preferred. Noise mitigation targeted to the first part of the night is believed to be an effective means for helping people fall asleep. It should be noted that the adverse effect of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

Reading Acquisition. Chronic exposure to noise during early childhood appears to impair reading acquisition and reduces motivational capabilities. Evidence indicates that the longer the exposure, the greater the damage. Of recent concern are the concomitant psychophysiological changes (blood pressure and stress hormone levels). There is insufficient information on these effects to set specific guideline values. It is clear, however, that daycare centres and schools should not be located near major noise sources, such as highways, airports, and industrial sites.

Annoyance. The capacity of a noise to induce annoyance depends upon its physical characteristics, including the sound pressure level, spectral characteristics and variations of these properties with time. During daytime, few people are highly annoyed at LAeq levels below 55 dB(A), and few are moderately annoyed at LAeq levels below 50 dB(A). Sound levels during the evening and night should be 5–10 dB lower than during the day. Noise with low-frequency components require lower guideline values. For intermittent noise, it is emphasized that it is necessary to take into account both the maximum sound pressure level and the number of noise events. Guidelines or noise abatement measures should also take into account residential outdoor activities.

Social Behaviour. The effects of environmental noise may be evaluated by assessing its interference with social behavior and other activities. For many community noises, interference with rest/recreation/watching television seem to be the most important effects. There is fairly consistent evidence that noise above 80 dB(A) causes reduced helping behavior, and that loud noise also increases aggressive behavior in individuals predisposed to aggressiveness. In schoolchildren, there is also concern that high levels of chronic noise contribute to feelings of helplessness. Guidelines on this issue, together with cardiovascular and mental effects, must await further research.

Specific environments.

A noise measure based only on energy summation and expressed as the conventional equivalent measure, LAeq, is not enough to characterize most noise environments. It is equally important to measure the maximum values of noise fluctuations, preferably combined with a measure of the number of noise events. If the noise includes a large proportion of low-frequency components, still lower values than the guideline values below will be needed. When prominent low-frequency components are present, noise measures based on A-weighting are inappropriate. The difference between dB(C) and dB(A) will give crude information about the presence of low-frequency components in noise, but if the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed. It should be noted that a large proportion of low-frequency components in noise may increase considerably the adverse effects on health.

In Dwellings. The effects of noise in dwellings, typically, are sleep disturbance, annoyance and speech interference. For bedrooms the critical effect is sleep disturbance. Indoor guideline values for bedrooms are 30 dB LAeq for continuous noise and 45 dB LAmax for single sound events. Lower noise levels may be disturbing depending on the nature of the noise source. At night-time, outside sound levels about 1 metre from facades of living spaces should not exceed 45 dB LAeq, so that people may sleep with bedroom windows open. This value was obtained by assuming that the noise reduction from outside to inside with the window open is 15 dB. To enable casual conversation indoors during daytime, the sound level of interfering noise should not exceed 35 dB LAeq. The maximum sound pressure level should be measured with the sound pressure meter set at "Fast".

To protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55 dB LAeq on balconies, terraces and in outdoor living areas. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound level should not exceed 50 dB LAeq. Where it is practical and feasible, the lower outdoor sound level should be considered the maximum desirable sound level for new development.

In Schools and Preschools. For schools, the critical effects of noise are speech interference, disturbance of information extraction (e.g. comprehension and reading acquisition), message communication and annoyance. To be able to hear and understand spoken messages in class rooms, the background sound level should not exceed 35 dB LAeq during teaching sessions. For hearing impaired children, a still lower sound level may be needed. The reverberation time in the classroom should be about 0.6 s, and preferably lower for hearing impaired children. For assembly halls and cafeterias in school buildings, the reverberation time should be less than 1 s. For outdoor playgrounds the sound level of the noise from external sources should not exceed 55 dB LAeq, the same value given for outdoor residential areas in daytime.

For preschools, the same critical effects and guideline values apply as for schools. In bedrooms in preschools during sleeping hours, the guideline values for bedrooms in dwellings should be used.

In Hospitals. For most spaces in hospitals, the critical effects are sleep disturbance, annoyance, and communication interference, including warning signals. The LAmax of sound events during the night should not exceed 40 dB(A) indoors. For ward rooms in hospitals, the guideline values indoors are 30dB LAeq, together with 40 dB LAmax during night. During the day and evening the guideline value indoors is 30 dB LAeq. The maximum level should be measured with the sound pressure instrument set at "Fast".

Since patients have less ability to cope with stress, the LAeq level should not exceed 35 dB in most rooms in which patients are being treated or observed. Attention should be given to the sound levels in intensive care units and operating theaters. Sound inside incubators may result in health problems for neonates, including sleep disturbance, and may also lead to hearing impairment. Guideline values for sound levels in incubators must await future research.

Ceremonies, Festivals and Entertainment Events. In many countries, there are regular ceremonies, festivals and entertainment events to celebrate life periods. Such events typically produce loud sounds, including music and impulsive sounds. There is widespread concern about the effect of loud music and impulsive sounds on young people who frequently attend concerts, discotheques, video arcades, cinemas, amusement parks and spectator events. At these events, the sound level typically exceeds 100 dB LAeq. Such noise exposure could lead to significant hearing impairment after frequent attendances.

Noise exposure for employees of these venues should be controlled by established occupational standards; and at the very least, the same standards should apply to the patrons of these premises. Patrons should not be exposed to sound levels greater than 100 dB LAeq during a four-hour period more than four times per year. To avoid acute hearing impairment the LAmax should always be below 110 dB.

Headphones. To avoid hearing impairment from music played back in headphones, in both adults and children, the equivalent sound level over 24 hours should not exceed 70 dB(A). This implies that for a daily one hour exposure the LAeq level should not exceed 85 dB(A). To avoid acute hearing impairment LAmax should always be below 110 dB(A). The exposures are expressed in free-field equivalent sound level

Toys, Fireworks and Firearms. To avoid acute mechanical damage to the inner ear from impulsive sounds from toys, fireworks and firearms, adults should never be exposed to more than 140 dB(lin) peak sound pressure level. To account for the vulnerability in children when playing, the peak sound pressure produced by toys should not exceed 120 dB(lin), measured close to the ears (100 mm). To avoid acute hearing impairment LAmax should always be below 110 dB(A).

Parkland and Conservation Areas. Existing large quiet outdoor areas should be preserved and the signal-to-noise ratio kept low.

Table 1 presents the WHO guideline values arranged according to specific environments and critical health effects. The guideline values consider all identified adverse health effects for the specific environment. An adverse effect of noise refers to any temporary or long-term impairment of physical, psychological or social functioning that is associated with noise exposure. Specific noise limits have been set for each health effect, using the lowest noise level that produces an adverse health effect (i.e. the critical health effect). Although the guideline values refer to sound levels impacting the most exposed receiver at the listed environments, they are applicable to the general population. The time base for LAeq for "daytime" and "night-time" is 12–16 hours and 8 hours, respectively. No time base is given for evenings, but typically the guideline value should be 5–10 dB lower than in the daytime. Other time bases are recommended for schools, preschools and playgrounds, depending on activity.

It is not enough to characterize the noise environment in terms of noise measures or indices based only on energy summation (e.g., LAeq), because different critical health effects require different descriptions. It is equally important to display the maximum values of the noise fluctuations, preferably combined with a measure of the number of noise events. A separate characterization of night-time noise exposures is also necessary. For indoor environments, reverberation time is also an important factor for things such as speech intelligibility. If the noise includes a large proportion of low-frequency components, still lower guideline values should be applied. Supplementary to the guideline values given in Table 1, precautions should be taken for vulnerable groups and for noise of certain character (e.g. low-frequency components, low background noise).

Table 1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	L_{Aeq} [dB(A)]	Time base [hours]	L_{Amax} fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors	Speech intelligibility & moderate annoyance, daytime & evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms & pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoor	Sleep disturbance	30	sleeping-time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music and other sounds through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservations areas	Disruption of tranquillity	#3		

1: As low as possible.

#2: Peak sound pressure (not LAF, max) measured 100 mm from the ear

#3: Existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low.

#4: Under headphones, adapted to free field values.

5. Noise Management

Chapter 5 is devoted to noise management with discussions on: strategies and priorities in managing indoor noise levels; noise policies and legislation; the impact of environmental noise; and on the enforcement of regulatory standards.

The fundamental goals of noise management are to develop criteria for deriving safe noise exposure levels and to promote noise assessment and control as part of environmental health programmes. These basic goals should guide both international and national policies for noise management. The United Nation's Agenda 21 supports a number of environmental management principles on which government policies, including noise management policies, can be based: the principle of precaution; the "polluter pays" principle; and noise prevention. In all cases, noise should be reduced to the lowest level achievable in the particular situation. When there is a reasonable possibility that the public health will be endangered, even though scientific proof may be lacking, action should be taken to protect the public health, without awaiting the full scientific proof. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision) should be met by those responsible for the source of noise. Action should be taken where possible to reduce noise at the source.

A legal framework is needed to provide a context for noise management. National noise standards can usually be based on a consideration of international guidelines, such as these *Guidelines for Community Noise*, as well as national criteria documents, which consider dose-response relationships for the effects of noise on human health. National standards take into account the technological, social, economic and political factors within the country. A staged program of noise abatement should also be implemented to achieve the optimum health protection levels over the long term.

Other components of a noise management plan include: noise level monitoring; noise exposure mapping; exposure modeling; noise control approaches (such as mitigation and precautionary measures); and evaluation of control options. Many of the problems associated with high noise levels can be prevented at low cost, if governments develop and implement an integrated strategy for the indoor environment, in concert with all social and economic partners. Governments should establish a "National Plan for a Sustainable Noise Indoor Environment" that applies both to new construction as well as to existing buildings.

The actual priorities in national noise management will differ for each country. Priority setting in noise management refers to prioritizing the health risks to be avoided and concentrating on the most important sources of noise. Different countries have adopted a range of approaches to noise control, using different policies and regulations. A number of these are outlined in chapter 5 and Appendix 2, as examples. It is evident that noise emission standards have proven insufficient and that the trends in noise pollution are unsustainable.

The concept of environmental an environmental noise impact analysis is central to the philosophy of managing environmental noise. Such an analysis should be required before implementing any project that would significantly increase the level of environmental noise in a community (typically, greater than a 5 dB increase). The analysis should include: a baseline description of the existing noise environment; the expected level of noise from the new source; an assessment of the adverse health effects; an estimation of the population at risk; the calculation of exposure-response relationships, an assessment of risks and their acceptability; and a cost-benefit analysis.

Noise management should:

1. Start monitoring human exposures to noise.
2. Have health control require mitigation of noise immissions, and not just of noise source emissions. The following should be taken into consideration:
   - specific environments such as schools, playgrounds, homes, hospitals.
   - environments with multiple noise sources, or which may amplify the effects of noise.
   - sensitive time periods such as evenings, nights and holidays.
   - groups at high risk, such as children and the hearing impaired.
3. Consider the noise consequences when planning transport systems and land use.
4. Introduce surveillance systems for noise-related adverse health effects.
5. Assess the effectiveness of noise policies in reducing adverse health effects and exposure, and in improving supportive "soundscapes".
6. Adopt these *Guidelines for Community Noise* as intermediary targets for improving human health.
7. Adopt precautionary actions for a sustainable development of the acoustical environments.

Conclusions and recommendations

In chapter 6 are discussed. the implementation of the guidelines, further WHO work on noise; and research needs are recommended.

Implementation. For implementation of the guidelines it is recommended that:

- Governments should protection the population from community noise and consider it an integral part of their policy of environmental protection.
- Governments should consider implementing action plans with short-term, medium-term and long-term objectives for reducing noise levels.
- Governments should adopt the *Health Guidelines for Community Noise* values as targets to be achieved in the long-term.
- Governments should include noise as an important public health issue in environmental impact assessments.
- Legislation should be put in place to allow for the reduction of sound levels.
- Existing legislation should be enforced.
- Municipalities should develop low noise implementation plans.
- Cost-effectiveness and cost-benefit analyses should be considered potential instruments for meaningful management decisions.
- Governments should support more policy-relevant research.

Future Work. The Expert Task Force worked out several suggestions for future work for the WHO in the field of community noise. WHO should:

- Provide leadership and technical direction in defining future noise research priorities.
- Organize workshops on how to apply the guidelines.

- Provide leadership and coordinate international efforts to develop techniques for designing supportive sound environments (e.g. "soundscapes").
- Provide leadership for programs to assess the effectiveness of health-related noise policies and regulations.
- Provide leadership and technical direction for the development of sound methodologies for environmental and health impact plans.
- Encourage further investigation into using noise exposure as an indicator of environmental deterioration (e.g. black spots in cities).
- Provide leadership and technical support, and advise developing countries to facilitate development of noise policies and noise management.

Research and Development. A major step forward in raising the awareness of both the public and of decision makers is the recommendation to concentrate more research and development on variables which have monetary consequences. This means that research should consider not only dose response relationships between sound levels, but also politically relevant variables, such as noise-induced social handicap; reduced productivity; decreased performance in learning, workplace and school absenteeism; increased drug use; and accidents.

In Appendices 1–6 are given bibliographic references; examples of regional noise situations (African Region, American Region, Eastern Mediterranean Region, South East Asian Region, Western Pacific Region); a glossary, a list of acronyms, and a list of participants.

Introduction

Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources, except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic, industries, construction and public work, and the neighbourhood. Typical neighbourhood noise comes from premises and installations related to the catering trade (restaurant, cafeterias, discotheques, etc.); from live or recorded music; from sporting events including motor sports; from playgrounds and car parks; and from domestic animals such as barking dogs. The main indoor sources are ventilation systems, office machines, home appliances and neighbours. Although many countries have regulations on community noise from road, rail and air traffic, and from construction and industrial plants, few have regulations on neighbourhood noise. This is probably due to the lack of methods to define and measure it, and to the difficulty of controlling it. In developed countries, too, monitoring of compliance with, and enforcement of, noise regulations are weak for lower levels of urban noise that correspond to occupationally controlled levels (>85 dB LAeq,8h; Frank 1998). Recommended guideline values based on the health effects of noise, other than occupationally-induced effects, are often not taken into account.

The extent of the community noise problem is large. In the European Union about 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dBA daytime; and 20% is exposed to levels exceeding 65 dBA (Lambert & Vallet 19 1994). When all transportation noise is considered, about half of all European Union citizens live in zones that do not ensure acoustical comfort to residents. At night, it is estimated that more than 30% is exposed to equivalent sound pressure levels exceeding 55 dBA, which are disturbing to sleep. The noise pollution problem is also severe in the cities of developing countries and is caused mainly by traffic. Data collected alongside densely traveled roads were found to have equivalent sound pressure levels for 24 hours of 75-80 dBA (e.g. National Environment Board Thailand 19 1990; Mage & Walsh 19 1998).

(a) In contrast to many other environmental problems, noise pollution continues to grow, accompanied by an increasing number of complaints from affected individuals. Most people are typically exposed to several noise sources, with road traffic noise being a dominant source (OECD-ECMT 19 1995). Population growth, urbanization and to a large extent technological development are the main driving forces, and future enlargements of highway systems, international airports and railway systems will only increase the noise problem. Viewed globally, the growth in urban environmental noise pollution is unsustainable, because it involves not simply the direct and cumulative adverse effects on health. It also adversely affects future generations by degrading residential, social and learning environments, with corresponding economical losses (Berglund 1998). Thus, noise is not simply a local problem, but a global issue that affects everyone (Lang 1999, Sandberg 1999) and calls for precautionary action in any environmental planning situation.

The objective of the World Health Organization (WHO) is the attainment by all peoples of the highest possible level of health. As the first principle of the WHO Constitution the definition of 'health' is given as: "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". This broad definition of health embraces the concept of well-being and, thereby, renders noise impacts such as population annoyance, interference with communication, and impaired task performance as 'health' issues. In 1992, a WHO Task Force also identified the following specific health effects for the general population that may result from community noise: interference with communication; annoyance responses; effects on sleep, and on the cardiovascular and psychophysiological systems; effects on performance, productivity, and social behavior; and noise-induced hearing impairment (WHO 1993, Berglund & Lindvall 1995; *cf.* WHO 1980). Hearing damage is expected to result from both occupational and environmental noise, especially in developing countries, where compliance with noise regulation is known to be weak (Smith 1998).

Noise is likely to continue as a major issue well into the next century, both in developed and in developing countries. Therefore, strategic action is urgently required, including continued noise control at the source and in local areas. Most importantly, joint efforts among countries are necessary at a system level, in regard to the access and use of land, airspace and seawaters, and in regard to the various modes of transportation. Certainly, mankind would benefit from societal reorganization towards healthy transport. To understand noise we must understand the different types of noise and how we measure it, where noise comes from and the effects of noise on human beings. Furthermore, noise mitigation, including noise management, has to be actively introduced and in each case the policy implications have to be evaluated for efficiency.

This document is organized as follows. In Chapter 2 noise sources and measurement are discussed, including the basic aspects of source characteristics, sound propagation and transmission. In Chapter 3 the adverse health effects of noise are characterized. These include noise-induced hearing impairment, interference with speech communication, sleep disturbance, cardiovascular and physiological effects, mental health effects, performance effects, and annoyance reactions. This chapter is rounded out by a consideration of combined noise sources and their effects, and a discussion of vulnerable groups. In Chapter 4 the Guideline values are presented. Chapter 5 is devoted to noise management. Included are discussions of: strategies and priorities in the management of indoor noise levels; noise policies and legislation; environmental noise impact; and enforcement of regulatory standards. In Chapter 6 implementation of the WHO Guidelines is discussed, as well as future WHO work on noise and its research needs. In Appendices 1–6 are given: bibliographic references; examples of regional noise situations (African Region, American Region, Eastern Mediterranean Region, South East Asian Region, Western Pacific Region); a glossary; a list of acronyms; and a list of participants.

2. Noise sources and their measurement

2.1.Basic Aspects of Acoustical Measurements

Most environmental noises can be approximately described by one of several simple measures. They are all derived from overall sound pressure levels, the variation of these levels with time and the frequency of the sounds. Ford (1987) gives a more extensive review of various environmental noise measures. Technical definitions are found in the glossary in Appendix 3.

2.1.1. Sound pressure level

The sound pressure level is a measure of the air vibrations that make up sound. All measured sound pressures are referenced to a standard pressure that corresponds roughly to the threshold of hearing at 1 000 Hz. Thus, the sound pressure level indicates how much greater the measured sound is than this threshold of hearing. Because the human ear can detect a wide range of sound pressure levels (10–102 Pascal (Pa)), they are measured on a logarithmic scale with units of decibels (dB). A more technical definition of sound pressure level is found in the glossary.

The sound pressure levels of most noises vary with time. Consequently, in calculating some measures of noise, the instantaneous pressure fluctuations must be integrated over some time interval. To approximate the integration time of our hearing system, sound pressure meters have a standard *Fast* response time, which corresponds to a time constant of 0.125 s. Thus, all measurements of sound pressure levels and their variation over time should be made using the *Fast* response time, to provide sound pressure measurements more representative of human hearing. Sound pressure meters may also include a *Slow* response time with a time constant of 1 s, but its sole purpose is that one can more easily estimate the average value of rapidly fluctuating levels. Many modern meters can integrate sound pressures over specified periods and provide average values. It is not recommended that the *Slow* response time be used when integrating sound pressure meters are available.

Because sound pressure levels are measured on a logarithmic scale they cannot be added or averaged arithmetically. For example, adding two sounds of equal pressure levels results in a total pressure level that is only 3 dB greater than each individual sound pressure level. Consequently, when two sounds are combined the resulting sound pressure level will be significantly greater than the individual sound levels only if the two sounds have similar pressure levels. Details for combining sound pressure levels are given in Appendix 2.

2.1.2. Frequency and frequency weighting

The unit of frequency is the Hertz (Hz), and it refers to the number of vibrations per second of the air in which the sound is propagating. For tonal sounds, frequency is associated with the perception of pitch. For example, orchestras often tune to the frequency of 440 Hz. Most environmental sounds, however, are made up of a complex mix of many different frequencies. They may or may not have discrete frequency components superimposed on noise with a broad frequency spectrum (i.e. sound with a broad range of frequencies). The audible frequency range is normally considered to range from 20–20 000 Hz. Below 20 Hz we hear individual sound pulses rather than recognizable tones. Hearing sensitivity to higher frequencies decreases with age and exposure to noise. Thus, 20 000 Hz represents an upper limit of audibility for younger listeners with unimpaired hearing.

Our hearing systems are not equally sensitive to all sound frequencies (ISO 1987a). Thus, not all frequencies are perceived as being equally loud at the same sound pressure level, and when calculating overall environmental noise ratings it is necessary to consider sounds at some frequencies as more important than those at other frequencies. Detailed frequency analyses are commonly performed with standard sets of octave or 1/3 octave bandwidth filters. Alternatively, Fast Fourier Transform techniques or other types of filters can be used to determine the relative strengths of the various frequency components making up a particular environmental noise.

Frequency weighting networks provide a simpler approach for weighting the importance of different frequency components in one single number rating. The A-weighting is most commonly used and is intended to approximate the frequency response of our hearing system. It weights lower frequencies as less important than mid- and higher-frequency sounds. C-weighting is also quite common and is a nearly flat frequency response with the extreme high and low frequencies attenuated. When no frequency analysis is possible, the difference between A-weighted and C-weighted levels gives an indication of the amount of low frequency content in the measured noise. When the sound has an obvious tonal content, a correction to account for the additional annoyance may be used (ISO 1987b).

2.1.3. Equivalent continuous sound pressure level

According to the equal energy principle, the effect of a combination of noise events is related to the combined sound energy of those events. Thus, measures such as the equivalent continuous sound pressure level (LAeq,T) sum up the total energy over some time period (T) and give a level equivalent to the average sound energy over that period. Such average levels are usually based on integration of A-weighted levels. Thus LAeq,T is the average energy equivalent level of the A-weighted sound over a period T.

2.1.4. Individual noise events

It is often desired to measure the maximum level (LAmax) of individual noise events. For cases such as the noise from a single passing vehicle, LAmax values should be measured using the *Fast* response time because it will give a good correlation with the integration of loudness by our hearing system. However, for very short-duration impulsive sounds it is often desirable to measure the instantaneous peak amplitude to assess potential hearing-damage risk. If actual instantaneous pressure cannot be determined, then a time-integrated 'peak' level with a time constant of no more than 0.05 ms should be used (ISO 1987b). Such peak readings are often made using the C- (or linear) frequency weightings.

Alternatively, discrete sound events can be evaluated in terms of their A-weighted sound exposure level (SEL, for definition see appendix 5). The total amount of sound energy in a particular event is assessed by the SEL. One can add up the SEL values of individual events to calculate a LAeq,T over some time period, T, of interest. In some cases the SEL may provide more consistent evaluations of individual noise events because they are derived from the complete history of the event and not just one maximum value. However, A-weighted SEL measurements have been shown to be inadequate for assessing the (perceived) loudness of complex impulsive sounds, such as those from large and small weapons (Berglund et al. 1986). In contrast, C-weighted SEL values have been found useful for rating impulsive sounds such as gun shots (Vos 1996, Buchta 1996; ISO 1987b).

2.1.5. Choice of noise measure

LAeq,T should be used to measure continuing sounds such as road traffic noise, many types of industrial noises and noise from ventilation systems in buildings. When there are distinct events to the noise such as with aircraft or railway noise, measures of the individual events should be obtained (using, for example, LAmax or SEL), in addition to LAeq,T measurements.

In the past, time-varying environmental sound levels have also been described in terms of percentile levels. These are derived from a statistical distribution of measured sound levels over some period. For example, L10 is the A-weighted level exceeded 10% of the time. L10 values have been widely used to measure road-traffic noise, but they are usually found to be highly correlated measures of the individual events, as are LAmax and SEL. L90 or L95 can be used as a measure of the general background sound pressure level that excludes the potentially confounding influence of particular local noise events.

2.1.6. Sound and noise

Physically, there is no distinction between sound and noise: sound is a sensory perception evoked by physiological processes in the auditory brain. The complex pattern of sound waves is perceptually classified as "Gestalts" and are labeled as noise, music, speech, etc. Consequently, it is not possible to define noise exclusively on the basis of the physical parameters of sound. Instead, it is common practice to define noise simply as unwanted sound. However, in some situations noise may adversely affect health in the form of acoustical energy.

2.2. Sources of Noise

This section describes various sources of noise that can affect a community. Namely, noise from industry, transportation, and from residential and leisure areas. It should be noted that equal values of LAeq,T for different sources do not always imply the same expected effect.

2.2.1. Industrial noise

Mechanized industry creates serious noise problems. It is responsible for intense noise indoors as well as outdoors. This noise is due to machinery of all kinds and often increases with the power of the machines. Sound generation mechanisms of machinery are reasonably well understood. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sound patterns. Rotating and reciprocating machines generate sound that includes tonal components; and air-moving equipment tends also to generate noise with a wide frequency range. The high sound pressure levels are caused by components or gas flows that move at high speed (for example, fans, steam pressure relief valves), or by operations involving mechanical impacts (for example, stamping, riveting, road breaking). Machinery should preferably be silenced at the source.

Noise from fixed installations, such as factories or construction sites, heat pumps and ventilation systems on roofs, typically affect nearby communities. Reductions may be achieved by encouraging quieter equipment or by zoning of land into industrial and residential areas. Requirements for passive (sound insulating enclosures) and active noise control, or restriction of operation time, may also be effective.

2.2.2. Transportation noise

Transportation noise is the main source of environmental noise pollution, including road traffic, rail traffic and air traffic. As a general rule, larger and heavier vehicles emit more noise than smaller and lighter vehicles. Exceptions would include: helicopters and 2- and 3-wheeled road vehicles.

The noise of road vehicles is mainly generated from the engine and from frictional contact between the vehicle and the ground and air. In general, road-contact noise exceeds engine noise at speeds higher than 60 km/h. The physical principle responsible for generating noise from tire-road contact is less well understood. The sound pressure level from traffic can be predicted from the traffic flow rate, the speed of the vehicles, the proportion of heavy vehicles, and the nature of the road surface. Special problems can arise in areas where the traffic movements involve a change in engine speed and power, such as at traffic lights, hills, and intersecting roads; or where topography, meteorological conditions and low background levels are unfavourable (for example, mountain areas).

Railway noise depends primarily on the speed of the train, but variations are present depending upon the type of engine, wagons, and rails and their foundations, as well as the roughness of wheels and rails. Small radius curves in the track, such as may occur for urban trains, can lead to very high levels of high-frequency sound referred to as wheel squeal. Noise can be generated in stations because of running engines, whistles and loudspeakers, and in marshaling yards because of shunting operations. The introduction of high-speed trains has created special noise problems with sudden, but not impulsive, rises in noise. At speeds greater than 250 km/h, the proportion of high-frequency sound energy increases and the sound can be perceived as similar to that of overflying jet aircraft. Special problems can arise in areas close to tunnels, in valleys or in areas where the ground conditions help generate vibrations. The long-distance propagation of noise from high-speed trains will constitute a problem in the future if otherwise environment-friendly railway systems are expanded.

Aircraft operations generate substantial noise in the vicinity of both commercial and military airports. Aircraft takeoffs are known to produce intense noise, including vibration and rattle. The landings produce substantial noise in long low-altitude flight corridors. The noise is produced by the landing gear and automatic power regulation, and also when reverse thrust is applied, all for safety reasons. In general, larger and heavier aircraft produce more noise than lighter aircraft. The main mechanism of noise generation in the early turbojet-powered aircraft was the turbulence created by the jet exhaust mixing with the surrounding air. This noise source has been significantly reduced in modern high by-pass ratio turbo-fan engines that surround the high-velocity jet exhaust with lower velocity airflow generated by the fan. The fan itself can be a significant noise source, particularly during landing and taxiing operations. Multi-bladed turbo-prop engines can produce relatively high levels of tonal noise. The sound pressure level from aircraft is, typically, predicted from the number of aircraft, the types of airplanes, their flight paths, the proportions of takeoffs and landings and the atmospheric conditions. Severe noise problems may arise at airports hosting many helicopters or smaller aircraft used for private business, flying training and leisure purposes. Special noise problems may also arise inside airplanes because of vibration. The noise emission from future superjets is unknown.

A sonic boom consists of a shock wave in the air, generated by an aircraft when it flies at a speed slightly greater than the local speed of sound. An aircraft in supersonic flight trails a sonic boom that can be heard up to 50 km on either side of its ground track, depending upon the flight altitude and the size of the aircraft (Warren 1972). A sonic boom can be heard as a loud double-boom sound. At high intensity it can damage property.

Noise from military airfields may present particular problems compared to civil airports (von Gierke & Harris 1987). For example, when used for night-time flying, for training interrupted landings and takeoffs (so-called touch-and-go), or for low-altitude flying. In certain instances, including wars, specific military activities introduce other intense noise pollution from heavy vehicles (tanks), helicopters, and small and large fire-arms.

2.2.3. Construction noise and building services noise

Building construction and excavation work can cause considerable noise emissions. A variety of sounds come from cranes, cement mixers, welding, hammering, boring and other work processes. Construction equipment is often poorly silenced and maintained, and building operations are sometimes carried out without considering the environmental noise consequences. Street services such as garbage disposal and street cleaning can also cause considerable disturbance if carried out at sensitive times of day. Ventilation and air conditioning plants and ducts, heat pumps, plumbing systems, and lifts (elevators), for example, can compromise the internal acoustical environment and upset nearby residents.

2.2.4. Domestic noise and noise from leisure activities

In residential areas, noise may stem from mechanical devices (e.g. heat pumps, ventilation systems and traffic), as well as voices, music and other kinds of sounds generated by neighbours (e.g. lawn movers, vacuum cleaners and other household equipment, music reproduction and noisy parties). Aberrant social behavior is a well-recognized noise problem in multifamily dwellings, as well as at sites for entertainment (e.g. sports and music events). Due to predominantly low-frequency components, noise from ventilation systems in residential buildings may also cause considerable concern even at low and moderate sound pressure levels.

The use of powered machines in leisure activities is increasing. For example, motor racing, off-road vehicles, motorboats, water skiing, snowmobiles etc., and these contribute significantly to loud noises in previously quiet areas. Shooting activities not only have considerable potential for disturbing nearby residents, but can also damage the hearing of those taking part. Even tennis playing, church bell ringing and other religious activities can lead to noise complaints.

Some types of indoor concerts and discotheques can produce extremely high sound pressure levels. Associated noise problems outdoors result from customers arriving and leaving. Outdoor concerts, fireworks and various types of festivals can also produce intense noise. The general problem of access to festivals and leisure activity sites often adds to road traffic noise problems. Severe hearing impairment may also arise from intense sound produced as music in headphones or from children's toys.

2.3. The Complexity of Noise and Its Practical Implications

2.3.1. The problem

One must consider many different characteristics to describe environmental noises completely. We can consider the sound pressure level of the noise and how this level varies over a variety of periods, ranging from minutes or seconds to seasonal variations over several months. Where sound pressure levels vary quite substantially and rapidly, such as in the case of low-level jet aircraft, one might also want to consider the rate of change of sound pressure levels (Berry 1995; Kerry et al. 1997). At the same time, the frequency content of each noise will also determine its effect on people, as will the number of events when there are relatively small numbers of discrete noisy events. Combinations of these characteristics determine how each type of environmental noise affects people. These effects may be annoyance, sleep disturbance, speech interference, increased stress, hearing impairment or other health-related effects.

Thus, in total there is a very complex multidimensional relationship between the various characteristics of the environmental noise and the effects it has on people. Unfortunately, we do not completely understand all of the complex links between noise characteristics and the resulting effects on people. Thus, current practice is to reduce the assessment of environmental noise to a small number of quite simple quantities that are known to be reasonably well related to the effects of noise on people (LAeq,T for continuing sounds and LAmax or SEL where there are a small number of distinct noise events). These simple measures have the distinct advantage that they are relatively easy and inexpensive to obtain and hence are more likely to be widely adopted. On the other hand they may ignore some details of the noise characteristics that relate to particular types of effects on people.

2.3.2. Time variation

There is evidence that the pattern of noise variation with time relates to annoyance (Berglund et al. 1976). It has been suggested that the equal-energy principle is a simple concept for obtaining a measure representative of the annoyance of a number of noise events. For example, the LAeq,T of the noise from a busy road may be a good indicator of the annoyance this noise may cause for nearby residents. However, such a measure may not be very useful for predicting the disturbance to sleep of a small number of very noisy aircraft fly-overs. The disturbance caused by small numbers of such discrete events is usually better related to maximum sound pressure levels and the number of events.

While using LAeq,T measures is the generally accepted approach, it is still important to appreciate the limitations and errors that may occur. For example, some years ago measures that assessed the variation of sound pressure levels with time were popular. Subsequently, these have been shown not to improve predictions of annoyance with road traffic noise (Bradley 1978). However, it is possible that time variations may contribute to explaining the very different amounts of annoyance caused by equal LAeq,T levels of road-traffic noise, train noise and aircraft noise (*cf.* Miedema & Vos 1998).

More regular variations of sound pressure levels with time have been found to increase the annoying aspects of the noise. For example, noises that vary periodically to create a throbbing or pulsing sensation can be more disturbing than continuous noise (Bradley 1994b). Research suggests that variations at about 4 per second are most disturbing (Zwicker 1989). Noises with very rapid onsets could also be more disturbing than indicated by their LAeq,T (Berry 1995; Kerry et al. 1997).

LAeq,T values can be calculated for various time periods and it is very important to specify this period. It is quite common to calculate LAeq,T values separately for day- and night-time periods. In combining day and night LAeq,T values it is usually assumed that people will be more sensitive to noise during the night-time period. A weighting is thus normally added to night-time LAeq,T values when calculating a combined measure for a 24 hour period. For example, day-night sound pressure measures commonly include a 10 dB night-time weighting. Other night-time weightings have been proposed, but it has been suggested that it is not possible to determine precisely an optimum value for night-time weightings from annoyance survey responses, because of the large variability in responses within groups of people (Fields 1986; see also Berglund & Lindvall 1995). Night-time weightings are intended to indicate the expected increased sensitivity to annoyance at night and do not protect people from sleep disturbance.

2.3.3. Frequency content and loudness

Noise can also be characterized by its frequency content. This can be assessed by various types of frequency analysis to determine the relative contributions of the frequency components to the total noise. The combined effects of the different frequencies on people, perceived as noise, can be approximated by simple frequency weightings. The A-weighting is now widely used to obtain an approximate, single-number rating of the combined effects of the various frequencies. The A-weighting response is a simplification of an equal-loudness contour. There is a family of these equal-loudness contours (ISO 1987a) that describe the frequency response of the hearing system for a wide range of frequencies and sound pressure levels. These equal-loudness contours can be used to determine the perceived loudness of a single frequency sound. More complicated procedures have been derived to estimate the perceived loudness of complex sounds (ISO 1975). These methods involve determining the level of the sound in critical bands and the mutual masking of these bands.

Many studies have compared the accuracy of predictions based on A-weighted levels with those based on other frequency weightings, as well as more complex measures such as loudness levels and perceived noise levels (see also Berglund & Lindvall 1995). The comparisons depend on the particular effect that is being predicted, but generally the correlation between the more complex measures and subjective scales are a little stronger. A-weighted measures have been particularly criticized as not being accurate indicators of the disturbing effects of noises with strong low-frequency components (Kjellberg et al. 1984; Persson & Björkman 1988, Broner & Leventhall 1993; Goldstein 1994). However, these differences in prediction accuracy are usually smaller than the variability of responses among groups of people (Fields 1986; see also Berglund & Lindvall 1995). Thus, in practical situations the limitations of A-weighted measures may not be so important.

In addition to equal-loudness contours, equal-noisiness contours have also been developed for calculating perceived noise levels (PNL) (Kryter 1959; Kryter 1994; see also section 2.7.2). Critics have pointed out that in addition to equal-loudness and equal-noisiness contours, we could have many other families of equal-sensation contours corresponding to other attributes of the noises (Molino 1974). There seems to be no limit to the possible complexity and number of such measures.

2.3.4. Influence of ambient noise level

A number of studies have suggested that the annoyance effect of a particular noise would depend on how much that noise exceeded the level of ambient noise. This has been shown to be true for noises that are relatively constant in level (Bradley 1993), but has not been consistently found for time-varying noises such as aircraft noise (Gjestland et al. 1990; Fields 1998). Because at some time during an aircraft fly-over the noise almost always exceeds the ambient level, responses to this type of noise are less likely to be influenced by the level of the ambient noise.

2.3.5. Types of noise

A number of studies have concluded that equal levels of different noise types lead to different annoyance (Hall et al. 1981; Griffiths 1983; Miedema 1993; Bradley 1994a; Miedema & Vos 1998). For example, equal LAeq,T levels of aircraft noise and road traffic noise will not lead to the same mean annoyance in groups of people exposed to these noises. This may indicate that the LAeq,T measure is not a completely satisfactory description of these noises and perhaps does not completely reflect the characteristics of these noises that lead to annoyance. Alternatively, the differences may be attributed to various other factors that are not part of the noise characteristics (e.g. Flindell & Stallen 1999). For example, it has been said that aircraft noise is more disturbing, because of the associated fear of aircraft crashing on people's homes (cf. Berglund & Lindvall 1995).

2.3.6. Individual differences

Finally, there is the problem of individual response differences. Different people will respond quite differently to the same noise stimulus (Job 1988). These individual differences can be quite large and it is often most useful to consider the average response of groups of people exposed to the same sound pressure levels. In annoyance studies the percentage of highly annoyed individuals is usually considered, because it correlates better with measured sound pressure levels. Individual differences also exist for susceptibility to hearing impairment (e.g. Katz 1994).

2.3.7. Recommendations

In many cases we do not have specific, accurate measures of how annoying sound will be and must rely on the simpler quantities. As a result, current practice is to assume that the equal energy principle is approximately valid for most types of noise, and that a simple LAeq,T type measure will indicate reasonably well the expected effects of the noise. Where the noise consists of a small number of discrete events, the A-weighted maximum level (LAmax) will be a better indicator of the disturbance to sleep and other activities. However, in most cases the A-weighted sound exposure level (SEL) will provide a more consistent measure of such single-noise events, because it is based on an integration over the complete noise event.

2.4. Measurement Issues

2.4.1. Measurement objectives

The details of noise measurements must be planned to meet some relevant objective or purpose. Some typical objectives would include:

a. Investigating complaints.
b. Assessing the number of persons exposed.
c. Compliance with regulations.
d. Land use planning and environmental impact assessments.
e. Evaluation of remedial measures.
f. Calibration and validation of predictions.
g. Research surveys.
h. Trend monitoring.

The sampling procedure, measurement location, type of measurements and the choice of equipment should be in accord with the objective of the measurements.

2.4.2. Instrumentation

The most critical component of a sound pressure meter is the microphone, because it is difficult to produce microphones with the same precision as the other, electronic components of a pressure meter. In contrast, it is usually not difficult to produce the electronic components of a microphone with the desired sensitivity and frequency-response characteristics. Lower quality microphones will usually be less sensitive and so cannot measure very low sound pressure levels. They may also not be able to accurately measure very high sound pressure levels found closer to loud noise sources. Lower quality microphones will also have less well-defined frequency-response characteristics. Such lower quality microphones may be acceptable for survey type measurements of overall A-weighted levels, but would not be preferred for more precise measurements, including detailed frequency analysis of the sounds.

Sound pressure meters will usually include both A- and C-weighting frequency-response curves. The uses of these frequency weightings were discussed above. They may also include a linear weighting. Linear weightings are not defined in standards and may in practice be limited by the response of the particular microphone being used. Instead of, or in addition to, frequency-response weightings, more complex sound pressure meters can also include sets of standard bandpass filters, to permit frequency analysis of sounds. For acoustical measurements, octave and one-third octave bandwidth filters are widely used with centre frequencies defined in standards (ISO 1975b).

The instantaneous sound pressures are integrated with some time constant to provide sound pressure levels. As mentioned above most meters will include both *Fast*- and *Slow*-response times. *Fast*-response corresponds to a time constant of 0.125 s and is intended to approximate the time constant of the human hearing system. *Slow*-response corresponds to a time constant of 1 s and is an old concept intended to make it easier to obtain an approximate average value of fluctuating levels from simple meter readings.

Standards (IEC 1979) classify sound pressure meters as type 1 or type 2. Type 2 meters are adequate for broad band A-weighted level measurements, where extreme precision is not required and where very low sound pressure levels are not to be measured. Type 1 meters are usually much more expensive and should be used where more precise results are needed, or in cases where frequency analysis is required.

Many modern sound pressure meters can integrate sound pressure levels over some specified time period, or may include very sophisticated digital processing capabilities. Integrating meters make it possible to directly obtain accurate measures of LAeq,T values over a user-specified time interval, T. By including small computers in some sound pressure meters, quite complex calculations can be performed on the measured levels and many such results can be stored for later read out. For example, some meters can determine the statistical distribution of sound pressure levels over some period, in addition to the simple LAeq,T value. Recently, hand-held meters that perform loudness calculations in real time have become available. Continuing rapid developments in instrumentation capabilities are to be expected.

2.4.3. Measurement locations

Where local regulations do not specify otherwise, measurements of environmental noise are usually best made close to the point of reception of the noise. For example, if there is concern about residents exposed to road traffic noise it is better to measure close to the location of the residents, rather than close to the road. If environmental noises are measured close to the source, one must then estimate the effect of sound propagation to the point of reception. Sound propagation can be quite complicated and estimates of sound pressure levels at some distance from the source will inevitably introduce further errors into the measured sound pressure levels. These errors can be avoided by measuring at locations close to the point of reception.

Measurement locations should normally be selected so that there is a clear view of the sound source and so that the propagation of the sound to the microphone is not shielded or blocked by structures that would reduce the incident sound pressure levels. For example, measurements of aircraft noise should be made on the side of the building directly exposed to the noise. The position of the measuring microphone relative to building façades or other sound-reflective surfaces is also important and will significantly influence measured sound pressure levels (ISO 1978). If the measuring microphone is located more than several meters from reflecting surfaces, it will provide an unbiased indication of the incident sound pressure level. At the other extreme, when a measuring microphone is mounted on a sound-reflecting surface, such as a building façade, sound pressure levels will be increased by 6 dB, because the direct and reflected sound will coincide. Some standards recommend a position 2 m from the façade and an associated 3 dB correction (ISO 1978; ASTM 1992). The effect of façade reflections must be accounted for to represent the true level of the incident sound. Thus, while locating the measuring microphone close to the point of reception is desirable, it leads to some other issues that must be considered to accurately interpret measurement results. Where exposures are measured indoors, it is necessary to measure at several positions to characterize the average sound pressure level in a room. In other situations, it may be necessary to measure at the position of the exposed person.

2.4.4. Sampling

Many environmental noises vary over time, such as for different times of day or from season to season. For example, road traffic noise may be considerably louder during some hours of the day but much quieter at night. Aircraft noise may vary with the season due to different numbers of aircraft operations. Although permanent noise monitoring systems are becoming common around large airports, it is usually not possible to measure sound pressure levels continuously over a long enough period of time to completely define the environmental noise exposure. In practice, measurements usually only sample some part of the total exposure. Such sampling will introduce uncertainties in the estimates of the total noise exposure.

Traffic noise studies have identified various sampling schemes that can introduce errors of 2-3 dB in estimates of daytime LAeq,T values and even larger errors in night-time sound pressure levels (Vaskor et al. 1979). These errors relate to the statistical distributions of sound pressure levels over time (Bradley et al. 1979). Thus, the sampling errors associated with road traffic noise may be quite different from those associated with other noise, because of the quite different variations of sound pressure levels over time. It is also difficult to give general estimates of sampling errors due to seasonal variations. When making environmental noise measurements it is important that the measurement sample is representative of all of the variations in the noise in question, including variations of the source and variations in sound propagation, such as due to varying atmospheric conditions.

2.4.5. Calibration and quality assurance

Sound pressure meters can be calibrated using small calibrated sound sources. These devices are placed on the measurement microphone and produce a known sound pressure level with a specified accuracy. Such calibrations should be made at least daily, and more often if there is some possibility that handling of the sound pressure meter may have modified its sensitivity. It is also important to have a complete quality assurance plan. This should require annual calibration of all noise measuring equipment to traceable standards and should clearly specify correct measurement and operating procedures (ISO 1994).

2.5. Source Characteristics and Sound Propagation

To make a correct assessment of noise it is important to have some appreciation of the characteristics of environmental noise sources and of how sound propagates from them. One should consider the directionality of noise sources, the variability with time and the frequency content. If these are in some way unusual, the noise may be more disturbing than expected. The most common types of environmental noise sources are directional and include: road-traffic noise, aircraft noise, train noise, industrial noise and outdoor entertainment facilities (*cf.* section 2.2). All of these types of environmental noise are produced by multiple sources, which in many cases are moving. Thus, the characteristics of individual sources, as well as the characteristics of the combined sources, must be considered.

For example, we can consider the radiation of sound from individual vehicles, as well as from a line of vehicles on a particular road. Sound from an ideal point source (i.e. non-directional source) will spread out spherically and sound pressure levels would decrease 6 dB for each doubling of distance from the source. However, for a line of such sources, or for an integration over the complete pass-by of an individual moving source, the combined effect leads to sound that spreads cylindrically and to sound pressure levels that decrease at 3 dB per doubling of distance. Thus, there are distinct differences between the propagation of sound from an ideal point source and from moving sources. In practice one cannot adequately assess the noise from a fixed source with measurements at a single location; it is essential to measure in a number of directions from the source. If the single source is moving, it is necessary to measure over a complete pass-by, to account for sound variation with direction and time.

In most real situations this simple behaviour is considerably modified by reflections from the ground and from other nearby surfaces. One expects that when sound propagates over loose ground, such as grass, that some sound energy will be absorbed and sound pressure levels will actually decrease more rapidly with distance from the source. Although this is approximately true, the propagation of sound between sources and receivers close to the ground is much more complicated than this. The combination of direct and ground-reflected sound can combine in a complex manner which can lead to strong cancellations at some frequencies and not at others (Embleton & Piercy 1976). Even at quite short source-to-receiver distances, these complex interference effects can significantly modify the propagating sound. At larger distances (approximately 100 m or more), the propagation of sound will also be significantly affected by various atmospheric conditions. Temperature and wind gradients as well as atmospheric turbulence can have large effects on more distant sound pressure levels (Daigle et al. 1986). Temperature and wind gradients can cause propagating sound to curve either upwards or downwards, creating either areas of increased or decreased sound pressure levels at points quite distant from the source. Atmospheric turbulence can randomize sound so that the interference effects resulting from combinations of sound paths are reduced. Higher frequency sound is absorbed by air depending on the exact temperature and relative humidity of the air (Crocker &

Price 1975; Ford 1987). Because there are many complex effects, it is not usually possible to accurately predict sound pressure levels at large distances from a source.

Using barriers or screens to block the direct path from the source to the receiver can reduce the propagation of sound. The attenuating effects of the screen are limited by sound energy that diffracts or bends around the screen. Screens are more effective at higher frequencies and when placed either close to the sound source or the receiver; they are less effective when placed far from the receiver. Although higher screens are better, in practice it is difficult to achieve more than about a 10 dB reduction. There should be no gaps in the screen and it must have an adequate mass per unit area. A long building can be an effective screen, but gaps between buildings will reduce the sound attenuation.

In some cases, it may be desirable to estimate environmental sound pressure levels using mathematical models implemented as computer programmes (House 1987). Such computer programmes must first model the characteristics of the source and then estimate the propagation of the sound from the source to some receiver point. Although such prediction schemes have several advantages, there will be some uncertainty as to the accuracy of the predicted sound pressure levels. Such models are particularly useful for road traffic noise and aircraft noise, because it is possible to create data bases of information describing particular sources. For more varied types of noise, such as industrial noise, it would be necessary to first characterize the noise sources. The models then sum up the effects of multiple sources and calculate how the sound will propagate to receiver points. Techniques for estimating sound propagation are improving and the accuracy of these models is also expected to improve. These models can be particularly useful for estimating the combined effect of a large number of sources over an extended period of time. For example, aircraft noise prediction models are typically used to predict average yearly noise exposures, based on the combination of aircraft events over a complete year. Such models can be applied to predict sound pressure level contours around airports for these average yearly conditions. This is of course much less expensive than measuring at many locations over a complete one year-period. However, such models can be quite complex, and require skilled users and accurate data bases. Because environmental noise prediction models are still developing, it is advisable to confirm predictions with measurements.

2.6. Sound transmission Into and Within Buildings

Sources of environmental noise are usually located outdoors; for example, road traffic, aircraft or trains. However, people exposed to these noises are often indoors, inside their home or some other building. It is, therefore, important to understand how environmental noises are transmitted into buildings. Most of the same fundamentals discussed earlier apply to airborne sound propagation between homes in multifamily dwellings, via common walls and floors. However, within buildings we can also consider impact sound sources, such as footsteps, as well as airborne sounds.

The amount of incident sound that is transmitted through a building façade is measured in terms of the sound reduction index. The sound reduction index, or transmission loss, is defined as 10 times the logarithm of the ratio of incident-to-transmitted sound power, and it describes in decibels how much the incident sound is reduced on passing through a particular panel. This index of constructions usually increases with the frequency of the incident sound and with the mass of the construction (Kremer 1950). Thus, heavier or more massive constructions tend to have higher sound reductions. When it is not possible to achieve the desired transmission loss by increasing the mass of a panel, increased sound reduction can be achieved by a double panel construction. The two layers should be isolated with respect to vibrations and there should be sound absorbing material in the cavity. Such double panel constructions can provide much greater sound reduction than a single panel. Because sound reduction is also greater at higher frequencies most problems occur at lower frequencies, where most environmental noise sources produce relatively high sound pressure levels.

The sound reduction of buildings can be measured in standard laboratory tests, where the test panel is constructed in an opening between two reverberant test chambers (ISO 1995; ASTM 1997). In these tests sound fields are quite diffuse in both test chambers and the sound reduction index is calculated as the difference between the average sound pressure levels in the two rooms, plus a correction involving the area of the test panel and the total sound absorption in the receiving room. The sound reduction of a complete building façade can also be measured in the field using either natural environmental noises or test signals from loudspeakers (ISO 1978; ASTM 1992). In either case the noise, as transmitted through the façade, must be greater in level than other sounds in the receiving room. For this outdoor-to-indoor sound propagation case, the measured sound reduction index will also depend on the angle of incidence of the outdoor sound, as well as the position of the outdoor measuring microphone relative to the building façade. Corrections of up to 6 dB must be made to the sound pressure level measured outdoors, to account for the effect of reflections from the façade (see also section 2.4.3).

The sound reduction of most real building façades is determined by a combination of several different elements. For example, a wall might include windows, doors or some other type of element. If the sound reduction index values of each element are known, the values for the combined construction can be calculated from the area-weighted sums of the sound energy transmitted through each separate element. Although parts of the building façade, such as massive wall constructions, can be very effective barriers to sound, the sound reduction index of the complete façade is often greatly reduced by less effective elements such as windows, doors or ventilation openings. Completely open windows as such would have a sound reduction index of 0 dB. If window openings makes up 10% of the area of a wall, the sound reduction index of the combined wall and open window could not exceed 10 dB. Thus it is not enough to specify effective sound reducing façade constructions, without also solving the problem of adequate ventilation that does not compromise the sound transmission reduction by the building façade

Sound reduction index values are measured at different frequencies and from these, single number ratings are determined. Most common are the ISO weighted sound reduction index (ISO 1996) and the equivalent ASTM sound transmission class (ASTM 1994a). However, in their original form these single number ratings are only appropriate for typical indoor noises that usually do not have strong low frequency components. Thus, they are usually not appropriate single number ratings of the ability of a building façade to block typical environmental noises. More recent additions to the ISO procedure have included source spectrum corrections intended to correct approximately for other types of sources (ISO 1996). Alternatively, the ASTM-Outdoor-Indoor Transmission Class rating calculates the A-weighted level reduction to a standard environmental noise source spectrum (ASTM 1994b). Within buildings the impact sound insulation index can be measured with a standard impact source and determined according to ISO and ASTM standards (ISO 1998; ASTM 1994c 1996)

2.7. More Specialized Noise Measures

2.7.1. Loudness and perceived noise levels

There are procedures to accurately rate the loudness of complex sounds (Zwicker 1960; Stevens 1972; ISO 1975a) These usually start from a 1/3 octave spectrum of the noise. The combination of the loudness contributions of each 1/3 octave band with estimates of mutual masking effects, leads to a single overall loudness rating in sones. A similar system for rating the noisiness of sounds has also been developed (Kryter 1994). Again a 1/3 octave spectrum of the noise is required and the 1/3 octave noise levels are compared with a set of equal-noisiness contours. The individual 1/3 octave band noisiness estimates are combined to give an overall perceived noise level (PNL) that is intended to accurately estimate subjective evaluations of the same sound. The PNL metric was initially developed to rate jet aircraft noise.

PNL values will vary with time, for example when an aircraft flies by a measuring point. The effective perceived noise level measure (EPNL) is derived from PNL values and is intended to provide a complete rating of an aircraft fly-over. EPNL values add both a duration correction and a tone correction to PNL values. The duration correction ensures that longer duration events are rated as more disturbing. Similarly, noise spectra that seem to have prominent tonal components are rated as more disturbing by the tone-correction procedure. There is some evidence that these tone corrections are not always successful in improving predictions of adverse responses to noise events (Scharf & Hellman 1980). EPNL values are used in the certification testing of new aircraft. These more precise measures ensure that the noise from new aircraft is rated as accurately as possible.

2.7.2. Aviation noise measures

There are many measures for evaluating the long-term average sound pressure levels from aircraft near airports (Ford 1987, House 1987) They include different frequency weightings, different summations of levels and numbers of events, as well as different time-of-day weightings. Most measures are based on either A-weighted or PNL-weighted sound pressure levels. Because of the many other large uncertainties in predicting community response to aircraft noise, there seems little justification for using the more complex PNL-weighted sound pressure levels and there is a trend to change to A-weighted measures.

Most aviation noise measures are based on an equal energy approach and hence they sum up the total energy of a number of aircraft fly-overs. However, some older measures were based on different combinations of the level of each event and the number of events. These types of measures are gradually being replaced by measures based on the equal energy hypothesis such as LAeq,T values There is also a range of time-of-day weightings incorporated into current aircraft noise measures. Night-time weightings of 6–12 dB are currently in use. Some countries also include an intermediate evening weighting.

The day-night sound pressure level L_{dn} (von Gierke 1975; Ford 1987) is an LAeq,T based measure with a 10 dB night-time weighting. It is based on A-weighted sound pressure levels and the equal energy principle. The noise exposure forecast (NEF) (Bishop & Horonjeff 1967) is based on the EPNL values of individual aircraft events and includes a 12 dB night-time weighting. It sums multiple events on an equal energy basis. However, the Australian variation of the NEF measure has a 6 dB evening weighting and a 6 dB night-time weighting (Bullen & Hede 1983). The German airport noise equivalent level (LEQ(FLG)) is based on A-weighted levels, but does not follow the equal energy principle

The weighted equivalent continuous perceived noise level (WECPNL) measure (Ford 1987) proposed by ICAO is based on the equal energy principle and maximum PNL values of aircraft fly-overs. However, in Japan an approximation to this measure is used and is based on maximum A-weighted levels. The noise and number index (NNI), formerly used in the United Kingdom, was derived from maximum PNL values but was not based on the equal energy principle. An approximation to the original version of the NNI has been used in Switzerland and is based on maximum A-weighted levels of aircraft fly-overs, but its use will soon be discontinued. Changes in these measures are slow because their use is often specified in national legislation. However, several countries have changed to measures that are based on the equal energy principle and A-weighted sound pressure levels.

2.7.3. Impulsive noise measures

Impulsive sounds, such as gun shots, hammer blows, explosions of fireworks or other blasts, are sounds that significantly exceed the background sound pressure level for a very short duration. Typically each impulse lasts less than one second. Measurements with the meter set to 'Fast' response (section 2.1.1) do not accurately represent impulsive sounds. Therefore the meter response time must be shorter to measure such impulse type sounds. C-weighted levels have been found useful for ratings of gun shots (ISO 1987). Currently no mathematical description exists which unequivocally defines impulsive sounds, nor is there a universally accepted procedure for rating the additional annoyance of impulsive sounds (HCN 1997). Future versions of ISO Standard 1996 (present standard in ISO 1987b) are planned to improve this situation.

2.7.4. Measures of speech intelligibility

The intelligibility of speech depends primarily on the speech-to-noise ratio. If the level of the speech sounds are 15 dB or more above the level of the ambient noise, the speech intelligibility at 1 m distance will be close to 100% (Houtgast 1981; Bradley 1986b). This can be most simply rated in terms of the speech-to-noise ratio of the A-weighted speech and noise levels. Alternatively, the speech intelligibility index (formerly the articulation index) can be used if octave or 1/3 octave band spectra of the speech and noise are available (ANSI 1997).

When indoors, speech intelligibility also depends on the acoustical properties of the space. The acoustical properties of spaces have for many years been rated in terms of reverberation times. The reverberation time is approximately the time it takes for a sound in a room to decrease to inaudibility after the source has been stopped. Optimum reverberation times for speech have been specified as a function of the size of the room. In large rooms, such as lecture halls and theaters, a reverberation time for speech of about 1 s is recommended. In smaller rooms such as classrooms, the recommended value for speech is about 0.6 s (Bradley 1986b,c). More modern measures of room acoustics have been found to be better correlates of speech intelligibility, and some combine an assessment of both the speech/noise ratio and room acoustics (Bradley 1986a,c). The most widely known is the speech transmission index (STI) (Houtgast & Steeneken 1983), or the abbreviated version of this measure referred to as RASTI (Houtgast & Steeneken 1985; IEC 1988). In smaller rooms, such as school classrooms, the conventional approach of requiring adequately low ambient noise levels, as well as some optimum reverberation time, is probably adequate to ensure good speech intelligibility (Bradley 1986b). In larger rooms and other more specialized situations, use of the more modern measures may be helpful.

2.7.5. *Indoor noise ratings*

The simplest procedure for rating levels of indoor noise is to measure them in terms of integrated A-weighted sound pressure levels, as measured by LAeq,T. As discussed earlier, this approach has been criticized as not being the most accurate rating of the negative effects of various types of noises, and is thought to be particularly inadequate when there are strong low-frequency components. Several more complex rating schemes are available based on octave band measurements of indoor noises. In Europe the noise rating system (Burns 1968), and in North America the noise criterion (Beranek 1971), both include sets of equal-disturbance type contours. Measured octave band sound pressure levels are compared with these contours and an overall noise rating is determined. More recently, two new schemes have been proposed: the balanced noise criterion procedure (Beranek 1989) and the room criterion system (Blazier 1998). These schemes are based on a wider range of octave bands extending from 16–8 000 Hz. They provide both a numerical and a letter rating of the noise. The numerical part indicates the level of the central frequencies important for speech communication and the letter indicates whether the quality of the sound is predominantly low-, medium- or high-frequency in nature. Extensive comparisons of these room noise rating procedures have yet to be performed. Because the newer measures include a wider range of frequencies, they can better assess a wider range of noise problems.

2.8. Summary

Where there are no clear reasons for using other measures, it is recommended that LAeq,T be used to evaluate more-or-less continuous environmental noises. LAeq,T should also be used to assess ongoing noises that may be composed of individual events with randomly varying sound pressure levels. Where the noise is principally composed of a small number of discrete events the additional use of LAmax or SEL is recommended. As pointed out in this chapter, there are definite limitations to these simple measures, but there are also many practical advantages, including economy and the benefits of a standardized approach.

The sound pressure level measurements should include all variations over time to provide results that best represent the noise in question. This would include variations in both the source and in propagation of the noise from the source to the receiver. Measurements should normally be made close to typical points of reception. The accuracy of the measurements and the details of the measurement procedure must be adapted to the type of noise and to other details of the noise exposure. Assessment of speech intelligibility, aviation noise or impulse noise may require the use of more specialized methods. Where the exposed people are indoors and noise measurements are made outdoors, the sound attenuating properties of the building façade must also be measured or estimated.

3. Adverse Health Effects Of Noise

3.1. Introduction

The perception of sounds in day-to-day life is of major importance for human well-being. Communication through speech, sounds from playing children, music, natural sounds in parklands, parks and gardens are all examples of sounds essential for satisfaction in every day life. Conversely, this document is related to the adverse effects of sound (noise). According to the International Programme on Chemical Safety (WHO 1994), an adverse effect of noise is defined as a change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences. This definition includes any temporary or long-term lowering of the physical, psychological or social functioning of humans or human organs. The health significance of noise pollution is given in this chapter under separate headings, according to the specific effects: noise-induced hearing impairment; interference with speech communication; disturbance of rest and sleep; psychophysiological, mental-health and performance effects; effects on residential behaviour and annoyance; as well as interference with intended activities. This chapter also considers vulnerable groups and the combined effects of sounds from different sources. Conclusions based on the details given in this chapter are given in Chapter 4 as they relate to guideline values.

3.2. Noise-Induced Hearing Impairment

Hearing impairment is typically defined as an increase in the threshold of hearing. It is assessed by threshold audiometry. Hearing handicap is the disadvantage imposed by hearing impairment sufficient to affect one's personal efficiency in the activities of daily living. It is usually expressed in terms of understanding conventional speech in common levels of background noise (ISO 1990). Worldwide, noise-induced hearing impairment is the most prevalent irreversible occupational hazard. In the developing countries, not only occupational noise, but also environmental noise is an increasing risk factor for hearing impairment. In 1995, at the World Health Assembly, it was estimated that there are 120 million persons with disabling hearing difficulties worldwide (Smith 1998). It has been shown that men and women are equally at risk of noise-induced hearing impairment (ISO 1990; Berglund & Lindvall 1995).

Apart from noise-induced hearing impairment, hearing damage in populations is also caused by certain diseases, some industrial chemicals; ototoxic drugs; blows to the head; accidents; and hereditary origins. Deterioration of hearing capability is also associated with the aging process *per se* (presbyacusis). Present knowledge of the physiological effects of noise on the auditory system is based primarily on laboratory studies on animals. After noise exposure, the first morphological changes are usually found in the inner and outer hair cells of the cochlea, where the stereocilia become fused and bent. After more prolonged exposure, the outer and inner hair cells related to transmission of high-frequency sounds are missing. See Berglund & Lindvall (1995) for further discussion.

The ISO Standard 1999 (ISO 1990) gives a method for calculating noise-induced hearing impairment in populations exposed to all types of noise (continuous, intermittent, impulse) during working hours. Noise exposure is characterized by LAeq over 8 hours (LAeq,8h). In the Standard, the relationships between LAeq,8h and noise-induced hearing impairment are given for frequencies of 500–6 000 Hz, and for exposure times of up to 40 years. These relations show that noise-induced hearing impairment occurs predominantly in the high-frequency range of 3 000–6 000 Hz, the effect being largest at 4 000 Hz. With increasing LAeq,8h and increasing exposure time, noise-induced hearing impairment also occurs at 2 000 Hz. But at LAeq,8h levels of 75 dBA and lower, even prolonged occupational noise exposure will not result in noise-induced hearing impairment (ISO 1990). This value is equal to that specified in 1980 by the World Health Organization (WHO 1980a).

The ISO Standard 1999 (ISO 1990) specifies hearing impairment in statistical terms (median values, and percentile fractions between 0.05 and 0.95). The extent of noise-induced hearing impairment in populations exposed to occupational noise depends on the value of LAeq,8h and the number of years of noise exposure. However, for high LAeq,8h values, individual susceptibility seems to have a considerable effect on the rate of progression of hearing impairment. For daily exposures of 8–16 h, noise-induced hearing impairment can be reasonably well estimated from LAeq,8h extrapolated to the longer exposure times (Axelsson et al. 1986). In this adaptation of LAeq,8h for daily exposures other than 8 hours, the equal energy principle is assumed to be applicable. For example, the hearing impairment due to a 16 h daily exposure is equivalent to that at LAeq,8h plus 3 dB (LAeq,16h = LAeq,8h + $10*\log_{10}(16/8)$ = LAeq,8h + 3 dB. For a 24 h exposure, LAeq,24h = LAeq,8h + $10*\log_{10}(24/8)$ = LAeq,8h + 5 dB).

Since the calculation method specified in the ISO Standard 1999 (ISO 1990) is the only universally adopted method for estimating occupational noise-induced hearing impairment, attempts have been made to assess whether the method is also applicable to hearing impairment due to environmental noise, including leisure-time noise. There is ample evidence that shooting noise, with LAeq,24h values of up to 80 dB, induces the same hearing impairment as an equivalent occupational noise exposure (Smoorenburg 1998). Moreover, noise-induced hearing impairment studies from motorbikes are also in agreement with results from ISO Standard 1999 (ISO 1990). Hearing impairment in young adults and children 12 years and older has been assessed by LAeq on a 24 h time basis, for a variety of environmental and leisure-time exposure patterns (e.g. Passchier-Vermeer 1993; HCN 1994). These include pop music in discotheques and concerts (Babisch & Ising 1989; ISO 1990); pop music through headphones (Ising et al. 1994; Struwe et al. 1996; Passchier-Vermeer et al. 1998); music played by brass bands and symphony orchestras (van Hees 1992). The results are in agreement with values predicted by the ISO Standard 1999 method on the basis of adjusted time.

In the publications cited above, exposure to noise with known characteristics, such as duration and level, was related to hearing impairment. In addition to these publications, there is also an extensive literature showing hearing impairment in populations exposed to specific types of non-occupational noise, although these exposures are not well characterized. These noises originate from shooting, motorcycling, snowmobile driving, playing in arcades, listening to music at concerts and through headphones, using noisy toys, and fireworks (e.g. Brookhouser et al. 1992; see also Berglund & Lindvall 1995). Although the characteristics of these exposures are to a certain extent unknown, the details in the publications suggest that LAeq,24h values of these exposures exceed 70 dB.

In contrast, epidemiological studies failed to show hearing damage in populations exposed to an LAeq,24h of less than 70 dB (Lindemann et al. 1987). The data imply that even a lifetime exposure to environmental and leisure-time noise with an LAeq,24h <70 dBA would not cause hearing impairment in the large majority of people (over 95%). Overall, the results of many studies strongly suggest that the method from ISO Standard 1999 can also be used to estimate hearing impairment due to environmental and leisure-time noise, in addition to estimating the effects of occupational noise exposure.

Although the evidence suggests that the calculation method from ISO Standard 1999 (ISO 1990) should also be accepted for environmental and leisure time noise exposures, large-scale epidemiological studies of the general population do not exist to support this proposition. Taking into account the limitations of the studies, care should be taken with respect to the following aspects:

a. Data from animal experiments indicate that children may be more vulnerable in acquiring noise-induced hearing impairment than adults.

b. At very high instantaneous sound pressure levels, mechanical damage to the ear may occur (Hanner & Axelsson 1988). Occupational limits are set at peak sound pressure levels of 140 dB (EU 1986a). For adults exposed to environmental and leisure-time noise, this same limit is assumed to be valid. In the case of children, however, taking into account their habits while playing with noisy toys, peak sound pressure levels should never exceed 120 dB.

c. For shooting noise with LAeq,24h over 80 dB, studies on temporary threshold shift suggest the possibility of an increased risk for noise-induced hearing impairment (Smoorenburg 1998).

d. Risk for noise-induced hearing impairment may increase when the noise exposure is combined with exposure to vibrations, the use of ototoxic drugs, or some chemicals (Fechter 1999). In these circumstances, long-term exposure to LAeq,24h of 70 dBA may induce small hearing impairments.

e. It is uncertain whether the relationships between hearing impairment and noise exposure given in ISO Standard 1999 (ISO 1990) are applicable for environmental sounds of short rise time. For example, in the case of military low-altitude flying areas (75–300 m above ground) LAmax values of 110–130 dB occur within seconds after the onset of the sound.

Usually noise-induced hearing impairment is accompanied by an abnormal loudness perception which is known as loudness recruitment (*cf.* Berglund & Lindvall 1995). With a considerable loss of auditory sensitivity, some sounds may be perceived as distorted (paracusis). Another sensory effect that results from noise exposure is tinnitus (ringing in the ears). Commonly, tinnitus is referred to as sounds that are emitted by the inner ear itself (physiological tinnitus).

Tinnitus is a common and often disturbing accompaniment of occupational hearing impairment (Vernon and Moller 1995) and has become a risk for teenagers attending pop concerts and discotheques (Hetu & Fortin 1995; Passchier-Vermeer et al. 1998; Axelsson & Prasher 1999). Noise-induced tinnitus may be temporary, lasting up to 24 hours after exposure, or may have a more permanent character, such as after prolonged occupational noise exposure. Sometimes tinnitus is due to the sound produced by the blood flow through structures in the ear.

The main social consequence of hearing impairment is an inability to understand speech in daily living conditions, which is considered a severe social handicap. Even small values of hearing impairment (10 dB averaged over 2 000 and 4 000 Hz, and over both ears) may have an effect on the understanding of speech. When the hearing impairment exceeds 30 dB (again averaged over 2 000 and 4 000 Hz and both ears) a social hearing handicap is noticeable (*cf.* Katz 1994; Berglund & Lindvall 1995).

In the past, hearing protection has mainly emphasized occupational noise exposures at high values of LAeq,8h, or situations with high impulsive sounds. The near-universal adoption of an LAeq,8h value of 85 dB (or lower) as the limit for unprotected occupational noise exposure, together with requirements for personal hearing protection, has made cases of severe unprotected exposures more rare. This is particularly true for developed countries. However, monitoring of compliance and enforcement action for sound pressure levels just over the limits may be weak, especially in non-industrial environments in developed countries (Franks 1998), as well as in occupational and urban environments in developing countries (Smith 1998). Nevertheless, regulations for occupational noise exposure exist almost worldwide and exposures to occupational noise are to a certain extent under control.

On the other hand, environmental noise exposures due to a number of noisy activities, especially those during leisure-time activities of children and young adults, have scarcely been regulated. Given both the increasing number of noisy activities and the increasing exposure duration, such as loud music in cars and the use of Walkmen and Discmen, regulatory activities in this field are to be encouraged. Dose-response data are lacking for the general population. However, judging from the limited data for study groups (teenagers, young adults and women), and the assumption that time of exposure can be equated with sound energy, the risk for hearing impairment would be negligible for LAeq,24h values of 70 dBA over a lifetime. To avoid hearing impairment, impulse noise exposures should never exceed 140 dB peak sound pressure in adults, and 120 dB peak sound pressure in children.

3.3. Interference with Speech Communication

Noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioural changes. Problems with concentration, fatigue, uncertainty and lack of self-confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified (Lazarus 1998). Particularly vulnerable to these types of effects are the hearing impaired, the elderly, children in the process of language and reading acquisition, and individuals who are not familiar with the spoken language (e.g., Lazarus 1998). Thus, vulnerable persons constitute a substantial proportion of a country's population.

Most of the acoustical energy of speech is in the frequency range 100–6 000 Hz, with the most important cue-bearing energy being between 300–3 000 Hz. Speech interference is basically a masking process in which simultaneous, interfering noise renders speech incapable of being understood. The higher the level of the masking noise, and the more energy it contains at the most important speech frequencies, the greater will be the percentage of speech sounds that become indiscernible to the listener. Environmental noise may also mask many other acoustical signals important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music (e.g., Edworthy & Adams 1996). The masking effect of interfering noise in speech discrimination is more pronounced for hearing-impaired persons than for persons with normal hearing, particularly if the interfering noise is composed of speech or babble.

As the sound pressure level of an interfering noise increases, people automatically raise their voice to overcome the masking effect upon speech (increase of vocal effort). This imposes an additional strain on the speaker. For example, in quiet surroundings, the speech level at 1 m distance averages 45–50 dBA, but is 30 dBA higher when shouting. However, even if the interfering noise is moderately loud, most of the sentences during ordinary conversation can still be understood fairly well. Nevertheless, the interpretation required for compensating the masking effect of the interfering sounds, and for comprehending what was said, imposes an additional strain on the listener. One contributing factor could be that speech spoken loudly is more difficult to understand than speech spoken softly, when compared at a constant speech-to-noise ratio (*cf.* Berglund & Lindvall 1995).

Speech levels vary between individuals because of factors such as gender and vocal effort. Moreover, outdoor speech levels decrease by about 6 dB for a doubling in the distance between talker and listener. Speech intelligibility in everyday living conditions is influenced by speech level, speech pronunciation, talker-to-listener distance, sound pressure levels, and to some extent other characteristics of interfering noise, as well as room characteristics (e.g. reverberation). Individual capabilities of the listener, such as hearing acuity and the level of attention of the listener, are also important for the intelligibility of speech. Speech communication is affected also by the reverberation characteristics of the room. For example, reverberation times greater than 1 s produce loss in speech discrimination. Longer reverberation times, especially when combined with high background interfering noise, make speech perception more difficult. Even in a quiet environment, a reverberation time below 0.6 s is desirable for adequate speech intelligibility by vulnerable groups. For example, for older hearing-handicapped persons, the optimal reverberation time for speech intelligibility is 0.3–0.5 s (Plomp 1986).

For complete sentence intelligibility in listeners with normal hearing, the signal-to-noise ratio (i.e. the difference between the speech level and the sound pressure level of the interfering noise) should be 15–18 dBA (Lazarus 1990). This implies that in smaller rooms, noise levels above 35 dBA interferes with the intelligibility of speech (Bradley 1985). Earlier recommendations suggested that sound pressure levels as high as 45 dBA would be acceptable (US EPA 1974). With raised voice (increased vocal effort) sentences may be 100% intelligible for noise levels of up to 55 dBA, and sentences spoken with straining vocal effort can be 100% intelligible with noise levels of about 65 dBA. For speech to be intelligible when listening to complicated messages (at school, listening to foreign languages, telephone conversation), it is recommended that the signal-to-noise ratio should be at least 15 dBA. Thus, with a speech level of 50 dBA, (at 1 m distance this level corresponds to a casual speech level of both women and men), the sound pressure level of interfering noise should not exceed 35 dBA. For vulnerable groups even lower background levels are needed. If it is not possible to meet the strictest criteria for vulnerable persons in sensitive situations (e.g. in classrooms), one should strive for as low background levels as possible.

3.4. Sleep Disturbance

Uninterrupted sleep is known to be a prerequisite for good physiological and mental functioning of healthy persons (Hobson 1989); sleep disturbance, on the other hand, is considered to be a major environmental noise effect. It is estimated that 80-90% of the reported cases of sleep disturbance in noisy environments are for reasons other than noise originating outdoors. For example, sanitary needs; indoor noises from other occupants; worries, illness; and climate (e.g. Reyner & Horne 1995). Our understanding of the impact of noise exposure on sleep stems mainly from experimental research in controlled environments. Field studies conducted with people in their normal living situations are scarce. Most of the more recent field research on sleep disturbance has been conducted for aircraft noise (Fidell et al. 1994 1995a,b 1998; Horne et al. 1994 1995; Maschke et al. 1995 1996, Ollerhead et al. 1992; Passchier-Vermeer 1999). Other field studies have examined the effects of road traffic and railway noise (Griefahn et al. 1996 1998).

The primary sleep disturbance effects are: difficulty in falling asleep (increased sleep latency time), awakenings; and alterations of sleep stages or depth, especially a reduction in the proportion of REM-sleep (REM = rapid eye movement) (Hobson 1989). Other primary physiological effects can also be induced by noise during sleep, including increased blood pressure; increased heart rate; increased finger pulse amplitude, vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements (cf. Berglund & Lindvall 1995). For each of these physiological effects, both the noise threshold and the noise-response relationships may be different. Different noises may also have different information content and this also could affect physiological threshold and noise-response relationships (Edworthy 1998).

Exposure to night-time noise also induces secondary effects, or so-called after effects. These are effects that can be measured the day following the night-time exposure, while the individual is awake. The secondary effects include reduced perceived sleep quality; increased fatigue, depressed mood or well-being; and decreased performance (Öhrström 1993a; Passchier-Vermeer 1993; Carter 1996, Pearsons et al. 1995; Pearsons 1998).

Long-term effects on psychosocial well-being have also been related to noise exposure during the night (Öhrström 1991). Noise annoyance during the night-time increased the total noise annoyance expressed by people in the following 24 h. Various studies have also shown that people living in areas exposed to night-time noise have an increased use of sedatives or sleeping pills. Other frequently reported behavioural effects of night-time noise include closed bedroom windows and use of personal hearing protection. Sensitive groups include the elderly, shift workers, persons especially vulnerable to physical or mental disorders and other individuals with sleeping difficulties.

Questionnaire data indicate the importance of night-time noise on the perception of sleep quality. A recent Japanese investigation was conducted for 3 600 women (20-80 years old) living in eight roadside zones with different road traffic noise. The results showed that four measures of perceived sleep quality (difficulty in falling asleep; waking up during sleep, waking up too early; feelings of sleeplessness one or more days a week) correlated significantly with the average traffic volumes during night-time. An in-depth investigation of 19 insomnia cases and their matched controls (age,work) measured outdoor and indoor sound pressure levels during sleep (Kageyama et al. 1997). The study showed that road traffic noise in excess of 30 dB LAeq for nighttime induced sleep disturbance, consistent with the results of Öhrström (1993b).

Meta-analyses of field and laboratory studies have suggested that there is a relationship between the SEL for a single night-time noise event and the percentage of people awakened or who showed sleep stage changes (e.g. Ollerhead et al. 1992, Passchier-Vermeer 1993; Finegold et al. 1994, Pearsons et al. 1995). All of these studies assumed that the number of awakenings per night for each SEL value is proportional to the number of night-time noise events. However, the results have been criticized for methodological reasons. For example, there were small groups of sleepers, too few original studies; and indoor exposure was estimated from outdoor sound pressure levels (NRC-CNRC 1994, Beersma & Altena 1995; Vallet 1998). The most important result of the meta-analyses is that there is a clear difference in the dose-response curves for laboratory and field studies, and that noise has a lower effect under real-life conditions (Pearsons et al. 1995, Pearsons 1998).

However, this result has been questioned, because the studies were not controlled for such things as the sound insulation of the buildings, and the number of bedrooms with closed windows. Also, only two indicators of sleep disturbance were considered (awakening and sleep stage changes). The meta-analyses thus neglected other important sleep disturbance effects (Öhrström 1993b; Carter et al. 1994a; Carter et al. 1994b; Carter 1996; Kuwano et al. 1998). For example, for road traffic noise, perceived sleep quality is related both to the time needed to fall asleep and the total sleep time (Öhrström & Björkman 1988). Individuals who are more sensitive to noise (as assessed by different questionnaires) report worse sleep quality both in field studies and in laboratory studies.

A further criticism of the meta-analyses is that laboratory experiments have shown that habituation to night-time noise events occurs, and that noise-induced awakening decreases with increasing number of sound exposures per night. This is in contrast to the assumption used in the meta-analyses, that the percentage of awakenings is linearly proportional to the number of night-time noise events. Studies have also shown that the frequency of noise-induced awakenings decreases for at least the first eight consecutive nights. So far, habituation has been shown for awakenings, but not for heart rate and after effects such as perceived sleep quality, mood and performance (Öhrström and Björkman 1988).

Other studies suggest that it is the difference in sound pressure levels between a noise event and background, rather than the absolute sound pressure level of the noise event, that determines the reaction probability. The time interval between two noise events also has an important influence of the probability of obtaining a response (Griefahn 1977; *cf* Berglund & Lindvall 1995). Another possible factor is the person's age, with older persons having an increased probability of awakening. However, one field study showed that noise-induced awakenings are independent of age (Reyner & Horne 1995).

For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dB LAmax more than 10–15 times per night (Vallet & Vernet 1991), and most studies show an increase in the percentage of awakenings at SEL values of 55–60 dBA (Passchier-Vermeer 1993; Finegold et al. 1994; Pearsons et al. 1995). For intermittent events that approximate aircraft noise, with an effective duration of 10–30 s, SEL values of 55–60 dBA correspond to a LAmax value of 45 dB. Ten to 15 of these events during an eight-hour night-time implies an LAeq,8h of 20–25 dB. This is 5–10 dB below the LAeq,8h of 30 dB for continuous night-time noise exposure, and shows that the intermittent character of noise has to be taken into account when setting night-time limits for noise exposure. For example, this can be achieved by considering the number of noise events and the difference between the maximum sound pressure level and the background level of these events.

Special attention should also be given to the following considerations:

a. Noise sources in an environment with a low background noise level. For example, night-traffic in suburban residential areas.

b. Environments where a combination of noise and vibrations are produced. For example, railway noise, heavy duty vehicles.

c. Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA.

If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise. If the noise is not continuous, sleep disturbance correlates best with LAmax and effects have been observed at 45 dB or less. This is particularly true if the background level is low. Noise events exceeding 45 dBA should therefore be limited if possible. For sensitive people an even lower limit would be preferred. It should be noted that it should be possible to sleep with a bedroom window slightly open (a reduction from outside to inside of 15 dB). To prevent sleep disturbances, one should thus consider the equivalent sound pressure level and the number and level of sound events. Mitigation targeted to the first part of the night is believed to be effective for the ability to fall asleep.

3.5. Cardiovascular and Physiological Effects

Epidemiological and laboratory studies involving workers exposed to occupational noise, and general populations (including children) living in noisy areas around airports, industries and noisy streets, indicate that noise may have both temporary and permanent impacts on physiological functions in humans. It has been postulated that noise acts as an environmental stressor (for a review see Passchier-Vermeer 1993, Berglund & Lindvall 1995). Acute noise exposures activate the autonomic and hormonal systems, leading to temporary changes such as increased blood pressure, increased heart rate and vasoconstriction. After prolonged exposure, susceptible individuals in the general population may develop permanent effects, such as hypertension and ischaemic heart disease associated with exposures to high sound pressure levels (for a review see Passchier-Vermeer 1993; Berglund & Lindvall 1995). The magnitude and duration of the effects are determined in part by individual characteristics, lifestyle behaviours and environmental conditions. Sounds also evoke reflex responses, particularly when they are unfamiliar and have a sudden onset.

Laboratory experiments and field quasi-experiments show that if noise exposure is temporary, the physiological system usually returns - after the exposure terminates - to a normal (pre-exposure) state within a time in the range of the exposure duration. If the exposure is of sufficient intensity and unpredictability, cardiovascular and hormonal responses may appear, including increases in heart rate and peripheral vascular resistance; changes in blood pressure, blood viscosity and blood lipids; and shifts in electrolyte balance (Mg/Ca) and hormonal levels (epinephrine, norepinephrine, cortisol). The first four effects are of interest because of noise-related coronary heart disease (Ising & Günther 1997). Laboratory and clinical data suggest that noise may significantly elevate gastrointestinal motility in humans.

By far the greatest number of occupational and community noise studies have focused on the possibility that noise may be a risk factor for cardiovascular disease. Many studies in occupational settings have indicated that workers exposed to high levels of industrial noise for 5-30 years have increased blood pressure and statistically significant increases in risk for hypertension, compared to workers in control areas (Passchier-Vermeer 1993). In contrast, only a few studies on environmental noise have shown that populations living in noisy areas around airports and on noisy streets have an increased risk for hypertension. The overall evidence suggests a weak association between long-term environmental noise exposure and hypertension (HCN 1994; Berglund & Lindvall 1995; IEH 1997), and no dose-response relationships could be established.

Recently, an updated summary of available studies for ischaemic heart disease has been presented (Babisch 1998a, Babisch 1998b; Babisch et al. 1999; see also Thompson 1996). The studies reviewed include case-control and cross-sectional designs, as well as three longitudinal studies. However, it has not yet been possible to conduct the most advanced quantitative integrated analysis of the available studies. Relative risks and their confidence intervals could be estimated only for the classes of high noise levels (mostly >65 dBA during daytime) and low levels (mostly <55 dBA during daytime), rather than a range of exposure levels. For methodological reasons identified in the meta-analysis, a cautious interpretation of the results is warranted (Lercher et al. 1998).

Prospective studies that controlled for confounding factors suggest an increase in ischaemic heart disease when the noise levels exceed 65–70 dB for LAeq (6-22). (For road traffic noise, the difference between LAeq (6-22h) and LAeq,24h usually is of the order of 1.5 dB). When orientation of the bedroom, window opening habits and years of exposure are taken into account, the risk of heart disease is slightly higher (Babisch et al. 1998; Babisch et al. 1999). However, disposition, behavioural and environmental factors were not sufficiently accounted for in the analyses carried out to date. In epidemiological studies the lowest level at which traffic noise had an effect on ischaemic heart disease was 70 dB for LAeq,24h (HCN 1994).

The overall conclusion is that cardiovascular effects are associated with long-term exposure to LAeq,24h values in the range of 65–70 dB or more, for both air- and road-traffic noise. However, the associations are weak and the effect is somewhat stronger for ischaemic heart disease than for hypertension. Nevertheless, such small risks are potentially important because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Furthermore, only the average risk is considered and sensitive subgroups of the populations have not been sufficiently characterized. For example, a 10% increase in risk factors (a relative risk of 1.1) may imply an increase of up to 200 cases per 100 000 people at risk per year. Other observed psychophysiological effects, such as changes in stress hormones, magnesium levels, immunological indicators, and gastrointestinal disturbances are too inconsistent for conclusions to be drawn about the influence of noise pollution.

3.6. Mental Health Effects

Mental health is defined as the absence of identifiable psychiatric disorders according to current norms (Freeman 1984). Environmental noise is not believed to be a direct cause of mental illness, but it is assumed that it accelerates and intensifies the development of latent mental disorder. Studies on the adverse effects of environmental noise on mental health cover a variety of symptoms, including anxiety; emotional stress; nervous complaints; nausea; headaches; instability; argumentativeness; sexual impotency; changes in mood; increase in social conflicts, as well as general psychiatric disorders such as neurosis, psychosis and hysteria. Large-scale population studies have suggested associations between noise exposure and a variety of mental health indicators, such as single rating of well-being; standard psychological symptom profiles; the intake of psychotropic drugs; and consumption of tranquilizers and sleeping pills. Early studies showed a weak association between exposure to aircraft noise and psychiatric hospital admissions in the general population surrounding an airport (see also Berglund & Lindvall 1995). However, the studies have been criticized because of problems in selecting variables and in response bias (Halpern 1995).

Exposure to high levels of occupational noise has been associated with development of neurosis and irritability; and exposure to high levels of environmental noise with deteriorated mental health (Stansfeld 1992). However, the findings on environmental noise and mental health effects are inconclusive (HCN 1994; Berglund & Lindvall 1995; IEH 1997). The only longitudinal study in this field (Stansfeld et al. 1996) showed an association between the initial level of road traffic noise and minor psychiatric disorders, although the association for increased anxiety was weak and non-linear. It turned out that psychiatric disorders are associated with noise sensitivity.

rather than with noise exposure, and the association was found to disappear after adjustment for baseline trait anxiety. These and other results show the importance of taking vulnerable groups into account, because they may not be able to cope sufficiently with unwanted environmental noise (e.g. Stansfeld 1992). This is particularly true of children, the elderly and people with preexisting illnesses, especially depression (IEH 1997). Despite the weaknesses of the various studies, the possibility that community noise has adverse effects on mental health is suggested by studies on the use of medical drugs, such as tranquilizers and sleeping pills, on psychiatric symptoms and on mental hospital admission rates.

3.7. The Effects of Noise on Performance

It has been documented in both laboratory subjects and in workers exposed to occupational noise, that noise adversely affects cognitive task performance. In children, too, environmental noise impairs a number of cognitive and motivational parameters (Cohen et al. 1980; Evans & Lepore 1993; Evans 1998; Hygge et al. 1998; Haines et al. 1998). However, there are no published studies on whether environmental noise at home also impairs cognitive performance in adults. Accidents may also be an indicator of performance deficits. The few field studies on the effects of noise on performance and safety showed that noise may produce some task impairment and increase the number of errors in work, but the effects depend on the type of noise and the task being performed (Smith 1990).

Laboratory and workplace studies showed that noise can act as a distracting stimulus. Also, impulsive noise events (e.g. sonic booms) may produce disruptive effects as a result of startle responses. In the short term, noise-induced arousal may produce better performance of simple tasks, but cognitive performance deteriorates substantially for more complex tasks (i.e. tasks that require sustained attention to details or to multiple cues, or tasks that demand a large capacity of working memory, such as complex analytical processes). Some of the effects are related to loss in auditory comprehension and language acquisition, but others are not (Evans & Maxwell 1997). Among the cognitive effects, reading, attention, problem solving and memory are most strongly affected by noise. The observed effects on motivation, as measured by persistence with a difficult cognitive task, may either be independent or secondary to the aforementioned cognitive impairments.

Two types of memory deficits have been identified under experimental noise exposure: incidental memory and memory for materials that the observer was not explicitly instructed to focus on during a learning phase. For example, when presenting semantic information to subjects in the presence of noise, recall of the information content was unaffected, but the subjects were significantly less able to recall, for example, in which corner of the slide a word had been located. There is also some evidence that the lack of "helping behavior" that was noted under experimental noise exposure may be related to inattention to incidental cues (Berglund & Lindvall 1995). Subjects appear to process information faster in working memory during noisy performance conditions, but at a cost of available memory capacity. For example, in a running memory task, in which subjects were required to recall in sequence letters that they had just heard, subjects recalled recent items better under noisy conditions, but made more errors farther back into the list.

Experimental noise exposure consistently produces negative after-effects on performance (Glass & Singer 1972). Following exposure to aircraft noise, schoolchildren in the vicinity of Los Angeles airport were found to be deficient in proofreading, and in persistence with challenging puzzles (Cohen et al. 1980). The uncontrollability of noise, rather than the intensity of the noise, appears to be the most critical variable. The only prospective study on noise-exposed schoolchildren, designed around the move of the Munich airport (Hygge et al. 1996; Evans et al. 1998), confirmed the results of laboratory and workplace studies in adults, as well the results of the Los Angeles airport study with children (Cohen et al. 1980). An important finding was that some of the adaptation strategies for dealing with aircraft noise, such as tuning out or ignoring the noise, and the effort necessary to maintain task performance, come at a price. There is heightened sympathetic arousal, as indicated by increased levels of stress hormone, and elevation of resting blood pressure (Evans et al. 1995; Evans et al. 1998). Notably, in the airport studies reported above, the adverse effects were larger in children with lower school achievement.

For aircraft noise, it has been shown that chronic exposure during early childhood appears to impair reading acquisition and reduces motivational capabilities. Of recent concern are concomitant psychophysiological changes (blood pressure and stress hormone levels). Evidence indicates that the longer the exposure, the greater the damage. It seems clear that daycare centers and schools should not be located near major sources of noise, such as highways, airports and industrial sites.

3.8. Effects of Noise on Residential Behaviour and Annoyance

Noise annoyance is a global phenomenon. A definition of annoyance is "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" (Lindvall & Radford 1973; Koelega 1987). However, apart from "annoyance", people may feel a variety of negative emotions when exposed to community noise, and may report anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion (Job 1993; Fields et al. 1997 1998). Thus, although the term annoyance does not cover all the negative reactions, it is used for convenience in this document.

Noise can produce a number of social and behavioural effects in residents, besides annoyance (for review see Berglund & Lindvall 1995). The social and behavioural effects are often complex, subtle and indirect. Many of the effects are assumed to be the result of interactions with a number of non-auditory variables. Social and behavioural effects include changes in overt everyday behaviour patterns (e.g. closing windows, not using balconies, turning TV and radio to louder levels, writing petitions, complaining to authorities), adverse changes in social behaviour (e.g. aggression, unfriendliness, disengagement, non-participation); adverse changes in social indicators (e.g. residential mobility, hospital admissions, drug consumption, accident rates); and changes in mood (e.g. less happy, more depressed).

Although changes in social behaviour, such as a reduction in helpfulness and increased aggressiveness, are associated with noise exposure, noise exposure alone is not believed to be sufficient to produce aggression. However, in combination with provocation or pre-existing anger or hostility, it may trigger aggression. It has also been suspected that people are less willing to help, both during exposure and for a period after exposure. Fairly consistent evidence shows that noise above 80 dBA is associated with reduced helping behaviour and increased aggressive behaviour. Particularly, there is concern that high-level continuous noise exposures may contribute to the susceptibility of schoolchildren to feelings of helplessness (Evans & Lepore 1993).

The effects of community noise can be evaluated by assessing the extent of annoyance (low, moderate, high) among exposed individuals; or by assessing the disturbance of specific activities, such as reading, watching television and communication. The relationship between annoyance and activity disturbances is not necessarily direct and there are examples of situations where the extent of annoyance is low, despite a high level of activity disturbance. For aircraft noise, the most important effects are interference with rest, recreation and watching television. This is in contrast to road traffic noise, where sleep disturbance is the predominant effect (Berglund & Lindvall 1995).

A number of studies have shown that equal levels of traffic and industrial noises result in different magnitudes of annoyance (Hall et al. 1981; Griffiths 1983; Miedema 1993; Bradley 1994a; Miedema & Vos 1998). This has led to criticism (e.g. Kryter 1994; Bradley 1994a) of averaged dose-response curves determined by meta-analysis, which assumed that all traffic noises are the same (Fidell et al. 1991; Fields 1994a; Finegold et al. 1994). Schultz (1978) and Miedema & Vos (1998) have synthesized curves of annoyance associated with three types of traffic noise (road, air, railway). In these curves, the percentage of people highly or moderately annoyed was related to the day and night continuous equivalent sound level, L_{dn}. For each of the three types of traffic noise, the percentage of highly annoyed persons in a population started to increase at an L_{dn} value of 42 dBA, and the percentage of moderately annoyed persons at an L_{dn} value of 37 dBA (Miedema & Vos 1998). Aircraft noise produced a stronger annoyance response than road traffic, for the same L_{dn} exposure, consistent with earlier analyses (Kryter 1994; Bradley 1994a). However, caution should be exercised when interpreting synthesized data from different studies, since five major parameters should be randomly distributed for the analyses to be valid: personal, demographic, and lifestyle factors, as well as the duration of noise exposure and the population experience with noise (Kryter 1994).

Annoyance in populations exposed to environmental noise varies not only with the acoustical characteristics of the noise (source, exposure), but also with many non-acoustical factors of social, psychological, or economic nature (Fields 1993). These factors include fear associated with the noise source, conviction that the noise could be reduced by third parties, individual noise sensitivity, the degree to which an individual feels able to control the noise (coping strategies), and whether the noise originates from an important economic activity. Demographic variables such as age, sex and socioeconomic status, are less strongly associated with annoyance. The correlation between noise exposure and general annoyance is much higher at the group level than at the individual level, as might be expected. Data from 42 surveys showed that at the group level about 70% of the variance in annoyance is explained by noise exposure characteristics, whereas at the individual level it is typically about 20% (Job 1988).

When the type and amount of noise exposure is kept constant in the meta-analyses, differences between communities, regions and countries still exist (Fields 1990; Bradley 1996). This is well demonstrated by a comparison of the dose-response curve determined for road-traffic noise

(Miedema & Vos 1998) and that obtained in a survey along the North-South transportation route through the Austrian Alps (Lercher 1998b). The differences may be explained in terms of the influence of topography and meteorological factors on acoustical measures, as well as the low background noise level on the mountain slopes.

Stronger reactions have been observed when noise is accompanied by vibrations and contains low frequency components (Paulsen & Kastka 1995; Öhrström 1997; for review see Berglund et al. 1996), or when the noise contains impulses, such as shooting noise (Buchta 1996; Vos 1996; Smoorenburg 1998). Stronger, but temporary, reactions also occur when noise exposure is increased over time, in comparison to situations with constant noise exposure (e.g. HCN 1997; Klæboe et al. 1998). Conversely, for road traffic noise, the introduction of noise protection barriers in residential areas resulted in smaller reductions in annoyance than expected for a stationary situation (Kastka et al. 1995).

To obtain an indicator for annoyance, other methods of combining parameters of noise exposure have been extensively tested, in addition to metrics such as LAeq,24h and L_{dn}. When used for a set of community noises, these indicators correlate well both among themselves and with LAeq,24h or L_{dn} values (e.g. HCN 1997). Although LAeq,24h and L_{dn} are in most cases acceptable approximations, there is a growing concern that all the component parameters of the noise should be individually assessed in noise exposure investigations, at least in the complex cases (Berglund & Lindvall 1995).

3.9. The Effects of Combined Noise Sources

Many acoustical environments consist of sounds from more than one source. For these environments, health effects are associated with the total noise exposure, rather than with the noise from a single source (WHO 1980b). When considering hearing impairment, for example, the total noise exposure can be expressed in terms of LAeq,24h for the combined sources. For other adverse health effects, however, such a simple model most likely will not apply. It is possible that some disturbances (e.g. speech interference, sleep disturbance) may more easily be attributed to specific noises. In cases where one noise source clearly dominates, the magnitude of an effect may be assessed by taking into account the dominant source only (HCN 1997). Furthermore, at a policy level, there may be little need to identify the adverse effect of each specific noise, unless the responsibility for these effects is to be shared among several polluters (*cf.* The Polluter Pays Principle in Chapter 5; UNCED 1992).

There is no consensus on a model for assessing the total annoyance due to a combination of environmental noise sources. This is partly due to a lack of research into the temporal patterns of combined noises. The current approach for assessing the effects of "mixed noise sources" is limited to data on "total annoyance" transformed to mathematical principles or rules of thumb (Ronnebaum et al. 1996; Vos 1992; Miedema 1996; Berglund & Nilsson 1997). Models to assess the total annoyance of combinations of environmental noises may not be applicable to those health effects for which the mechanisms of noise interaction are unknown, and for which different cumulative or synergistic effects cannot be ruled out. When noise is combined with different types of environmental agents, such as vibrations, ototoxic chemicals, or chemical odours, again there is insufficient knowledge to accurately assess the combined effects on health

(Berglund & Lindvall 1995; HCN 1994; Miedema 1996; Zeichart 1998; Passchier-Vermeer & Zeichart 1998). Therefore, caution should be exercised when trying to predict the adverse health effects of combined factors in residential populations.

The evidence on low-frequency noise is sufficiently strong to warrant immediate concern. Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works), and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise. Low-frequency noise may also produce vibrations and rattles as secondary effects. Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general (Berglund et al. 1996). Since A-weighting underestimates the sound pressure level of noise with low-frequency components, a better assessment of health effects would be to use C-weighting.

In residential populations heavy noise pollution will most certainly be associated with a combination of health effects. For example, cardiovascular disease, annoyance, speech interference at work and at home, and sleep disturbance. Therefore, it is important that the total adverse health load over 24 hours be considered and that the precautionary principle for sustainable development is applied in the management of health effects (see Chapter 5).

3.10. Vulnerable Groups

Protective standards are essentially derived from observations on the health effects of noise on "normal" or "average" populations. The participants of these investigations are selected from the general population and are usually adults. Sometimes, samples of participants are selected because of their easy availability. However, vulnerable groups of people are typically underrepresented. This group includes people with decreased personal abilities (old, ill, or depressed people); people with particular diseases or medical problems; people dealing with complex cognitive tasks, such as reading acquisition; people who are blind or who have hearing impairment; fetuses, babies and young children; and the elderly in general (Jansen 1987; AAP 1997). These people may be less able to cope with the impacts of noise exposure and be at greater risk for harmful effects.

Persons with impaired hearing are the most adversely affected with respect to speech intelligibility. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people typically demonstrate an impaired ability to understand difficult, spoken messages with low linguistic redundancy. Therefore, based on interference with speech perception, a majority of the population belongs to the vulnerable group.

Children have also been identified as vulnerable to noise exposure (see Agenda 21; UNCED 1992). The evidence on noise pollution and children's health is strong enough to warrant monitoring programmes at schools and preschools to protect children from the effects of noise. Follow up programmes to study the main health effects of noise on children, including effects on speech perception and reading acquisition, are also warranted in heavily noise polluted areas (Cohen et al. 1986; Evans et al. 1998).

The issue of vulnerable subgroups in the general population should thus be considered when developing regulations or recommendations for the management of community noise. This consideration should take into account the types of effects (communication, recreation, annoyance, etc.), specific environments (*in utero*, incubator, home, school, workplace, public institutions, etc.) and specific lifestyles (listening to loud music through headphones, or at discotheques and festivals; motor cycling, etc.).

4. Guideline Values

4.1. Introduction

The human ear and lower auditory system continuously receive stimuli from the world around us. However, this does not mean that all the acoustical inputs are necessarily disturbing or have harmful effects. This is because the auditory nerve provides activating impulses to the brain that enable us to regulate the vigilance and wakefulness necessary for optimal performance. On the other hand, there are scientific reports that a completely silent world can have harmful effects, because of sensory deprivation. Thus, both too little sound and too much sound can be harmful. For this reason, people should have the right to decide for themselves the quality of the acoustical environment they live in.

Exposure to noise from various sources is most commonly expressed as the average sound pressure level over a specific time period, such as 24 hours. This means that identical average sound levels for a given time period could be derived from either a large number of sound events with relatively low, almost inaudible levels, or from a few events with high sound levels. This technical concept does not fully agree with common experience on how environmental noise is experienced, or with the neurophysiological characteristics of the human receptor system.

Human perception of the environment through vision, hearing, touch, smell and taste is characterized by a good discrimination of stimulus intensity differences, and by a decaying response to a continuous stimulus (adaptation or habituation). Single sound events cannot be discriminated if the interval between events drops below a threshold value; if this occurs, the sound is interpreted as continuous. These characteristics are linked to survival, since new and different stimuli with low probability and high information value indicate warnings. Thus, when assessing the effects of environmental noise on people it is relevant to consider the importance of the background noise level, the number of events, and the noise exposure level independently.

Community noise studies have traditionally considered noise annoyance from single specific sources such as aircraft, road traffic or railways. In recent years, efforts have been made to compare the results from road traffic, aircraft and railway surveys. Data from a number of sources show that aircraft noise is more annoying than road traffic noise, which, in turn, is more annoying than railway noise. However, there is not a clear understanding of the mechanisms that create these differences. Some populations may also be at greater risk for the harmful effects of noise. Young children (especially during language acquisition), the blind, and perhaps fetuses are examples of such populations. There are no definite conclusions on this topic, but the reader should be alerted that guidelines in this report are developed for the population at large; guidelines for potentially more vulnerable groups are addressed only to a limited extent.

In the following, guideline values are summarized with regard to specific environments and effects. For each environment and situation, the guideline values take into consideration the identified health effects and are set, based on the lowest levels of noise that affect health (critical health effect). Guideline values typically correspond to the lowest effect level for general populations, such as those for indoor speech intelligibility. By contrast, guideline values for annoyance have been set at 50 or 55 dBA, representing daytime levels below which a majority of the adult population will be protected from becoming moderately or seriously annoyed, respectively.

In these *Guidelines for Community Noise* only guideline values are presented. These are essentially values for the onset of health effects from noise exposure. It would have been preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission standards). However, exposure-response relationships could not be established as the scientific literature is very limited. The best-studied exposure-response relationship is that between L_{dn} and annoyance (WHO 1995a; Berglund & Lindvall 1995; Miedema & Vos 1998). Even the most recent relationships between integrated noise levels and the percentage of highly or moderately annoyed people are still being scrutinized. The results of a forthcoming meta-analysis are expected to be published in the near future (Miedema, personal communication).

4.2. Specific Effects

4.2.1. Interference with communication

Noise tends to interfere with auditory communication, in which speech is a most important signal. However, it is also vital to be able to hear alarming and informative signals such as door bells, telephone signals, alarm clocks, fire alarms etc., as well as sounds and signals involved in occupational tasks. The effects of noise on speech discrimination have been studied extensively and deal with this problem in lexical terms (mostly words but also sentences). For communication distances beyond a few metres, speech interference starts at sound pressure levels below 50 dB for octave bands centered on the main speech frequencies at 500, 1 000 and 2 000 Hz. It is usually possible to express the relationship between noise levels and speech intelligibility in a single diagram, based on the following assumptions and empirical observations, and for speaker-to-listener distance of about 1 m:

a. Speech in relaxed conversation is 100% intelligible in background noise levels of about 35 dBA, and can be understood fairly well in background levels of 45 dBA.

b. Speech with more vocal effort can be understood when the background sound pressure level is about 65 dBA.

A majority of the population belongs to groups sensitive to interference with speech perception. Most sensitive are the elderly and persons with impaired hearing. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people demonstrate impaired ability to interpret difficult, spoken messages with low linguistic redundancy, when compared to people aged 20–30 years. It has also been shown that children, before language acquisition has been completed, have more adverse effects than young adults to high noise levels and long reverberation times.

For speech outdoors and for moderate distances, the sound level drops by approximately 6 dB for a doubling of the distance between speaker and listener. This relationship is also applicable to indoor conditions, but only up to a distance of about 2 m. Speech communication is affected also by the reverberation characteristics of the room, and reverberation times beyond 1 s can produce a loss in speech discrimination. A longer reverberation time combined with background noise makes speech perception still more difficult.

Speech signal perception is of paramount importance, for example, in classrooms or conference rooms. To ensure any speech communication, the signal-to-noise relationship should exceed zero dB. But when listening to complicated messages (at school, listening to foreign languages, telephone conversation) the signal-to-noise ratio should be at least 15 dB. With a voice level of 50 dBA (at 1 m distance this corresponds on average to a casual voice level in both women and men), the background level should not exceed 35 dBA. This means that in classrooms, for example, one should strive for as low background levels as possible. This is particularly true when listeners with impaired hearing are involved, for example, in homes for the elderly. Reverberation times below 1 s are necessary for good speech intelligibility in smaller rooms; and even in a quiet environment a reverberation time below 0.6 s is desirable for adequate speech intelligibility for sensitive groups.

4.2.2. Noise-induced hearing impairment

The ISO Standard 1999 (ISO 1990) gives a method of calculating noise-induced hearing impairment in populations exposed to all types of occupational noise (continuous, intermittent, impulse). However, noise-induced hearing impairment is by no means restricted to occupational situations alone. High noise levels can also occur in open-air concerts, discotheques, motor sports, shooting ranges, and from loudspeakers or other leisure activities in dwellings. Other loud noise sources, such as music played back in headphones and impulse noise from toys and fireworks, are also important. Evidence strongly suggests that the calculation method from ISO Standard 1999 for occupational noise (ISO 1990) should also be used for environmental and leisure time noise exposures. This implies that long term exposure to LAeq,24h of up to 70 dBA will not result in hearing impairment. However, given the limitations of the various underlying studies, care should be taken with respect to the following:

a. Data from animal experiments indicate that children may be more vulnerable in acquiring noise-induced hearing impairment than adults.

b. At very high instantaneous sound pressure levels mechanical damage to the ear may occur (Hanner & Axelsson 1988). Occupational limits are set at peak sound pressure levels of 140 dBA (EU 1986a). For adults, this same limit is assumed to be in order for exposure to environmental and leisure time noise. In the case of children, however, considering their habits while playing with noisy toys, peak sound pressure levels should never exceed 120 dBA.

c. For shooting noise with LAeq,24h over 80 dB, studies on temporary threshold shift suggest there is the possibility of an increased risk for noise induced hearing impairment (Smoorenburg 1998).

d. The risk for noise-induced hearing impairment increases when noise exposure is combined with vibrations, ototoxic drugs or chemicals (Fechter 1999). In these circumstances, long-term exposure to LAeq,24h of 70 dB may induce small hearing impairments.

e. It is uncertain whether the relationships in ISO Standard 1999 (ISO 1990) are applicable to environmental sounds having a short rise time. For example, in the case of military low-altitude flying areas (75–300 m above ground) LAmax values of 110–130 dB occur within seconds after onset of the sound.

In conclusion, dose-response data are lacking for the general population. However, judging from the limited data for study groups (teenagers, young adults and women), and on the assumption that time of exposure can be equated with sound energy, the risk for hearing impairment would be negligible for LAeq,24h values of 70 dB over a lifetime. To avoid hearing impairment, impulse noise exposures should never exceed a peak sound pressure of 140 dB peak in adults, and 120 dB in children.

4.2.3. Sleep disturbance effects

Electrophysiological and behavioral methods have demonstrated that both continuous and intermittent noise indoors lead to sleep disturbance. The more intense the background noise, the more disturbing is its effect on sleep. Measurable effects on sleep start at background noise levels of about 30 dB LAeq. Physiological effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM sleep. Subjective effects have also been identified, such as difficulty in falling asleep, perceived sleep quality, and adverse after-effects such as headache and tiredness. Sensitive groups mainly include elderly persons, shift workers and persons with physical or mental disorders.
Where noise is continuous, the equivalent sound pressure level should not exceed 30 dBA indoors, if negative effects on sleep are to be avoided. When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low-frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels. It should be noted that the adverse effect of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

If the noise is not continuous, LAmax or SEL are used to indicate the probability of noise-induced awakenings. Effects have been observed at individual LAmax exposures of 45 dB or less. Consequently, it is important to limit the number of noise events with a LAmax exceeding 45 dB. Therefore, the guidelines should be based on a combination of values of 30 dB LAeq,8h and 45 dB LAmax. To protect sensitive persons, a still lower guideline value would be preferred when the background level is low. Sleep disturbance from intermittent noise events increases with the maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep.

Therefore, to avoid sleep disturbance, guidelines for community noise should be expressed in terms of equivalent sound pressure levels, as well as LAmax/SEL and the number of noise events. Measures reducing disturbance during the first part of the night are believed to be the most effective for reducing problems in falling asleep.

4.2.4. Cardiovascular and psychophysiological effects

Epidemiologial studies show that cardiovascular effects occur after long-term exposure to noise (aircraft and road traffic) with LAeq,24h values of 65–70 dB. However, the associations are weak. The association is somewhat stronger for ischaemic heart disease than for hypertension. Such small risks are important, however, because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Other possible effects, such as changes in stress hormone levels and blood magnesium levels, and changes in the immune system and gastro-intestinal tract, are too inconsistent to draw conclusions. Thus, more research is required to estimate the long-term cardiovascular and psychophysiological risks due to noise. In view of the equivocal findings, no guideline values can be given.

4.2.5. Mental health effects

Studies that have examined the effects of noise on mental health are inconclusive and no guideline values can be given. However, in noisy areas, it has been observed that there is an increased use of prescription drugs such as tranquilizers and sleeping pills, and an increased frequency of psychiatric symptoms and mental hospital admissions. This strongly suggests that adverse mental health effects are associated with community noise.

4.2.6. Effects on performance

The effects of noise on task performance have mainly been studied in the laboratory and to some extent in work situations. But there have been few, if any, detailed studies on the effects of noise on human productivity in community situations. It is evident that when a task involves auditory signals of any kind, noise at an intensity sufficient to mask or interfere with the perception of these signals will also interfere with the performance of the task. A novel event, such as the start of an unfamiliar noise, will also cause distraction and interfere with many kinds of tasks. For example, impulsive noises such as sonic booms can produce disruptive effects as the result of startle responses; and these types of responses are more resistant to habituation.

Mental activities involving high load in working memory, such as sustained attention to multiple cues or complex analysis, are all directly sensitive to noise and performance suffers as a result. Some accidents may also be indicators of noise-related effects on performance. In addition to the direct effects on performance, noise also has consistent after-effects on cognitive performance with tasks such as proof-reading, and on persistence with challenging puzzles. In contrast, the performance of tasks involving either motor or monotonous activities is not always degraded by noise.

Chronic exposure to aircraft noise during early childhood appears to damage reading acquisition.

Evidence indicates that the longer the exposure, the greater the damage. Although there is insufficient information on these effects to set specific guideline values, it is clear that day-care centres and schools should not be located near major noise sources, such as highways, airports and industrial sites.

4.2.7. Annoyance responses

The capacity of a noise to induce annoyance depends upon many of its physical characteristics, including its sound pressure level and spectral characteristics, as well as the variations of these properties over time. However, annoyance reactions are sensitive to many non-acoustical factors of social, psychological or economic nature, and there are also considerable differences in individual reactions to the same noise. Dose-response relations for different types of traffic noise (air, road and railway) clearly demonstrate that these noises can cause different annoyance effects at equal LAeq,24h values. And the same type of noise, such as that found in residential areas around airports, can also produce different annoyance responses in different countries.

The annoyance response to noise is affected by several factors, including the equivalent sound pressure level and the highest sound pressure level of the noise, the number of such events, and the time of day. Methods for combining these effects have been extensively studied. The results are not inconsistent with the simple, physically based equivalent energy theory, which is represented by the LAeq noise index.

Annoyance to community noise varies with the type of activity producing the noise. Speech communication, relaxation, listening to radio and TV are all examples of noise-producing activities. During the daytime, few people are seriously annoyed by activities with LAeq levels below 55 dB; or moderately annoyed with LAeq levels below 50 dB. Sound pressure levels during the evening and night should be 5–10 dB lower than during the day. Noise with low-frequency components require even lower levels. It is emphasized that for intermittent noise it is necessary to take into account the maximum sound pressure level as well as the number of noise events. Guidelines or noise abatement measures should also take into account residential outdoor activities.

4.2.8. Effects on social behaviour

The effects of environmental noise may be evaluated by assessing the extent to which it interferes with different activities. For many community noises, interference with rest, recreation and watching television seem to be the most important issues. However, there is evidence that noise has other effects on social behaviour: helping behaviour is reduced by noise in excess of 80 dBA; and loud noise increases aggressive behavior in individuals predisposed to aggressiveness. There is concern that schoolchildren exposed to high levels of chronic noise could be more susceptible to helplessness. Guidelines on these issues must await further research.

4.3. Specific Environments

Noise measures based solely on LAeq values do not adequately characterize most noise environments and do not adequately assess the health impacts of noise on human well-being. It is also important to measure the maximum noise level and the number of noise events when deriving guideline values. If the noise includes a large proportion of low-frequency components, values even lower than the guideline values will be needed, because low-frequency components in noise may increase the adverse effects considerably. When prominent low-frequency components are present, measures based on A-weighting are inappropriate. However, the difference between dBC (or dBlin) and dBA will give crude information about the presence of low-frequency components in noise. If the difference is more than 10 dB, it is recommended that a frequency analysis of the noise be performed.

4.3.1. Dwellings

In dwellings, the critical effects of noise are on sleep, annoyance and speech interference. To avoid sleep disturbance, indoor guideline values for bedrooms are 30 dB LAeq for continuous noise and 45 dB LAmax for single sound events. Lower levels may be annoying, depending on the nature of the noise source. The maximum sound pressure level should be measured with the instrument set at "*Fast*".

To protect the majority of people from being seriously annoyed during the daytime, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 55 dB LAeq for a steady, continuous noise. To protect the majority of people from being moderately annoyed during the daytime, the outdoor sound pressure level should not exceed 50 dB LAeq. These values are based on annoyance studies, but most countries in Europe have adopted 40 dB LAeq as the maximum allowable level for new developments (Gottlob 1995). Indeed, the lower value should be considered the maximum allowable sound pressure level for all new developments whenever feasible.

At night, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB LAeq and 60 dB LAmax, so that people may sleep with bedroom windows open. These values have been obtained by assuming that the noise reduction from outside to inside with the window partly open is 15 dB.

4.3.2. Schools and preschools

For schools, the critical effects of noise are on speech interference, disturbance of information extraction (e.g. comprehension and reading acquisition), message communication and annoyance. To be able to hear and understand spoken messages in classrooms, the background sound pressure level should not exceed 35 dB LAeq during teaching sessions. For hearing impaired children, an even lower sound pressure level may be needed. The reverberation time in the classroom should be about 0.6 s, and preferably lower for hearing-impaired children. For assembly halls and cafeterias in school buildings, the reverberation time should be less than 1 s. For outdoor playgrounds, the sound pressure level of the noise from external sources should not exceed 55 dB LAeq, the same value given for outdoor residential areas in daytime.

For preschools, the same critical effects and guideline values apply as for schools. In bedrooms in preschools during sleeping hours, the guideline values for bedrooms in dwellings should be used.

4.3.3. Hospitals

For most spaces in hospitals, the critical effects of noise are on sleep disturbance, annoyance and communication interference, including interference with warning signals. The LAmax of sound events during the night should not exceed 40 dB indoors. For wardrooms in hospitals, the guideline values indoors are 30 dB LAeq, together with 40 dB LAmax during the night. During the day and evening the guideline value indoors is 30 dB LAeq. The maximum level should be measured with the instrument set at "*Fast*".

Since patients have less ability to cope with stress, the equivalent sound pressure level should not exceed 35 dB LAeq in most rooms in which patients are being treated or observed. Particular attention should be given to the sound pressure levels in intensive care units and operating theatres. Sound inside incubators may result in health problems, including sleep disturbance, and may lead to hearing impairment in neonates. Guideline values for sound pressure levels in incubators must await future research.

4.3.4. Ceremonies, festivals and entertainment events

In many countries, there are regular ceremonies, festivals and other entertainment to celebrate life events. Such events typically produce loud sounds including music and impulsive sounds. There is widespread concern about the effect of loud music and impulse sounds on young people who frequently attend concerts, discotheques, video arcades, cinemas, amusement parks and spectator events, etc. The sound pressure level is typically in excess of 100 dB LAeq. Such a noise exposure could lead to significant hearing impairment after frequent attendance.

Noise exposure for employees of these venues should be controlled by established occupational standards. As a minimum, the same standards should apply to the patrons of these premises. Patrons should not be exposed to sound pressure levels greater than 100 dB LAeq during a 4-h period, for at most four times per year. To avoid acute hearing impairment the LAmax should always be below 110 dB.

4.3.5. Sounds through headphones

To avoid hearing impairment in both adults and children from music and other sounds played back in headphones, the LAeq,24h should not exceed 70 dB. This implies that for a daily one-hour exposure the LAeq should not exceed 85 dB. The exposures are expressed in free-field equivalent sound pressure levels. To avoid acute hearing impairment, the LAmax should always be below 110 dB.

4.3.6. Impulsive sounds from toys, fireworks and firearms

To avoid acute mechanical damage to the inner ear, adults should never be exposed to more than 140 dB peak sound pressure. To account for the vulnerability in children, the peak sound pressure level produced by toys should not surpass 120 dB, measured close to the ears (100 mm). To avoid acute hearing impairment, LAmax should always be below 110 dB.

4.3.7. Parkland and conservation areas

Existing large quiet outdoor areas should be preserved and the signal-to-noise ratio kept low.

4.4. WHO Guideline Values

The WHO guideline values in Table 4.1 are organized according to specific environments. When multiple adverse health effects are identified for a given environment, the guideline values are set at the level of the lowest adverse health effect (the critical health effect). An adverse health effect of noise refers to any temporary or long-term deterioration in physical, psychological or social functioning that is associated with noise exposure. The guideline values represent the sound pressure levels that affect the most exposed receiver in the listed environment.

The time base for LAeq for "daytime" and "night-time" is 16 h and 8 h, respectively. No separate time base is given for evenings alone, but typically, guideline value should be 5 - 10 dB lower than for a 12 h daytime period. Other time bases are recommended for schools, preschools and playgrounds, depending on activity.

The available knowledge of the adverse effects of noise on health is sufficient to propose guideline values for community noise for the following:

a. Annoyance.
b. Speech intelligibility and communication interference
c. Disturbance of information extraction
d. Sleep disturbance.
e. Hearing impairment.

The different critical health effects are relevant to specific environments, and guideline values for community noise are proposed for each environment. These are.

a. Dwellings, including bedrooms and outdoor living areas.
b. Schools and preschools, including rooms for sleeping and outdoor playgrounds.
c. Hospitals, including ward and treatment rooms.
d. Industrial, commercial shopping and traffic areas, including public addresses, indoors and outdoors.
e. Ceremonies, festivals and entertainment events, indoors and outdoors.
f. Music and other sounds through headphones.
g. Impulse sounds from toys, fireworks and firearms.
h. Outdoors in parkland and conservation areas.

It is not enough to characterize the noise environment in terms of noise measures or indices based only on energy summation (e.g. LAeq), because different critical health effects require different descriptions. Therefore, it is important to display the maximum values of the noise fluctuations, preferably combined with a measure of the number of noise events. A separate characterization of noise exposures during night-time would be required. For indoor environments, reverberation time is also an important factor. If the noise includes a large proportion of low frequency components, still lower guideline values should be applied.

Supplementary to the guideline values given in Table 4.1, precautionary recommendations are given in Section 4.2 and 4.3 for vulnerable groups, and for noise of a certain character (e.g. low-frequency components, low background noise), respectively. In Section 3.10, information is given regarding which critical effects and specific environments are considered relevant for vulnerable groups, and what precautionary noise protection would be needed in comparison to the general population.

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax, fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime and evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school Bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial, shopping and traffic areas, indoors and Outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ Earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;
#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;
#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;
#4: under headphones, adapted to free-field values

5. Noise Management

The goal of noise management is to maintain low noise exposures, such that human health and well-being are protected. The specific objectives of noise management are to develop criteria for the maximum safe noise exposure levels, and to promote noise assessment and control as part of environmental health programmes. This is not always achieved (Jansen 1998). The United Nations' Agenda 21 (UNCED 1992), as well as the European Charter on Transport, Environment and Health (London Charter 1999), both support a number of environmental management principles on which government policies, including noise management policies, can be based. These include:

a. **The precautionary principle**. In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health without awaiting full scientific proof.

b. **The polluter pays principle**. The full costs associated with noise pollution (including monitoring, management, lowering levels and supervision) should be met by those responsible for the source of noise.

c. **The prevention principle**. Action should be taken where possible to reduce noise at the source. Land-use planning should be guided by an environmental health impact assessment that considers noise as well as other pollutants.

The government policy framework is the basis of noise management. Without an adequate policy framework and adequate legislation it is difficult to maintain an active or successful noise management programme. A policy framework refers to transport, energy, planning, development and environmental policies. The goals are more readily achieved if the interconnected government policies are compatible, and if issues which cross different areas of government policy are co-ordinated.

5.1. Stages in Noise Management

A legal framework is needed to provide a context for noise management (Finegold 1998; Hede 1998a). While there are many possible models, an example of one is given in Figure 5.1. This model depicts the six stages in the process for developing and implementing policies for community noise management. For each policy stage, there are groups of 'policy players' who ideally would participate in the process.

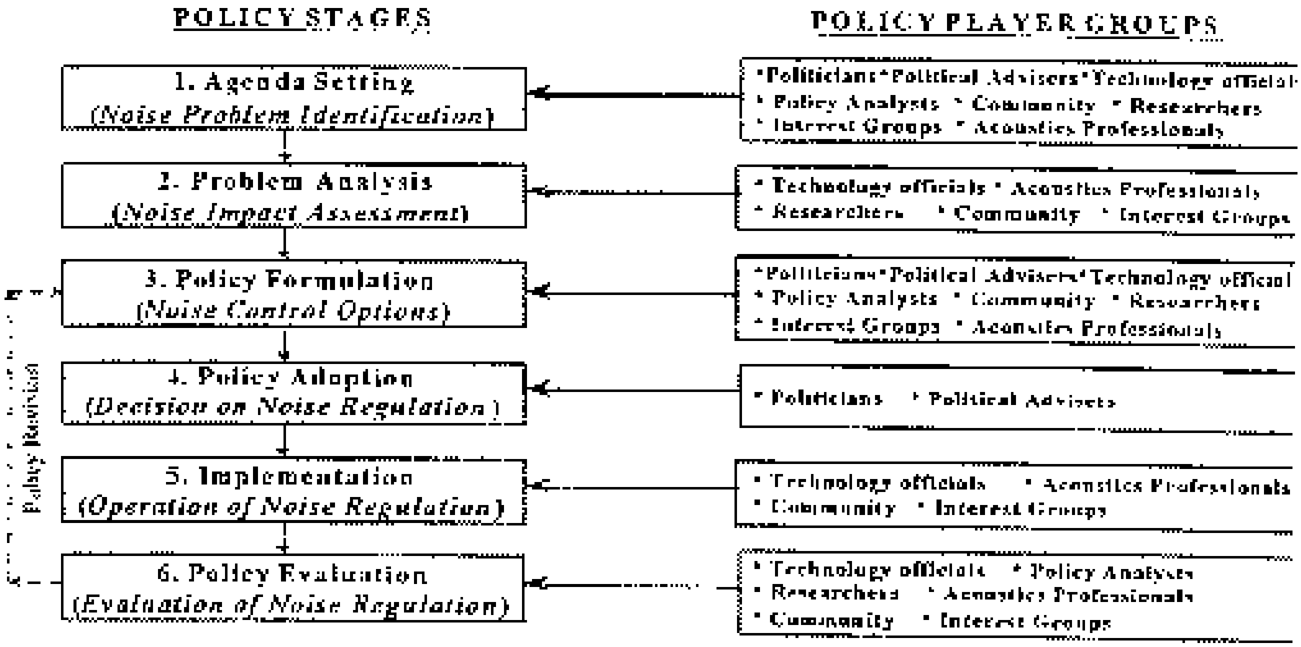

Figure 5.1. A model of the policy process for community noise management (Hede 1998a)

When goals and policies have been developed, the next stage is the development of the strategy or plan. Figure 5.2 summarizes the stages involved in the development of a noise management strategy. Specific abatement measures 19 are listed in Table 5.1.

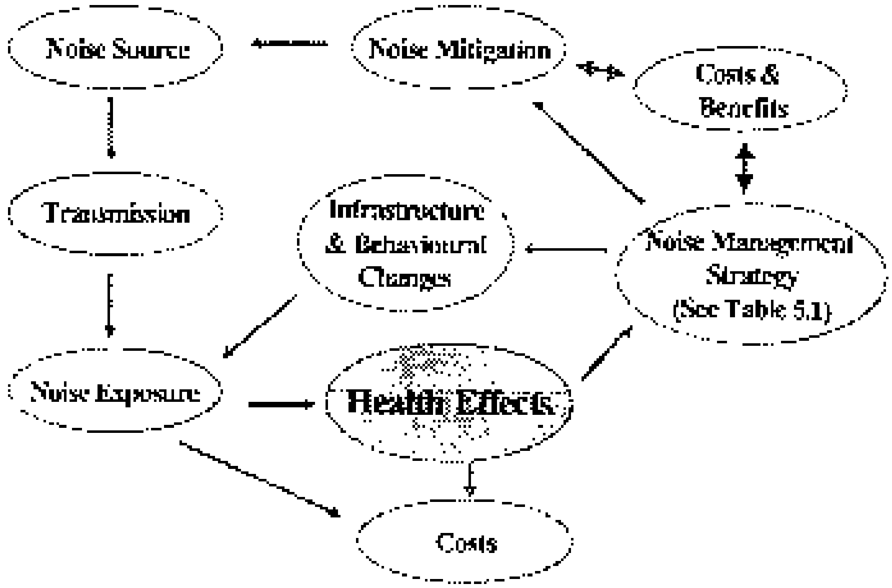

Figure 5.2. Stages involved in the development of a noise abatement strategy.

Table 5.1. Recommended Noise Management Measures (following EEA 1995)

Legal measures	Examples
Control of noise emissions	Emission standards for road and off-road vehicles; emission standards for construction equipment, emission standards for plants; national regulations, EU Directives
Control of noise transmission	Regulations on sound-obstructive measures
Noise mapping and zoning around roads, airports, industries	Initiation of monitoring and modeling programmes
Control of noise immissions	Limits for exposure levels such as national immission standards; noise monitoring and modeling; regulations for complex noise situations; regulations for recreational noise
Speed limits	Residential areas; hospitals
Enforcement of regulations	Low Noise Implementation Plan
Minimum requirements for acoustical properties of buildings	Construction codes for sound insulation of building parts
Engineering Measures	
Emission reduction by source modification	Tyre profiles; low-noise road surfaces, changes in engine properties
New engine technology	Road vehicles; aircraft, construction machines
Transmission reduction	Enclosures around machinery; noise screens
Orientation of buildings	Design and structuring of tranquille uses; using buildings for screening purposes
Traffic management	Speed limits; guidance of traffic flow by electronic means
Passive protection	Ear plugs; ear muffs; insulation of dwellings; façade design
Implementation of land-use planning	Minimum distance between industrial, busy roads and residential areas; location of tranquillity areas; by-pass roads for heavy traffic; separating out incompatible functions
Education and information	
Raising public awareness	Informing the public on the health impacts of noise, enforcement action taken, noise levels, complaints
Monitoring and modeling of soundscapes	Publication of results
Sufficient number of noise experts	University or highschool curricula
Initiation of research and development	Funding of information generation according to scientific research needs
Initiation of behaviour changes	Speed reduction when driving; use of horns; use of loudspeakers for advertisements

The process outlined in Figure 5.2 can start with the development of noise standards or guidelines. Ideally, it should also involve the identification and mapping of noise sources and exposed communities. Meteorological conditions and noise levels would also normally be monitored. These data can be used to validate the output of models that estimate noise levels. Noise standards and model outputs may be considered in devising noise control tactics aimed at achieving the noise standards. Before being enforced, current control tactics need to be revised, and if the standards are achieved they need continued enforcement. If the standards are not achieved after a reasonable period of time, the noise control tactics may need to be revised.

National noise standards can usually be based on a consideration of international guidelines, such as these Guidelines for Community Noise, as well as national criteria documents, which consider dose-response relations for the effects of noise on human health. National standards take into account the technological, social, economic, political and other factors specific for the country.

In many cases monitoring may show that noise levels are considerably higher than established guidelines. This may be particularly true in developing countries, and the question has to be raised as to whether national standards should reflect the optimum levels needed to protect human health, when this objective is unlikely to be achieved in the short- or medium-term with available resources. In some countries noise standards are set at levels that are realistically attainable under prevailing technological, social, economic and political conditions, even though they may not be fully consistent with the levels needed to protect human health. In such cases, a staged programme of noise abatement should be implemented to achieve the optimum health protection levels over the long term. Noise standards periodically change after reviews, as conditions in a country change over time, and with improved scientific understanding of the relationship between noise pollution and the health of the population. Noise level monitoring (Chapter 2) is used to assess whether noise levels at particular locations are in compliance with the standards selected.

5.2. Noise Exposure Mapping

A crucial component of a low-noise implementation plan is a reasonably quantitative knowledge of exposure (see Figure 5.2). Exposure should be mapped for all noise sources impacting a community; for example, road traffic, aircraft, railway, industry, construction, festivals and human activity in general. For some components of a noise exposure map or noise exposure inventory, accurate data may be available. In other cases, exposure can be calculated from the characteristics of the mechanical processes. While estimates of noise emissions are needed to develop exposure maps, measurements should be undertaken to confirm the veracity of the assumptions used in the estimates. Sample surveys may be used to provide an overall picture of the noise exposure. Such surveys would take account of all the relevant characteristics of the noise source. For example motor vehicle emissions may be estimated by calculations involving the types of vehicles, their number, their age and the characteristic properties of the road surface.

In developing countries, there is usually a lack of appropriate statistical information to produce noise exposure estimates. However, where action is needed to lower noise levels, the absence of comprehensive information should not prevent the development of provisional noise exposure estimates. Basic information about the exposed population, transport systems, industry and other relevant factors can be used to calculate provisional noise exposures. These can then be used to develop and implement interim noise management plans. The preliminary exposure estimates can be revised as more accurate information becomes available.

5.3. Noise Exposure Modeling

As indicated in Chapter 2 modeling is a powerful tool for the interpolation, prediction and optimization of control strategies. However, models need to be validated by monitoring data. A strength of models is that they enable examination and comparison of the consequences for noise exposure of the implementation of the various options for improving noise. However, the accuracy of the various models available depends on many factors, including the accuracy of the source emissions data and details of the topography (for which a geographical information system may be used). For transportation noise parameters such as the number, type and speed of vehicles, aircraft or trains, and the noise characteristics of each individual event must be known. An example of a model is the annoyance prediction model of the Government of the Netherlands (van den Berg 1996).

5.4. Noise Control Approaches

An integrated noise policy should include several control procedures: measures to limit the noise at the source, noise control within the sound transmission path, protection at the receiver's site, land-use planning, education and raising of public awareness. Ideally, countries should give priority to precautionary measures that prevent noise, but they must also implement measures to mitigate existing noise problems.

5.4.1. Mitigation measures

The most effective mitigation measure is to reduce noise emissions at the source. Therefore, regulations with noise level limits for the main noise sources should be introduced.

Road traffic noise. Limits on the noise emission of vehicles have been introduced in many countries (Sandberg 1995). Such limits, together with the relevant measuring methods, should also be introduced in other regions of the world. Besides these limits a special class of "low-noise trucks" has been introduced in Europe. These trucks follow state-of-the-art noise control and are widely used in Austria and Germany (Lang 1995). Their use is encouraged by economic incentives; for example, low-noise trucks are excepted from a night-time ban on certain routes, and their associated taxes are lower than for other trucks. In Europe, the maximum permissible noise levels range from 69 dBA for motor vehicles to 77 dBA for cars, and 83 dBA for heavy two-wheeled vehicles to 84 dBA for trucks. A number of European Directives give permissible sound levels for motor vehicles and motorcycles (EU 1970; EU 1978; EU 1996a; EU 1997). In addition to noise level limits for new vehicles (type test), noise emissions of vehicles already in use should be controlled regularly. Limits on the sound pressure levels for vehicles reduce the noise emission from the engines.

However, the main noise from traffic on highways is rolling noise. This may be reduced by quiet road surfaces (porous asphalt, "drain asphalt") or by selection of quiet tires. Road traffic noise may also be reduced by speed limits, provided the limits are enforced. For example, reducing the speed of trucks from 90 to 60 km/h on concrete roads would reduce the maximum sound pressure level by 5 dB, and the equivalent sound pressure level by 4 dB. Decreasing the speed of cars from 140 to 100 km/h would result in the same noise reduction (WHO 1995a). In the central parts of cities a speed limit of 30 km/h may be introduced. At 30 km/h cars produce maximum sound pressure levels that are 7 dB lower, and equivalent sound pressure levels that are 5 dB lower, than cars driving at 50 km/h

Noise emission from road traffic may be further reduced by a night-time ban for all vehicles, or especially for heavy vehicles. Traffic management designed to ensure uniform traffic flow in towns also serves to reduce noise. "Low-noise behaviour" of drivers should be encouraged as well, by advocating defensive driving manners. In some countries, car drivers use their horns frequently, which results in noise with high peak levels. The unnecessary use of horns within cities should be forbidden, especially during night-time, and this rule should be enforced.

Railway noise and noise from trams. The main noise sources are the engine and the wheel-rail contact. Noise at the source can be reduced by well-maintained rails and wheels, and by the use of disc brakes. Sound pressure levels may vary by more than 10 dB, depending on the type of railway material. Replacement of steel wheels by rubber wheels could also reduce noise from railways and trams substantially. Other measures include innovations in engine and track technology (Moehler 1988, Öhrström & Skånberg 1996).

Aircraft noise. The noise emission of aircraft is limited by ICAO Annex 16, Chapter 2 and Chapter 3, which estimates maximum potential sound emissions under certification procedures (ICAO 1993). Aircraft following the norms of Chapter 3 represent the state-of-the-art of noise control of the 1970s. In many countries, non-certified aircraft (i.e. aircraft not fulfilling the ICAO requirements) are not permitted and Chapter 2 aircraft may not be registered again. After the year 2002 only Chapter 3 aircraft will be allowed to operate in many countries.

Similar legislation should be adopted in other countries. The use of low-noise aircraft may also be encouraged by setting noise-related charges (that is, landing charges that are related not only to aircraft weight and capacity, but also to noise emission). Examples of systems for noise-related financial charges are given in OECD 1991 (see also OECD-ECMT 1995). Night-time aircraft movements should be discouraged where they impact residential communities. Particular categories of aircraft (such as helicopters, rotorcraft and supersonic aircraft) pose additional problems that require appropriate controls. For subsonic airplanes two EU Directive give the permissible sound levels (EU 1980; EU 1989).

Machines and Equipment. Noise emission has to be considered a main property of all types of machines and equipment. Control measures include design, insulation, enclosure and maintenance.

Consumers should be encouraged to take noise emission into account when buying a product. Declaring the A-weighted sound power level of a product would assist the consumer in making this decision. The introduction of sound labeling is a major tool for reducing the noise emission of products on the market. For example, within the European Community, "permissible sound levels" and "sound power levels" have to be stated for several groups of machines, for example, lawn mowers, construction machines and household equipment (EU 1984a-f; EU 1986b,c). For other groups of machines sound level data have been compiled and are state-of-the-art with respect to noise control.

A second step would be the introduction of limits on the sound power levels for certain groups of machines, heating and ventilation systems (e.g. construction machines, household appliances). These limits may be set by law, in recommendations and by consumers, using state-of-the-art measurements. There have also been promising developments in the use of active noise control (involving noise cancellation techniques). These are to be encouraged.

Noise control within the sound transmission path. The installation of noise barriers can protect dwellings close to the traffic source. In several European countries noise barrier regulations have been established (WHO 1995b), but in practice they are often not adequately implemented. These regulations must define:

a. Measuring and calculation methods for deriving the equivalent sound pressure level of road or railway traffic, and schemes for determining the effectiveness of the barrier.

b. The sound pressure limits that are to be achieved by installing barriers.

c. The budgetary provisions.

d. The responsible authority.

Noise protection at the receiver's site. This approach is mainly used for existing situations. However, this approach must also be considered for new and, eventually, for old buildings in noisy areas. Residential buildings near main roads with heavy traffic, or near railway lines, may be provided with sound-proofed windows.

5.4.2. *Precautionary measures*

With careful planning, noise exposure can be avoided or reduced. A sufficient distance between residential areas and an airport will make noise exposure minimal, although the realization of such a situation is not always possible. Additional insulation of houses can help to reduce noise exposure from railroad and road traffic. For new buildings, standards or building codes should describe the positions of houses, as well as the ground plans of houses with respect to noise sources. The required sound insulation of the façades should also be described. Various countries have set standards for the maximum sound pressure levels in front of buildings and for the minimum sound insulation values required for façades.

Land use planning. Land use planning is one of the main tools for noise control and includes:

a. Calculation methods for predicting the noise impact caused by road traffic, railways, airports, industries and others.

b. Noise level limits for various zones and building types. The limits should be based on annoyance responses to noise.

c. Noise maps or noise inventories that show the existing noise situation. The construction of noise-sensitive buildings in noisy areas, or the construction of noisy buildings in quiet areas may thus be avoided.

Suggestions on how to use land use planning tools are given in several dedicated books (e.g. Miller & de Roo 1997). Different zones, such as quiet areas, hospitals, residential areas, commercial and industrial districts, can be characterized by the maximum equivalent sound pressure levels permissible in the zones. Examples of this approach can be found in OECD 1991 (also see OECD-ECMT 1995). More emphasis needs to be given to the design or retrofit of urban centres, with noise management as a priority (e.g. "soundscapes").

It is recommended that countries adopt the precautionary principle in their national noise policies. This principle should be applied in all noise situations where adverse noise effects are either expected or possible, even when the noise is below standard values.

Education and public awareness. Noise abatement policies can only be established if basic knowledge and background material is available, and the people and authorities are aware that noise is an environmental hazard that needs to be controlled. It is, therefore, necessary to include noise in school curricula and to establish scientific institutes to study acoustics and noise control. People working in such institutes should have the option of studying in other countries and exchanging information at international conferences. Dissemination of noise control information to the public is an issue for education and public awareness. Ideally, national and local advisory groups should be formed to promote the dissemination of information, to establish uniform methods of noise measurement and impact assessment, and to participate in the development and implementation of educational and public awareness programmes.

5.5. Evaluation of Control Options

Unless legal constraints in a country prescribe a particular option, the evaluation of control options must take into account technical, financial, social, health and environmental factors. The speed with which control options can be implemented, and their enforceability, must also be considered. Although considerable improvements in noise levels have been achieved in some developed countries, the financial costs have been high, and the resource demands of some of these approaches make them unsuitable for the poorer developing countries.

Technical factors. There needs to be confidence that the selected options are technically practical given the resources of the region. It must be possible to bring a selected option into operation, and maintain the expected level of performance in the long term, given the resources available. This may require regular staff training and other programmes, especially in developing countries.

Financial factors. The selected options must be financially viable in the long term. This may require a comparative cost-benefit assessment of different options. These assessments must include not only the capital costs of bringing an option into operation but also the costs of maintaining the expected level of performance in the long term.

Social factors. The costs and benefits of each option should be assessed for social equity, and the potential impact of an option on people's way of life, community structures and cultural traditions must be considered. Impacts may include disruption or displacement of residents, changes of land-use, and impacts on community, culture and recreation. Some impacts can be managed; in other cases, the impacts of an option can be mitigated by substitution of resources or uses.

Health and environmental factors. The costs and benefits of each option should be assessed for health and environmental factors. This may involve use of dose-response relations, or risk assessment techniques.

Effect-oriented and source-oriented principles. Noise control requirements in European countries are typically determined from the effects of noise on health and the environment (effect oriented) (e.g. Gottlob 1995; ten Wolde 1998). Increased noise emissions may be permitted if there would be no adverse health impacts, or if noise standards would not be exceeded. Action may be taken to reduce noise levels when it is shown that adverse health impacts will occur, or when noise levels exceed limits. Other countries base their noise management policies on the requirement for best available technology, or for best available techniques that do not entail excessive cost (source-oriented) (e.g. for aircraft noise, ICAO 1993, for road traffic noise, Sandberg 1995). Most developed countries apply a combination of both source-oriented and effect-oriented principles (EU 1996b; Jansen 1998; ten Wolde 1998).

5.6. Management of Indoor Noise

In modern societies, human beings spend most of their time in indoor environments. Pollution and degradation of the indoor environment cause illness, increased mortality, loss of productivity, and have major economic and social implications. Indoor noise problems are related to inadequate urban planning, design, operation and maintenance of buildings, and to the materials and equipment in buildings. Problems with indoor noise affect all types of buildings, including homes, schools, offices, health care facilities and other public and commercial buildings. The health effects of indoor noise include an increase in the rates of diseases and disturbances described in chapter 2. World-wide, the medical and social cost associated with these illnesses, and the related reduction in human productivity, can result in substantial economic losses.

Protection against noise generated within a building, or originating from outside the building, is a very complex problem. Soundproofing of ceilings, walls, doors and windows against airborne noise is important. Soundproofing of ceilings has to be sufficient to absorb sounds due to treading. Finally, noise emissions from the technological devices in the house must be sufficiently low. Governments should provide measurement protocols and data for use in reducing noise exposures in buildings. Governments should also be encouraged to support research on the relationship between noise levels inside buildings and health effects.

5.6.1. Government policy on indoor noise

Many of the problems associated with high noise levels can be prevented at low cost if governments develop and implement an integrated strategy for the indoor environment, in concert with all social and economic partners. Governments should establish a "National Plan for a Sustainable Indoor Noise Environment", that would apply to new construction as well as to existing buildings. Governments should set up a specific structure at an appropriate governmental level to achieve acceptable sound exposure levels within buildings. An example of existing documents that provide guidance and regulations, including strategies and management for the design of buildings, is given by Jansen & Gottlob (1996).

Guidance/education. Because our understanding of indoor noise is still developing, government activity should be focused on raising the awareness of various audiences. This education can take the form of providing general information, as well as providing technical guidance and training on how to minimize indoor noise levels. General information presented in the form of documents, videos, and other media can bring indoor noise issues to the attention of the general public and building professionals, including architects.

Research support. Research is needed to develop technology for indoor noise diagnosis, mitigation and control. Efforts are also required to provide economical and practical alternatives for mitigation and control. Better means of measuring the effectiveness of absorption devices are needed; and diagnostic tools that are inexpensive and easy to use also need to be developed to help facility personnel. There is a particular need, too, for improving soundproofing methods, their implementation and for predicting the health effects of soundproofing techniques.

To provide accurate information for use in setting priorities for public health problems, governments should support problem assessment and surveys of indoor noise conditions. Building surveys are also necessary to provide baseline information about building characteristics and noise levels. When combined with occupant health surveys, these studies will help to establish the correlations between noise levels and adverse health effects. Surveys should be conducted to identify building types or vintages in which problems occur more frequently. The results of these studies will support effective risk reduction programmes. Epidemiological studies are also needed to aid in differentiating between noise-related symptoms and those due to other causes. Moreover, epidemiological studies are needed to assist in quantifying the extent of risk for indoor noise levels.

Economic research is needed to measure the costs of indoor noise control strategies to individuals, businesses and society. This includes developing methods for quantifying productivity loss and increased health costs due to noise, and for measuring the costs of various control strategies, including increased soundproofing and source control.

Development of standards and protocols. Efforts should be made to protect public health by setting reasonable noise exposure limits (immission standards) from known dose-response relationships. In cases where dose-response relationships have yet to be determined, but where health effects are generally recognized, exposure limits should be set conservatively and take into account risk, economic impact and feasibility. Efforts should also be made to incorporate noise-related specifications into building codes. Areas to target with building codes include ventilation design, building envelope design, site preparation, materials selection and commissioning. Standards and other regulations governing the use of sound proofing materials should also be developed.

Individuals involved in the diagnosis and mitigation of indoor noise problems should be trained in the multidisciplinary nature of the noise field. By instituting a series of credentials that recognize and highlight areas of expertise, consumers would be provided with the information to make informed choices when procuring indoor noise services. Companies which provide such services should be officially accredited. Guidelines or standards for sound emissions of air-conditioners, power generators and other building devices, would also provide useful information for manufacturers, architects, design engineers, building managers and others who play a role in selecting products used indoors.

5.6.2. Design considerations

Site investigation. Potential sites should be evaluated to determine whether they are prone to indoor noise problems. This evaluation should be consistent with national and local land use planning guidelines. Sites should be investigated to determine past uses and whether any sources of sound remain as a result. The potential for outdoor noise being carried to the site from adjacent areas, such as busy streets, should also be evaluated.

Building design. Buildings should be designed to be soundproof, to improve control over indoor noise. Soundproofing requires that outside noise be prevented from entering the building, and this should be estimated as part of the architectural and engineering design process. When soundproofing for outdoor noise, the total indoor noise load and the desired quality of the indoor space should be considered. Adequate soundproofing against outdoor noise is important in residential as well as commercial properties, and should be re-evaluated when interior spaces are rebuilt or renovated.

Indoor Spaces. The architectural layout should aim to reduce noise and provide a good sound quality to the space. This would include designing indoor spaces to have sufficiently short reverberation times. Designers and contractors should be encouraged to use sound-absorbing materials that lead to lower indoor noise levels, and materials with the best sound-absorbing properties should be specified. However, use of these materials should not be the only solution (Harris 1991). Possible conflicts with other environmental demands should also be identified, for example, the special demands by allergic people.

5.6.3. Indoor noise level control

Building maintenance personnel should be trained to understand the indoor noise aspects of their work, and be aware of how their work can directly impact the health and comfort of occupants. Many maintenance activities directly affect indoor noise levels, and some may indicate potential problems. Preventive maintenance is essential for the building systems to operate correctly and to provide suitable comfort conditions and low indoor noise levels. Detailed maintenance logs should be kept for all equipment. A schedule should be developed for routine equipment checks and calibration of control system components. Selection of low-noise domestic products should encouraged as far as is possible

5.6.4. *Resolving indoor noise problems*

Addressing occupant complaints and symptoms. When complaints are received from occupants of a building, the cognizant authority should be responsive. The initial investigation into the cause of the complaint may be conducted by the in-house management staff, and they should continue an investigation as far as possible. If necessary, they should be responsible for hiring an outside consultant

Building diagnostic procedures. After receiving complaints related to indoor noise levels, facility personnel or consultants should attempt to identify the cause of the problem through an iterative process of information collection and hypothesis testing. To begin, a walkthrough inspection of the building, including the affected areas and the mechanical systems serving these spaces is required. A walkthrough can provide information on the soundproofing system of the building, the sound pathways and sound sources. Visual indicators of sound sources and soundproofing malfunctions should be evaluated first. Symptom logs and schedules of building activities may provide enough additional information to resolve the problem.

If a walkthrough alone does not provide a solution, measurements of sound pressure levels at various locations should be taken, and indoor and ambient levels of noise pollution should be compared. As part of the investigation, the absorption characteristics of walls and ceilings should be evaluated. Sophisticated sampling methods may be necessary to provide proof of a problem to the building owner or other responsible party. The results may be used to confirm a hypothesis or ascertain the source of the indoor noise problem. Whenever a problem is discovered during the investigation, a remedy to the situation should be attempted and a determination made of whether the complaint has been resolved.

In some cases, it should be recognized that difficulties in interpreting the sampling results may exist. The costs of certain types of testing should also be taken into account. Simple, cost-effective screening methods should be developed to make sampling a more attractive option for both investigators and clients. Finally, it must be remembered that several factors cause symptoms similar to those induced by noise pollution. Examples include air pollutants, ergonomics, lighting, vibration and psychosocial factors. Consequently, any investigation of noise complaints should also evaluate non-noise factors.

5.7. Priority Setting in Noise Management

Priorities in noise management will differ between countries, according to policy objectives, needs and capabilities. Priority setting in noise management refers to prioritizing health risks and concentrating on the most important sources of noise. For effective noise management, the goals, policies and noise control schemes have to be defined. Goals for noise management include eliminating noise, or reducing noise to acceptable levels, and avoiding the adverse health effects of noise on human health. Policies for noise management encompass laws and regulations for setting noise standards and for ensuring compliance. The amount of information to be included in low-noise implementation plans and the use of cost-benefit comparisons also fall within the purview of noise management policies. Techniques for noise control include source control, barriers in noise pathways and receiver protection. Adequate calculation models for noise propagation, as well as programmes for noise monitoring, are part of an overall noise control scheme.

As emphasized above, a framework for a political, regulatory and administrative approach is required to guarantee the consistent and transparent promulgation of noise standards. This ensures a sound and practical framework for risk-reducing measures and for the selection of abatement strategies.

5.7.1. Noise policy and legislation

Noise is both a local and a global problem. Governments in every country have a responsibility to set up policies and legislation for controlling community noise. There is a direct relationship between the level of development in a country and the degree of noise pollution impacting its people. As a society develops, it increases its level of urbanization and industrialization, and the extent of its transportation system. Each of these developments brings an increase in noise load. Without appropriate intervention the noise impact on communities will escalate (see Figure 5.3). If governments implement only weak noise policies and regulations, they will not be able to prevent a continuous increase in noise pollution and associated adverse health effects. Failure to enforce strong regulations is ineffective in combating noise as well.

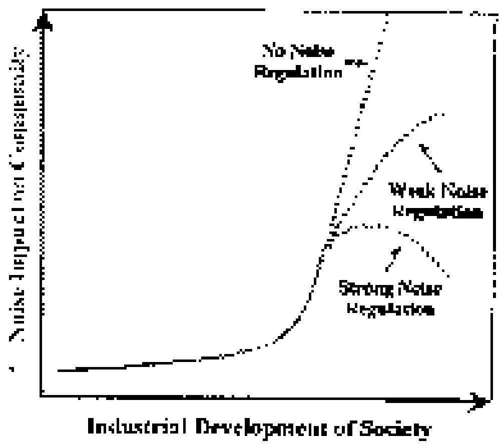

Figure 5.3. Relationship between noise regulation and impact with development (from Hede 1998b)

Policies for noise regulatory standards at the municipal, regional, national and supranational levels are usually determined by the legislatures. The regulatory standards adopted strongly depend on the risk management strategies of the legislatures, and can be influenced by sociopolitical considerations and/or international agreements. Although regulatory standards may be country specific, in general the following issues are taken into consideration:

a. Identification of the adverse public health effects that are to be avoided.

b. Identification of the population to be protected.

c. The type of parameters describing noise and the limit applicable to the parameters.

d. Applicable monitoring methodology and its quality assurance.

e. Enforcement procedures to achieve compliance with noise regulatory standards within a defined time frame.

f. Emission control measures and emission regulatory standards.

g. Immission standards (limits for sound pressure levels).

h. Identification of authorities responsible for enforcement.

i. Resource commitment.

Regulatory standards may be based solely on scientific and technical data showing the adverse effects of noise on public health. But other aspects are usually considered, either when setting standards or when designing appropriate noise abatement measures. These other aspects include the technological feasibility, costs of compliance, prevailing exposure levels, and the social, economic and cultural conditions. Several standards may be set. For example, effect-oriented regulatory standards may be set as a long-term goal, while less-stringent standards are adopted for the short term. As a consequence, noise regulatory standards differ widely from country to country (WHO 1995a; Gottlob 1995).

Noise regulatory standards can set the reference point for emission control and abatement policies at the national, regional or municipal levels, and can thus strongly influence the implementation of noise control policies. In many countries, exceeding regulatory standards is linked to an obligation to develop abatement action plans at the municipal, regional or national levels (low-noise implementation plans). Such plans have to address all relevant sources of noise pollution.

5.7.2. *Examples of noise policies*

Different countries have adopted a range of policies and regulations for noise control. A number of these are outlined in this section as examples.

Argentina. In Argentina, a national law recently limited the daily 8-h exposure to industrial noise to 80 dB, and it has had beneficial effects on hearing impairment and other hearing disorders among workers. In general, industry has responded by introducing constant controls on noise sources, combined with hearing tests and medical follow-ups for workers. Factory owners have recruited permanent health and safety engineers who control noise, supply advice on how to make further improvements, and routinely assess excessive noise levels. The engineers also provide education in personal protection and in the correct use of ear plugs, mufflers etc.

At the municipal level two types of noise have been considered. Unnecessary noise, which is forbidden; and excessive noise, which is defined for neighbourhood activities (zones), and for which both day and night-time maximum limits have been introduced. The results have been relatively successful in mitigating unwanted noise effects. At the provincial level, similar results have been accomplished for many cities in Argentina and Latin America.

Australia. In Australia, the responsibility for noise control is shared primarily by state and local governments. There are nationally-agreed regulatory standards for airport planning and new vehicle noise emissions. The Australian Noise Exposure Forecast (ANEF) index is used to describe how much aircraft noise is received at locations around an airport (DoTRS 1999). Around all airports, planning controls restrict the construction of dwellings within the 25 ANEF exposure contour and require sound insulation for those within 20 ANEF. Road traffic noise limits are set by state governments, but vary considerably in both the exposure metric and in maximum allowable levels. New vehicles are required to comply with stringent design rules for noise and air emissions. For example, new regulation in New South Wales adopts LAeq as the metric and sets noise limits of 60 dBA for daytime, and 55 dBA for night-time, along new roads. Local governments set regulations restricting noise emissions for household equipment, such as air conditioners, and the hours of use for noisy machines such as lawn mowers.

Europe. In Europe, noise legislation is not generally enforced. As a result, environmental noise levels are often higher than the legislated noise limits. Moreover, there is a gap between long-term political goals and what represents a "good acoustical environment". One reason for this gap is that noise pollution is most commonly regulated only for new land use or for the development of transportation systems, whereas enlargements at existing localities may be approved even though noise limits or guideline values are already surpassed (Gottlob 1995). A comprehensive overview of the noise situation in Europe is given in the Green Paper (EU 1996b), which was established to give noise abatement a higher priority in policy making. The Green Paper outlines a new framework for noise policy in Europe with the following options for future action:

a. Harmonizing the methods for assessing noise exposure, and encouraging the exchange of information among member states.

b. Establishing plans to reduce road traffic noise by applying newer technologies and fiscal instruments.

c. Paying more attention to railway noise in view of the future extension of rail networks.

d. Introducing more stringent regulation on air transport and using economic instruments to encourage compliance.

e. Simplifying the existing seven regulations on outdoor equipment by proposing a Framework Directive that covers a wider range of equipment, including construction machines and others.

Pakistan. In Pakistan, the Environmental Protection Agency is responsible for the control of air pollution nationwide. However, only recently have controls been enforced in Sindh in an attempt to raise public awareness and carry out administrative control on road vehicles producing noise (Zaidi, personal communication).

South Africa. In South Africa, noise control is three decades old. It began with codes of practice issued by the South African Bureau of Standards to address noise pollution in various sectors of the country (e.g. see SABS 1994 1996; and the contribution of Grond in Appendix 2). In 1989, the Environment Conservation Act made provision for the Minister of Environmental Affairs and Tourism to make regulations for noise, vibration and shock (DEAT 1989). These regulations were published in 1990 and local authorities could apply to the Minister to make them applicable in their areas. Later, the act was changed to make it obligatory for all authorities to apply the regulations. However, according to the new Constitution of South Africa of 1996, legislative responsibility for noise control rests exclusively with provincial and local authorities. The noise control regulations will apply to local authorities in South Africa as soon as they are published in the provinces. This will not only give local authorities the power to enforce the regulations, but also place an obligation on them to see that the regulations are enforced.

Thailand. In 1996, noise pollution regulations in Thailand stipulated that not more than 70 dBA LAeq,24h should be allowed in residential areas, and the maximum level of noise in industry should be no more than 85 dBA Leq 8h (Prasansuk 1997).

United States of America. Environmental noise was not addressed as a national policy issue in the USA until the implementation of the Noise Control Act of 1972. This congressional act directed the US Environmental Protection Agency to publish scientific information about noise exposure and its effects, and to identify acceptable levels of noise exposure under various conditions. The Noise Control Act was supposed to protect the public health and well-being with an adequate margin of safety. This was accomplished in 1974 with the publication of the US EPA "Levels Document" (US EPA 1974). It addressed issues such as the use of sound descriptions to describe sound exposure, the identification of the most important human effects resulting from noise exposure, and the specification of noise exposure criteria for various effects. Subsequent to the publication of the US EPA "Levels Document", guidelines for conducting environmental impact analysis were developed (Finegold et al. 1998). The day-night average sound level was thus established as the predominant sound descriptor for most environmental noise exposure.

It is evident from these examples that noise policies and regulations vary considerably across countries and regions. Moves towards global noise policies need to be encouraged to ensure that the world population gains the maximum health benefits from new developments in noise control.

5.7.3. Noise emission standards have proven to be inadequate

Much of the progress towards solving the noise pollution problem has come from advanced technology, which in turn has come about mainly as a result of governmental regulations (e.g. OECD-ECMT 1995). So far, however, the introduction of noise emission standards for vehicles has had limited impact on exposure to transportation noise, especially from aircraft and road traffic noise (Sandberg 1995). In part, this is because changes in human behaviour (of polluters, planners and citizens) have tended to offset some of the gains made. For example, mitigation efforts such as developing quieter vehicles, moving people to less noise-exposed areas, improving traffic systems and direct noise abatement and control (sound insulation, barriers etc.), have been counteracted by increases in the number of roads and highways built, by the number of traffic movements, and by higher driving speeds and the number of kilometers driven (OECD 1991; OECD-ECMT 1995).

Traffic planning and correction policies may diminish the number of people exposed to the very high community noise levels (>70 dB LAeq), but the number exposed to moderately high levels (55-65 dB LAeq) continues to increase in industrialized countries (Stanners & Bordeau 1995). In developing countries, exposure to excessive sound pressure levels (>85 dB LAeq), not only from occupational noise but also from urban, environmental noise, is the major avoidable cause of permanent hearing impairment (Smith 1998). Such sound pressure levels can also be reached by leisure activities at concerts, discotheques, motor sports and shooting ranges; by music played back in headphones; and by impulse noises from toys and fireworks.

A substantial growth in air transport is also expected in the future. Over the next 10 years large international airports may have to accommodate a doubling in passenger movements. General aviation noise at regional airports is also expected to increase (Large & House 1989). Although jet aircraft are expected to become less noisy due to regulation of noise emissions (ICAO 1993), the number of passengers is expected to increase. Increased air traffic movement between 1980 and 1990 is considered to be the main reason for the average 22% increase in the number of people exposed to noise above 67 dB LAeq at German airports (OECD 1993).

5.7.4. Unsustainable trends in noise pollution future policy planning

A number of trends are expected to increase environmental noise pollution, and are considered to be unsustainable in the long term. The OECD (1991) identified the following factors to be of increasing importance in the future:

a. The expanding use of increasingly powerful sources of noise.

b. The wider geographical dispersion of noise sources, together with greater individual mobility and spread of leisure activities.

c. The increasing invasion of noise, particularly into the early morning, evenings and weekends.

d. The increasing public expectations that are closely linked to increases in incomes and in education levels.

Apart from these, increased noise pollution is also linked to systemic changes in business practices (OECD-ECMT 1995). By accepting a just-in-time concept in transportation, products and components are stored in heavy-duty vehicles on roads, instead of in warehouses, and workers are recruited as temporary consultants just in time for the work, instead of as long-term employees.

In addition, the OECD (1991) report forecasts:

a. A strengthening of present noise abatement policies and their applications.

b. A further sharpening of emission standards

c. A co-ordination of noise abatement measures and transport planning, to specifically reduce mobility

d. A co-ordination of noise abatement measures with urban planning.

Planners need to know the likely effects of introducing a new noise source, or of increasing the level of an existing source, on the noise pollution in a community. Policy makers, when considering applications for new developmental projects, must take into account maximum levels, continuous equivalent sound pressure levels of both the background and the new noise source, the frequency of noise occurrence and the operating times of major noise sources.

5.7.3. *Analysis of the impact of environmental noise*

The concept of an environmental noise impact analysis (ENIA) is central to the philosophy of managing environmental noise. An ENIA should be required before implementing any project that would significantly increase the level of environmental noise in a community (typically, greater than a 5dB increase). The first step in performing an ENIA is to develop a baseline description of the existing noise environment. Next, the expected level of noise from a new source is added to the baseline exposure level to produce the new overall noise level. If the new total noise level is expected to cause an unacceptable impact on human health, trade-off analyses should then be performed to assess the cost, technical feasibility and community acceptance of noise mitigation measures. It is strongly recommended that countries develop standardized procedures for performing ENIAs (Finegold et al. 1998; SABS 1998).

Assessment of adverse health effects. In setting noise standards (for example on the basis of these guidelines), the adverse health effects from which the population is to be protected need to be defined. Health effects range from hearing impairment to sleep disturbance, speech interference to annoyance. The distinction between adverse and non-adverse effects sometimes poses considerable difficulties. Even the elaborate definition of an adverse health effect given in Chapter 3 incorporates significant subjectivity and uncertainty. More serious noise effects, such as hearing impairment or permanent threshold shift, are generally accepted as adverse. Consideration of health effects that are both temporary and reversible, or that involve functional changes with uncertain clinical significance, requires a judgement on whether these less-serious effects should be considered when deriving guideline values. Judgements as to the adversity of health effects may differ between countries, because of factors such as cultural backgrounds and different levels of health status.

Estimation of the population at risk. The population at risk is that part of the population in a given country or community that is exposed to enhanced levels of noise. Each population has sensitive groups or subpopulations that are at higher risk of developing health effects due to noise exposure. Sensitive groups include individuals impaired by concurrent diseases or other physiological limitations and those with specific characteristics that makes them more vulnerable to noise (e.g. premature babies, see the contribution of Zaidi in Appendix 2). The sensitive groups in a population may vary across countries due to differences in medical care, nutritional status, lifestyle and demographic factors, prevailing genetic factors, and whether endemic or debilitating diseases are prevalent.

Calculation of exposure-response relationships. In developing standards, regulators should consider the degree of uncertainty in the exposure-response relationships provided in the noise guidelines. Differences in the population structure (age, health status), climate (temperature, humidity) and geography (altitude, environment) can influence the prevalence and severity of noise-related health effects. In consequence, modified exposure-response relationships may need to be applied when setting noise standards.

Assessment of risks and their acceptability. In the absence of distinct thresholds for the onset of health effects, regulators must determine what constitutes an acceptable health risk for the population and select an appropriate noise standard to protect public health. This is also true in cases where thresholds are present, but where it would not be feasible to adopt noise guidelines as standards because of economical and/or technical constraints. The acceptability of the risks involved, and hence the standards selected, will depend on several factors. These include the expected incidence and severity of the potential effects, the size of the population at risk, the perception of related risks, and the degree of scientific uncertainty that the effects will occur at any given noise level. For example, if it is suspected that a health effect is severe and the size of the population at risk is large, a more cautious approach would be appropriate than if the effect were less troubling, or if the population were smaller.

Again, the acceptability of risk may vary among countries because of differences in social norms, and the degree of adversity and risk perception by the general population and stakeholders. Risk acceptability is also influenced by how the risks associated with noise compare with risks from other pollution sources or human activities.

5.7.6. *Cost-benefit analysis*

In the derivation of noise standards from noise guidelines two different approaches for decision making can be applied. Decisions can be based purely on health, cultural and environmental consequences, with little weight to economic efficiency. This approach has the objective of reducing the risk of adverse noise effects to a socially acceptable level. The second approach is based on a formal cost-effectiveness, or cost-benefit analysis (CBA). The objective is to identify control actions that achieve the greatest net economic benefit, or are the most economically efficient. The development of noise standards should account for both extremes, and involve stakeholders and assure social equity to all the parties involved. It should also provide sufficient information to guarantee that stakeholders understand the scientific and economic consequences.

To determine the costs of control action, the abatement measures used to reduce emissions must be known. This is usually the case for direct measures at the source and these measures can be monetarized. Costs of action should include all costs of investment, operation and maintenance. It may not be possible to monetarize indirect measures, such as alternative traffic plans or change in behaviour of individuals.

The steps in a cost-benefit analysis include:

a. The identification and cost analysis of control action (such as emission abatement strategies and tactics).

b. An assessment of noise and population exposure, with and without the control action.

c. The identification of benefit categories, such as improved health and reduced property loss.

d. A comparison of the health effects, with and without control action.

e. A comparison of the estimated costs of control action with the benefits that accrue from such action.

f. A sensitivity and uncertainty analysis

Action taken to reduce one pollutant may increase or decrease the concentration of other pollutants. These additional effects should be considered, as well as pollutant interactions that may lead to double counting of costs or benefits, or to disregarding some costly but necessary action. Due to different levels of knowledge about the costs of control action and health effects, there is a tendency to overestimate the cost of control action and underestimate the benefits.

CBA is a highly interdisciplinary task. Appropriately applied, it is a legitimate and useful way of providing information for managers who must make decisions that impact health. CBA is also an appropriate tool for drawing the attention of politicians to the benefits of noise control. In any case, however, a CBA should be peer-reviewed and never be used as the sole and overriding determinant of decisions.

5.7.7. Review of standard setting

The setting of standards should involve stakeholders at all levels (industry, local authorities, non-governmental organizations and the general public), and should strive for social equity or fairness to all parties involved. It should also provide sufficient information to guarantee that the scientific and economic consequences of the proposed standards are clearly understood by the stakeholders. The earlier that stakeholders are involved, the more likely is their co-operation. Transparency in moving from noise guidelines to noise standards helps to increase public acceptance of necessary measures. Raising public awareness of noise-induced health effects (changing of risk perception) also leads to a better understanding of the issues involved (risk communication) and serves to obtain public support for necessary control action, such as reducing vehicle emissions. Noise standards should be regularly reviewed and revised as new scientific evidence emerges.

5.7.8. Enforcement of noise standards: Low-noise implementation plans

The main objective of enforcing noise standards is to achieve compliance with the standards. The instrument used to achieve this goal is a Low-Noise Implementation Plan (LNIP). The outline of such a plan should be defined in the regulatory policies and should use the tactical instruments discussed above. A typical low-noise implementation plan includes:

a. A description of the area to be regulated.

b. An emissions inventory.

c. A monitored or simulated inventory of noise levels.

d. A comparison of the plan with emissions and noise standards or guidelines.

e. An inventory of the health effects.

f. A causal analysis of the health effects and their attribution to individual sources

g. An analysis of control measures and their costs

h. An analysis of transportation and land-use planning.

i. Enforcement procedures.

j. An analysis of the effectiveness of the noise management procedures

k. An analysis of resource commitment.

l. Projections for the future.

As the LNIP also addresses the effectiveness of noise control technologies and policies, it is very much in line with the Noise Control Assessment Programme (NCAP) proposed recently (Finegold et al. 1999).

5.8. Conclusions on Noise Management

Successful noise management should be based on the fundamental principles of precaution, the polluter pays and prevention. The noise abatement strategy typically starts with the development of noise standards or guidelines, and the identification, mapping and monitoring of noise sources and exposed communities. A powerful tool in developing and applying the control strategy is to make use of modeling. These models need to be validated by monitoring data. Noise parameters relevant to the important sources of noise must be known. Indoor noise exposures present specific and complex problems, but the general principles for noise management hold. The main means for noise control in buildings include careful site investigations, adequate building designs and building codes, effective means for addressing occupant complaints and symptoms, and building diagnostic procedures.

Noise control should include measures to limit the noise at the source, to control the sound transmission path, to protect the receiver's site, to plan land use, and to raise public awareness. With careful planning, exposure to noise can be avoided or reduced. Control options should take into account the technical, financial, social, health and environmental factors of concern. Cost-benefit relationships, as well as the cost-effectiveness of the control measures, must be considered in the context of the social and financial situation of each country. A framework for a political, regulatory and administrative approach is required for the consistent and transparent promulgation of noise standards. Examples are given for some countries, which may guide others in their development of noise policies.

Noise management should:

a. Start monitoring human exposures to noise.

b. Have health control require mitigation of noise emissions. The mitigation procedures should take into consideration specific environments such as schools, playgrounds, homes and hospitals; environments with multiple noise sources, or which may amplify the effects of noise; sensitive time periods, such as evenings, nights and holidays; and groups at high risk, such as children and the hearing impaired.

c. Consider noise consequences when making decisions on transport-system and land-use planning.

d. Introduce surveillance systems for noise-related adverse health effects.

e. Assess the effectiveness of noise policies in reducing noise exposure and related adverse health effects, and in improving supportive "soundscapes."

f. Adopt these Guidelines for Community Noise as long-term targets for improving human health.

g. Adopt precautionary actions for sustainable development of acoustical environments.

6. Conclusions And Recommendations

6.1. Implementation of the Guidelines

The potential health effects of community noise include hearing impairment; startle and defense reactions; aural pain; ear discomfort speech interference; sleep disturbance; cardiovascular effects, performance reduction; and annoyance responses. These health effects, in turn, can lead to social handicap; reduced productivity; decreased performance in learning, absenteeism in the workplace and school; increased drug use; and accidents. In addition to health effects of community noise, other impacts are important such as loss of property value. In these guidelines the international literature on the health effects of community noise was reviewed and used to derive guideline values for community noise. Besides the health effects of noise, the issues of noise assessment and noise management were also addressed. Other issues considered were priority setting in noise management; quality assurance plans; and the cost-efficiency of control actions. The aim of the guidelines is to protect populations from the adverse health impacts of noise.

The following recommendations were considered appropriate:

a. Governments should consider the protection of populations from community noise as an integral part of their policy for environmental protection.

b. Governments should consider implementing action plans with short-term, medium-term and long-term objectives for reducing noise levels

c. Governments should adopt the health guidelines for community noise as targets to be achieved in the long-term.

d. Governments should include noise as an important issue when assessing public health matters and support more research related to the health effects of noise exposure

a. Legislation should be enacted to reduce sound pressure levels, and existing legislation should be enforced.

b. Municipalities should develop low-noise implementation plans

c. Cost-effectiveness and cost-benefit analyses should be considered as potential instruments when making management decisions.

d. Governments should support more policy-relevant research into noise pollution (see section 6.3).

6.2. Further WHO Work on Noise

The WHO Expert Task Force proposed several issues for future work in the field of community noise. These are:

a. The WHO should consider updating the guidelines on a regular basis.

b. The WHO should provide leadership and technical direction in defining future research priorities into noise.

c. The WHO should organize workshops on the application of the guidelines

d. The WHO should provide leadership and co-ordinate international efforts to develop techniques for the design of supportive sound environments (e.g. "soundscapes").

e. The WHO should provide leadership for programmes to assess the effectiveness of health-related noise policies and regulations.

f. The WHO should provide leadership and technical direction for the development of sound methodologies for EIAP and EHIAP.

g. The WHO should encourage further investigation into using noise exposure as an indicator of environmental deterioration, such as found in black spots in cities.

h. The WHO should provide leadership, technical support and advice to developing countries, to facilitate the development of noise policies and noise management.

6.3. Research Needs

In the publication entitled "Community Noise", examples of essential research and development needs were given (Berglund & Lindvall 1995). In part, the scientific community has already addressed these issues.

A major step forward in raising public awareness and that of decision makers is the recommendation of the present Expert Task Force to concentrate more on variables which have monetary consequences. **This means that research should consider the dose-response relationships between sound pressure levels and politically relevant variables, such as noise-induced social handicap, reduced productivity, decreased performance in learning, workplace and school absenteeism, increased drug use and accidents.**

There is also a need for continued efforts to understand community noise and its effects on the health of the world population. Below is a list of essential research needs in non-prioritized order. Research priorities may vary over time and by place and capabilities. The main goal in suggesting these research activities is to improve the scientific basis for policy-making and noise management. This will protect and improve the public health with regard to the effects of community noise pollution.

Research related to measurement and monitoring systems for health effects

- Development of a global noise impact monitoring study. The study should be designed to obtain longitudinal data across countries on the health effects on communities of various types of environmental noise. A baseline survey could be undertaken in both developed and developing countries and monitoring surveys conducted every 3-5 years. Since a national map of noise exposure from all sources would be prohibitively expensive, periodic surveys of a representative sample of about 1000 people (using standard probability techniques) could be reliably generalized to the whole population of a country with an accuracy of plus-or-minus 3%. A small number of standard questions could be used across countries to obtain comparative data on the impact of all the main types of noise pollution.

- Development of continuous monitoring systems for direct health effects in critical locations.

- Development of standardized methods for low-cost assessment of local sound levels by measurement or model calculations.

- Development of instruments appropriate for local/regional surveys of people's perceptions of their noise/sound environments.

- Protocols for reliable measurements of high-frequency hearing (8000 Hz and above) and for evaluation of such measures as early biomarkers for hearing impairment/deficits.

Research related to combined noise sources and combined health effects

- Research into the combined health effects of traffic noise, with emphasis on the distribution of sound levels over time and over population sub-environments (time-activity pattern).

- Comprehensive studies on combined noise sources and their combinations of health effects in the 3 large areas of transport (road, rail and aircraft).

- Procedures for evaluating the various health effects of complex combined noise exposures over 24 hours on vulnerable groups and on the general population.

- Methods for assessing the total health effect from noise immission (and also other pollution) in sensitive areas (for example, airports, city centers and heavily-trafficked highways).

Research related to direct and/or long-term health effects (sensitive risk groups, sensitive areas and combined exposures)

- Identification of potential risk groups, including identification of sensitive individuals (such as people with particular health problems; people dealing with complex cognitive tasks; the blind; the hearing impaired; young children and the elderly), differences between sexes, discrimination of risk among age groups, and influence of transportation noise on pregnancy course and on fetal development.

- Studies of dose-response relationships for various effects, and for continuous transportation noise at relatively low levels of exposure and low number of noise events per unit time (including traffic flow composition).
- Studies on the perception of control of noise exposure, genetic traits, coping strategies and noise annoyance as modifiers of the effects of noise on the cardiovascular system, and as causes of variability in individual responses to noise.
- Prospective longitudinal studies of transportation noise that examine physiological measures of health, including standardized health status inventory, blood pressure, neuro-endocrine and immune function.
- Knowledge on the health effects of low-frequency components in noise and vibration.
-

Research related to indirect or after-effects of noise exposure

- Field studies on the effects of exposure to specific sounds such as aircraft noise and loud music, including effects such as noise-induced temporary and permanent threshold shifts, speech perception and misperception, tinnitus and information retrieval
- Studies on the influence of noise-induced sleep disturbance on health, work performance, accident risk and social life.
- Assessment of dose-response relationships between sound levels and politically relevant variables such as noise-induced social handicap, reduced productivity, decreased performance in learning, workplace and school absenteeism, increased drug use and accidents.
- Determination of the causal connection between noise and mental health effects, annoyance and (spontaneous) complaints in areas such as around large airports, heavy-trafficked highways, high-speed rail tracks and heavy vehicles transit routes. The connections could be examined by longitudinal studies, for example.
- Studies on the impact of traffic noise on recovery from noise-related stress, or from nervous system hyperactivity due to work and other noise exposures

Research on the efficiency of noise abatement policies which are health based

- Determination of the accuracy and effectiveness of modern sound insulation (active noise absorption), especially in residential buildings, in reducing the long-term effects of noise on annoyance/sleep disturbance/speech intelligibility. This can be accomplished by studying sites that provide data on remedial activities and changes in behavioral patterns among occupants.
- Evaluation of environmental (area layout, architecture) and traffic planning (e.g. rerouting) interventions on annoyance, speech interference and sleep disturbance.
- Comparative studies to determine whether children and the hearing impaired have equitable access to healthier lives when compared with normal adults in noise-exposed areas.

- Development of a methodology for the environmental health impact assessment of noise that is applicable in developing as well as developed countries.

Research into positive acoustical needs of the general population and vulnerable groups

- Development of techniques/protocols for the design of supportive acoustical environments for the general population and for vulnerable groups. The protocols should take into account time periods that are sensitive from physiological, psychological and socio-cultural perspectives.

- Studies to characterize good "restoration areas" which provide the possibility for rest without adverse noise load.

- Studies to assess the effectiveness of noise policies in maintaining and improving soundscapes and reducing human exposures.

Appendix 1 : Bibliographical References

AAP 1997 Noise: A hazard for the fetus and newborn. American Academy of Pediatrics. Committee on Environmental Health. Pediatrics 100: 724-27.

Altena K 1987 Medische gevolgen van lawaai. Report GA-HR-03-01, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieu, Den Haag, Netherlands.

ANSI 1994 American National Standard Acoustical Terminology. ANSI S1.-1994, American National Standards Institute, Inc., New York, NY, USA.

ANSI 1995 American National Standard Bioacoustical Terminology. ANSI S3.20-1995, American National Standards Institute, Inc., New York, NY, USA.

ANSI 1997 Methods for the Calculation of the Speech Intelligibility Index, American National Standard 3.5, American National Standard Institute, New York, NY, USA.

ASTM 1992 Standard Guide for Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements. ASTM E966, American Society For Testing and Materials, Philadelphia, West Conshohocken, PA, USA.

ASTM 1994a Classification of Rating Sound Insulation, ASTM E413, American Society For Testing and Materials, Philadelphia, PA, USA .

ASTM 1994b Standard Classification for Determination of Outdoor-Indoor Transmission Class, ASTM E1332, American Society For Testing and Materials, Philadelphia, PA, USA.

ASTM 1994c Standard Classification for Determination of Impact Insulation Class (IIC), ASTM E989, American Society For Testing and Materials, Philadelphia, PA, USA.

ASTM 1996 Standard Test Method for Laboratory Measurement of Impact Sound Transmission through Floor-ceiling Assemblies using the Tapping Machine, ASTM E492, American Society For Testing and Materials, Philadelphia, PA, USA.

ASTM 1997 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements. ASTM E90. American Society For Testing and Materials, Philadelphia, PA, USA

Axelsson A, Arvidson I, Jerson T 1986 Hearing in fishermen and coastguards. In R.J. Salvi, D. Henderson, R.P. Hamernik and V. Colletti (eds.), Basic and Applied Aspects of Noise-Induced Hearing Loss, pp. 513-20. Plenum Press, New York.

Axelsson A and Prasher DK 1999. Tinnitus: A warning signal to teenagers attending discotheques? Noise & Health 2: 1-2.

Babisch W 1998a Epidemiological studies on cardiovascular effects of traffic noise. In D. Prasher, D. and L. Luxon, L. (eds.) Advances in Noise Series, Vol. I: Biological Effects, pp. 312-327. Whurr Publishers, London, UK.

Babisch W 1998b Epidemiological studies of cardiovascular effects of traffic noise. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 221-229. Noise Effects '98 PTY Ltd., Sydney, Australia.

Babisch W and Ising H 1989 Zum Einfluss von Musik in Diskotheken auf die Hörfähigkeit von Jugendlichen. Sozial- und Präventivmedizin 34: 239-243.

Babisch W, Ising H, Gallacher JEJ, Sweetnam PM, Elwood PC 1998 The Caerphilly and Speedwell studies, 10 year follow up. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 230-35. Noise Effects '98 PTY Ltd., Sydney, Australia

Babisch W, Ising H, Gallacher JE, Sweetnam PM, Elwood PC 1999 Traffic noise and cardiovascular risk: The Caerphilly and Speedwell studies, third phase 10-year follow up. Archives of Environmental Health 54: 210-216.

Beersma DGM and Altena K 1995 Critical evaluation of the 1992 report of a field study of aircraft noise and sleep disturbance. Newsletter of the European Sleep Research Society 1: 5-7

Bendat JS and Piersol AG 1971 Random Data: Analysis and Measurement Procedures. Wiley, New York, USA

Beranek LL 1971 Noise and Vibration Control. McGraw Hill, New York, USA.

Beranek LL 1989 Balanced Noise Criterion (NCB) Curves. Journal of the Acoustical Society of America 86: 650-664.

Berglund B 1998 Community noise in a public health perspective. In V.C. Goodwin and D.C. Stevenson (eds.) Inter Noise 98. Sound and Silence: Setting the Balance, Vol. 1, pp. 19-24. New Zealand Acoustical Society, Auckland, New Zealand.

Berglund B, Hassmén P, Job RFS 1996 Sources and effects of low-frequency noise. Journal of the Acoustical Society of America. 99: 2985-3002

Berglund B and Lindvall T (Eds.) 1995 Community Noise. Document prepared for the World Health Organization. Archives of the Center for Sensory Research, 2: 1-195. A reprint of this document with corrections of language and references has been published in 1998. The 1995 document can be addressed on the Internet address www.who.int/peh/

Berglund B and Nilsson ME 1997 Empirical issues concerning annoyance models for combined community noise. In F. Augustinovicz (ed.) Inter Noise 97. Help Quiet the World for a Higher Quality Life, Vol. 2, pp. 1053-58. Noise Control Foundation, Poughkeepsie, NY, USA.

Berglund B, Berglund U, Lindvall T 1976 Scaling loudness, noisiness and annoyance of community noise. Journal of the Acoustical Society of America 60: 1119-1125.

Berglund B, Berglund U, Lindberg S 1986 Loudness of impulse sound from different weapons. In R. Lotz (ed.) Inter Noise '86, Vol. II, pp. 815-20. Noise Control Foundation, New York, USA..

Berry BF 1995 Towards a standardised descriptor of impulsive noise caused by low-altitude military aircraft". In R.J. Bernhard and S. Bolton (ed.) Inter Noise '95, Vol. 2, pp. 879-884. Noise Control Foundation, Poughkeepsie, NY, USA

Bishop DE and Horonjef RD 1967 Procedures for Developing Noise Exposure Forecast Areas for Aircraft Flight Operations. FAA Report DS-67-10 (August 1967), Washington DC, USA.

Blazier WE 1998 RC Mark II: A refined procedure for rating the noise of heating, ventilating, and air-conditioning (HVAC) systems in buildings. Noise Control Engineering Journal 45: 243-250

Bradley JS 1978 Predictors of Adverse Human Responses to Traffic Noise. Proceedings of the ASTM Symposium on Community Noise, Kansas City, pp. 108-123.

Bradley JS 1985 Uniform derivation of optimum conditions for speech in rooms. National Research Council, Building Research Note, BRN 239, Ottawa, Canada.

Bradley JS 1986a Predictors of Speech Intelligibility in Rooms. Journal of the Acoustical Society of America 80: 837-845.

Bradley JS 1986b Speech Intelligibility Studies in Classrooms. Journal of the Acoustical Society of America 80: 846-854.

Bradley JS 1986c Optimum Conditions for Speech in Rooms. Proceedings of the 12th International Congress on the Acoustics, Paper E10-5, Toronto, Canada.

Bradley JS 1993 Disturbance Caused by Residential Air Conditioner Noise. Journal of the Acoustical Society of America 93: 1978-1986

Bradley JS 1994a On dose response curves of annoyance to aircraft noise. In S. Kuwano (Ed.), Inter-Noise 94. Noise Quantity and Quality. Vol 1, pp. 235-38. Noise Control Foundation, Poughkeepsie, NY, USA.

Bradley JS 1994b Annoyance Caused by Constant-Amplitude and Amplitude- Modulated Sounds Containing Rumble. Noise Control Engineering Journal 42: 203-208.

Bradley, J.S. 1996. Determining acceptable limits for aviation noise. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96, Noise Control – The Next 25 Years, Book 5, pp. 2541-46. Institute of Acoustics, St Albans, UK.

Bradley JS, Vaskor JG, Dickinson SM 1979 The Effect of Skewness and Standard Deviation on Sampling Errors for Traffic Noise. Applied Acoustics 12: 397-409.

Broner N and Leventhall HG 1993 A Modified PNdB for Assessment of Low Frequency Noise. Journal of Sound and Vibration 73: 425-444.

Brookhouser PE, Worthington DW, Kelly WJ 1992 Noise-induced hearing loss in children. Laryngoscope 1992: 102: 645-655.

Brown AL 1994 Exposure of the Australian population to road traffic noise. Applied Acoustics, 43: 169-176.

Buchta E 1996 A field study on annoyance caused by shooting noise – Determination of the penalty for various weapon calibers. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96, Noise Control -- The Next 25 Years, Book 5, pp. 2495-2500. Institute of Acoustics, St Albans, UK

Bullen RB and Hede AJ 1983 Time of Day Corrections in Measures of Aircraft Noise Exposure. Journal of the Acoustical Society of America 73: 1624-1630.

Burns W 1968 Noise and Man. John Murray, London, UK

Carter NL 1996 Transportation noise, sleep, and possible after-effects. Environment International 22: 105-116

Carter NL and Hunyor SN 1991 A field study of traffic noise and cardiac arrythmia during sleep. In: Technical Papers: 4th Western Pacific Regional Acoustics Conference, pp. 165-172. Queensland Department of Environment and Heritage, Brisbane, Australia.

Carter NL, Hunyor SN, Crawford G, Kelly D, Smith AJ 1994a Environmental noise and sleep - a study of arousals, cardiac arrhytmia and urinary catecholamines. Sleep 17: 298-307.

Carter NL, Ingham P, Tran K, Hunyor S 1994b A field study of the effects of traffic noise on heart rate and cardiac arrhythmia during sleep. Journal of Sound and Vibration, 169, 221-227.

CEC 1992a Towards Sustainability: A European Community Programme of Policy and Action in Relation to the Environment and Sustainable Development. COM (92) 23 Final -- Vol. II. Office for Official Publications of the European Communities, Luxembourg.

CEC 1992b The Impact of Transport on the Environment: A Community Strategy for "Sustainable Mobility". COM (92) 46 Final. Office for Official Publications of the European Communities, Luxembourg .

CEC 1996. Future Noise Policy. European Commission Green Paper. COM(96) 540 Final Office for Official Publications of the European Communities, Luxembourg.

Chakrabarty D, Santra SC, Mukherjee, A 1997. Status of road traffic noise in Calcutta metropolis, India. Journal of the Acoustical Society of America 101: 943-949.

CMD (1997) Taber's Cyclopedic Medical Dictionary, edition 18, FA Davis Company, Philadelphia.

Cohen S 1980 Aftereffects of stress on human performance and social behavior: A review of research and theory. Psychological Bulletin. 88: 82-108

Cohen S, Evans GW, Krantz DS, Stokols D 1980 Physiological, motivational, and cognitive effects of aircraft noise on children. American Psychologist 35: 231-243

Cohen S, Evans GW, Stokols D, Krantz DS 1986 Behavior, Health and Environmental Stress. Plenum Press, New York.

Crocker MJ and Price AJ 1975 Noise and Noise Control. Volume I, CRC Press, Cleveland USA

Daigle GA, Embleton TFW, Piercy JE 1986 Propagation of Sound In the Presence of Gradients and Turbulence Close to the Ground. Journal of the Acoustical Society of America 79: 613-627

DEAT 1989 Environment Conservation Act (Act No. 73 of 1989) Noise Control Regulations, Ministry of Environmental Affairs and Tourism, Pretoria, South Africa.

DeKoning HW 1987 Setting Environmental Standards. Guidelines for Decision-Making. World Health Organization, Geneva, Switzerland.

DIMD 1985 Dorland's illustrated medical dictionary, 26th edition, Saunders, Philadelphia [etc.], USA

DiMento JS 1981 Making usable information on environmental stressors: Opportunities for the research and policy communities. Journal of Social Issues 37:172-204.

DoTRS 1999 What is an ANEF? Commonwealth of Australia 1999, Department of Transport and Regional Services. Internet address:
http://www.dotrs.gov.au/airports/avenv/noise/anef.htm

Edworthy J 1998 Warning people through noise. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98). Vol. 1, pp. 147-56. Noise Effects '98 PTY Ltd., Sydney, Australia.

Edworthy J and Adams AS 1996 Warning Design: A Research Perspective. Taylop and Francis. London

EEA 1995 Europe's Environment. The Dobris Assessment. D. Stanners, P. Bourdeau (Eds.), European Environment Agency, Copenhagen, Denmark.

Embleton TFW and Piercy JE 1976 Outdoor Sound Propagation Over Ground of Finite Impedance. Journal of the Acoustical Society of America 59: 267-277

EU 1970 Council Directive on the approximation of the laws of the Member States relating to the permissible sound level and the exhaust system of motor vehicles. Directive 70/157/EEC of 6 February 1970. Official Journal L 42 (23.2.1970), p. 16. Amended by 73/350/EEC of 7.11.1973; Official Journal L 321 (22.11.1973), p. 33. Amended by 77/212/EEC of 8.3.1977; Official Journal L 66 (12.3.1977), p. 33. Amended by 81/334/EEC of 13.4.1981; Official Journal L 131 (18.5.1981), p. 6. Amended by 84/424/EEC of 03.09.1984, Official Journal L 238 (06.09.84) p. 31. Amended by 87/354/EEC of 3/87; Official Journal L 192 (11.07.87) p. 43. Amended by 89/491/EEC of 3/89; Official Journal L 238 (15.08.89) p. 43. Amended by 92/97/EEC of 10.11.92; Official Journal L 371 (19.12.92) p. 1. Amended by 96/20/EEC of 27.03.1996; Official Journal L 92 (13.04.96) p. 23, Brussels, Belgium.

EU 1978 Council Directive on the approximation of the laws of the Member States on the permissible sound level and exhaust system of motorcycles. Directive 78/1015/EEC of 23 November 1978. Official Journal L 349 (13.12.1978), p. 21. Brussels, Belgium. (Directive 78/1015/EEC is superseded by 97/24/EC, see EU 1997).

EU 1980 Council Directive on the limitation of noise emissions from subsonic airplanes. Directive 80/51/EEC of 20 December 1979. Official Journal L 18 (24.01.80) p. 26, Brussels, Belgium.
EU 1984a Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of compressors. Directive 84/533/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 123. Amended by 85/406/EEC of 11.7.1985. Official Journal L 233 (30.8.1985), p. 11, Brussels, Belgium.
EU 1984b Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of tower cranes. Directive 84/534/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 123. Amended by 87/405/EEC of 25.6.1987. Official Journal L 220 (8.8.1987) p. 60, Brussels, Belgium.
EU 1984c Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of welding generators. Directive 84/535/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 142. Amended by 85/407/EEC of 11.7.1985.Official Journal L 233 (30.8.1985), p. 16, Brussels, Belgium.
EU 1984d Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of power generators. Directive 84/536/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 149. Amended by 85/408/EEC of 11.7.1985. Official Journal L 233 (30.8.1985), p. 18, Brussels, Belgium.
EU 1984e Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of powered hand-held concrete-breakers and picks. Directive 84/537/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 156. Amended by 85/409/EEC of 11.7.1985. Official Journal L 233 (30.8.1985), p. 20, Brussels, Belgium.
EU 1984f Council Directive on the approximation of the laws of the Member States relating to the permissible sound power level of lawnmowers. Directive 84/538/EEC of 17 September 1984. Official Journal L 300 (19.11.1984), p. 171. 87 Amended by 87/ 252/EEC of 7.4.87 Official Journal L 117 (5.5.1987), p. 22. Amended by 88/80/EEC of 22.3.1988. Official Journal L 81 (26.3.1988), p. 69. Amended by 88/181/EEC of 22.3.1988 Official Journal L 81 (26.3.1988), p. 71, Brussels, Belgium.
EU 1986a Council Directive on the protection of workers from the risks related to exposure of noise at work. Directive 86/188/EEC of 12.5.1986. Official Journal L 137 (24.5.1986), p. 28, Brussels, Belgium.
EU 1986b Council Directive on the limitation of noise emitted by hydraulic excavators, rope-operated excavators, dozers, loaders and excavator-loaders. Directive 86/662/EEC of 22.12.1986 as amended by the Directive of 2.8.1989. Official Journal L 384 (31.12.1986), p. 1. L 253 (30.8.1989), p. 35, Brussels, Belgium.
EU 1986c Council Directive on airborne noise emitted by household appliances. Directive 86/594/EEC of 1.12.1986 Official Journal L 344 (6.12.1986), p. 24, Brussels, Belgium.
EU 1989 Council Directive on the limitation of noise emission from civil subsonic jet aeroplanes. Directive 89/629/EEC of 04 December1989 Official Journal L 363 (13.12.89) p. 27, Brussels, Belgium.
EU 1996a Council Directive to adapt in the light of technical progress Directive 70/157/EEC of 6 February 1970 on the approximation of the laws of the Member States regarding permissible sound levels and exhaust systems of motor vehicles. Directive 96/20/EC of 27.03.1996. Official Journal L 92 (13.04.96) p. 23, Brussels, Belgium.

EU 1996b b Future Noise Policy -- European Commission Green Paper Report COM (96) 540 final. Commission of the Euopean Communities, Brussels.
EU 1997 Directive on certain components and charactristics of two or three-wheel motor vehicles Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997. Official Journal L 226 1997. Brussels, Belgium.
Evans GW 1998 Motivational consequences of exposure to noise. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98). Vol. 1, pp. 311-320. Noise Effects '98 PTY Ltd., Sydney, Australia.
Evans GW and Lepore SJ 1993 Non-auditory effects of noise on children: A critical review. Children's Environments 10: 31-51.
Evans GW and Maxwell L 1997 Chronic noise exposure and reading deficits. Environment and Behavior 29: 638-656.
Evans GW, Hygge S, Bullinger M 1995 Chronic noise and psychological stress. Psychological Science 6: 333-338.
Evans GW, Bullinger M, Hygge S 1998 Chronic noise exposure and physiological response: A prospective study of children living under environmental stress. Psychological Science 9. 75-77.
Faiz A, Sinha. K, Wals, M and Valma, A 1990: Automotive air pollution: Issues and options for developing countries. WPS 492, World Bank, Washington. USA
Falkemark G 1997 Trafikpolitiken, makten och miljön [Traffic politics, power and the environment]. I H B. Andersson (Red.), Trafik och miljö [Traffic and the Environment]. Kommunikationsforskningsberedningen [Swedish Transport and Communications Research Board], Stockholm, Sweden.Fechter LS 1999 Mechanisms of ototoxicity by chemical contaminants. Prospects for intervention. Noise and Health, 2: 10-27
Fidell S and Jones G 1975 Effects of cessation of late night on an airport community. Journal of Sound and Vibration, 42:411-427
Fidell S, Barber, DS, Schultz TJ 1991 Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise. Journal of the Acoustical Society of America 89: 221-233.
Fidell S, Pearsons K, Tabachnick B, Howe R, Silvati L, Barber DS 1995a Field study of noise-induced sleep disturbance. Journal of the Acoustical Society of America 98 (2 PART 1): 1025-1033
Fidell S, Howe R, T Tabachnick BG, Pearsons KS. Sneddon MD 1995b Noise-induced sleep disturbance in residences near two civil airports. NASA Contractor Report 198252. NASA Langley Research Center, Hampton VA, USA.
Fidell S, Howe R, Tabachnick B, Pearsons K, Silvati L, Sneddon M, Fletcher E 1998 Field studies of habituation to change in night-time aircraft noise and of sleep motility measurement methods. BBN Report 8195, BNN Systems and Technologies Corporation, Canogan Park, California, USA.
Fidell S, Pearsons K, Howe R et al. 1994 Noise-induced sleep disturbance in residential settings. BNN Report 7932. BNN Systems and Technologies Corporation, Canoga Park, California. USA.
Fields JM 1986 Cumulative Airport Noise Exposure Metrics: An Assessment of Evidence for Time-of-Day Weightings. US FAA Report, DOT/FAA/EE-86/10. United States Federal Aviation Administration, Washington D.C., USA.

Fields JM 1990 A quantitative summary of non-acoustical variables' effects on reactions to environmental noise. In: Noise Con 90, pp. 303-308. Noise Control Foundation, Poughkeepsie, NY, USA

Fields JM 1993 Effects of personal and situational variables on noise annoyance in residential areas. Journal of the Acoustical Society of America 93: 2753-2763

Fields JM 1994 A Review of an Updated Synthesis of Noise/Annoyance Relationships. NASA Contractor Report 194950, National Aeronautics and Space Administration, Langley Research Center, Hampton, VA, USA.

Fields JM 1998 Reactions to environmental noise in an ambient noise context in residential areas. Journal of the Acoustical Society of America 104: 2245-2260.

Fields JM, de Jong RG, Brown AL, Flindell IH, Gjestland T, Job RFS, Kurra S, Lercher P, Schuemer-Kors A, Vallet M, Yano M 1997 Guidelines for reporting core information from community noise reaction surveys. Journal of Sound and Vibration 206: 685-695.

Fields JM, de Jong RG, Flindell IA, Gjestland T, Job R.S, Kurra S, Schuemer-Kors,A, Lercher P, Vallet M, Yano T 1998 Recommendation for shared annoyance questions in noise annoyance surveys. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98.), Vol. 1, pp. 481-86. Noise Effects '98 PTY Ltd., Sydney, Australia.

Finegold LS, Harris CS, von Gierke HE 1994. Community annoyance and sleep disturbance: Updated criteria for assessing the impacts of general transportation noise on people. Noise Control Engineering Journal, 42: 25-30.

Finegold LS, von Gierke HE, McKinley RL and Schomer PD 1998 Addressing the effectiveness of noise control regulations and policies In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2, pp. 719-24. Noise Effects '98 PTY Ltd., Sydney, Australia.

Finegold LS, von Gierke HE, Schomer PD, Berry BF 1999 Proposal for monitoring worldwide noise exposure and assessing the effectiveness of noise exposure policies and noise control technologies. In: J. Cuschieri, S. Glegg, Yan Yong (eds.) Internoise 99 -- The 1999 International Congress on Noise Control Engineering, 6-8 December 1999, Fort Lauderdale, Florida, USA, pp. 1917-1922.

Finke H-O 1980 Akustische Kennwerte für die Messung und Beurteilung von Geräuschimmissionen und deren Zusammenhang mit der subjektiven Gestörtheit. Dissertation of Technical University, Braunschweig, Germany.

Flindell IH and Stallen, PJM 1999 Non-acoustical factors in environmental noise. Noise and Health 3: 11-16.

Florentine M, Buus S, Poulsen T 1996. Temporal integration of loudness as a function of level. Journal of the Acoustical Society of America. 99, 1633-44.

Ford RD 1987 Physical assessment of transportation noise. In P.M. Nelson (ed.) Transportation Noise Reference Book. Butterworth, London, UK

Franks JH 1998 Preventing noise-induced hearing loss: A perspective view from the next millennium. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98.), Vol. 1, pp. 11-16. Noise Effects '98 PTY Ltd., Sydney, Australia..

Freeman K 1984 Mental Health and the Environment. Churchill Livingstone, London, UK.

French NR and Steinberg JC 1947 Factors governing the intelligibility of speech sounds. Journal of the Acoustical Society of America 19:90-119.

Gjestland T, Liasjø K, Granøien I, Fields JM 1990 Response to Noise Around Oslo Airport Fornebu. ELAB-RUNIT Report No. STF40 A90189, Trondheim, Norway

Globus G, Friedmann J, Cohen H, Pearsons SK, Fidell S 1974 The effects of aircraft noise on sleep electrophysiology as recorded in the home. In: Noise as a Public Health Problem. US Environmental Protection Agency. Report EPA 550/9-73.008. pp. 587-591. Washington DC, USA.

Goldstein M 1994 Low-frequency components in complex noise and their perceived loudness and annoyance. Arbete & Haelsa 1994: 2 (Work and Health; Scientific Journal of the National Institute of Occupational Health, Solna, Sweden)

Gottlob D 1995 Regulations for community noise. Noise/News International, December 1995, pp.223-236

Griefahn B 1977 Long-term exposure to noise. Aspects of adaptation, habituation and compensation. Waking and Sleeping. 1:383-386.

Griefahn B 1990a Präventivmedizinische Vorschläge für den nächtlichen Schallschutz [Proposal for protection against noise during night from the point of view of preventive medicine]. Zeitschrift für Lärmbekämpfung 37: 7-14.

Griefahn B 1990b Sleeping in noisy environments: effects, limits and preventative measures. In: JA Horne (ed) Sleep 1990, pp. 391-93, Pontenagel Press. Bochum, Germany.

Griefahn B, Mehnert P, Moehler U, Schuemer-Kohrs A, Schuemer R 1996 Design of a field study on the effects of railway noise and road traffic noise. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96. Noise Control – The Next 25 Years, Book 4, pp. 2183-88. Institute of Acoustics. St Albans, UK.

Griefahn B, Deppe C, Mehnert P, Moog R, Moehler U, Schuemer R 1998 What nighttimes are adequate to prevent noise effects on sleep? In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2, pp. 445-450. Noise Effects '98 PTY Ltd., Sydney, Australia

Griffiths ID 1983 Review of Community Response to Noise. In G. Rossi, (ed.). Noise as a Public Health Problem, Vol. 2, pp. 1031-1047. Milano, Italy: Centro Ricerche e Studi Amplifon.

Guski R 1987 Lärm-Wirkungen unerwünschter Geräusche. Huber, Bern, Switzerland.

Haines M, Stansfeld SA, Job RFS, Berglund B 1998 Chronic aircraft noise exposure and child cognitive performance and stress. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 329-336. Noise Effects '98 PTY Ltd., Sydney, Australia.

Hall FL, Birnie SE, Taylor SM, Palmer JE 1981 Direct Comparison of Community Response to Road Traffic Noise and to Aircraft Noise. Journal of the Acoustical Society of America 70: 1690-1698.

Hall FL, Taylor SM, Birnie SE 1985 Activity interference and noise annoyance. Journal of Sound and Vibration 103: 237-252.

Halpern D 1995 Mental Health and the Built Environment. More than Bricks and Mortar? Taylor and Francis Ltd, London, UK.

Hanner P and Axelsson A 1988 Acute acoustic trauma. Scandinavian Audiology 17: 57-63

Harris CM 1991 Handbook of Acoustical Measurements and Noise Control. Mc Graw Hill, New York. USA.

Hasan S and Beg MHA 1994 Noise induced hearing loss in industrial workers of Karachi. Pakistan Journal of Otolaryngology 10: 200-205.

Hasan S and Zaidi SH 1997 The prevalence of noise induced hearing loss in industrial (textile) workers of Karachi. Thesis. University of Karachi. Karachi. Pakistan

HCN 1994 Noise and Health. Publication No 1994/15E, Health Council of the Netherlands. The Hague, Netherlands

HCN 1997 Assessing noise exposure for public health purposes. Publication no. 1997/23E. Health Council of the Netherlands, Rijswijk, Netherlands

Hede A 1998a Environmental noise regulation: A public policy perspective. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2, pp. 687-96. Noise Effects '98 PTY Ltd., Sydney, Australia

Hede, A 1998b: Towards a normative model of public policy for environmental noise. Acoustics Australia, 26, 95-100

Hellstrom PA, Dengerink HA, Axelsson A 1992 Noise levels from toys and recreational articles for children and teenagers. British Journal of Audiology, 26. 267-270.

Hetu R and Fortin M 1995 Potential risk of hearing damage associated with exposure to highly amplified music. Journal of the American Academy of Audiology 6: 378-386.

Hobson JA 1989 Sleep. Scientific American Library, W.H. Freeman and Co, New York, NY, USA.

Holmes G, Singh B.R. and Theodore L. 1993. Handbook of environmental management and technology. Wiley, New York.

Horne JA, Pankhurst FL, Reyner LA, Hume K, Diamond ID 1994 A field study of sleep disturbance: Effects of aircraft noise and other factors on 5,742 nights of actimetrically monitored sleep in a large subject sample. Sleep 17: 146-159.

House ME 1987 Measurement and Prediction of Aircraft Noise. In P.M. Nelson (ed.) Transportation Noise Reference Book, Butterworth, London.

Houtgast T 1981 The Effect of Ambient Noise on Speech Intelligibility in Classrooms. Applied Acoustics 14: 15-25.

Houtgast T and Steeneken, HJM. 1983. Experimental verification of the STI: A valid basis for setting indoor noise level criteria. In G. Rossi (ed.), Noise as a Public Health Problem. Vol. 1. pp. 477-487, Centro Ricerche e Studi Amplifon, Milano, Italy.

Houtgast T and Steeneken JM 1985 A Review of the MTF Concept in Room Acoustics and Its Use for Estimating Speech Intelligibility in Auditoria. Journal of the Acoustical Society of America 77. 1069-1077.

Humes LE, Dirks DD, Bell TS, Ahlstrom C, Kincaid GE 1986 Application of the Artic-ulation Index and the Speech Transmission Index to the recognition of speech by normal-hearing and hearing-impaired listeners. Journal of Speech Hearing Research, 29:447-462.

Hygge S, Evans GW, Bullinger M 1996 The Munich airport noise study. Cognitive effects on children from before to after the change over of airports. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96. Noise Control – The Next 25 Years, Vol. 5, pp. 2189-92, Institute of Acoustics, St Albans, UK.

Hygge S, Jones DM, Smith AP 1998 Recent developments in noise and performance. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 321-28, Noise Effects '98 PTY Ltd., Sydney, Australia.

ICAO 1993 International Standards and Recommended Practices: Environmental Protection. Annex 16, Volume 1: "Aircraft Noise". Annex 16 (Chapter 2 and 3) to the Convention on International Civil Aviation. International Civil Aviation Organization. [Air Navigation (Noise Certification) Order 1990 -Statutory Instrument 1514], Montreal, Canada.

IEC 1979 Sound Level Meters. IEC Publication 651, International Electrotechnical Commission, Geneva, Switzerland.

IEC 1988 Sound system equipment, part 16: The objective rating of speech intelligibility in auditoria by the RASTI method. IEC Publication 268-16, International Electrotechnical Commission, Geneva, Switzerland.

IEH 1997. The Non-Auditory Effects of Noise. IEH Report R10. Institute for Environment and Health, Leicester, UK

Irle M 1975 Is aircraft noise harming people? In M. Deutsch and H.A. Hornstein (eds.), Applying Social Psychology, pp. 115-138, Erlbaum, Hillsdale, NJ, USA.

Ising H and Gunther T 1997 Interaction between noise-induced stress and magnesium losses relevance for long-term health effects. In F. Augustinovicz (ed.), Inter Noise 97. Help Quiet the World for a Higher Quality Life, Vol. 2, pp. 1099-1104. Noise Control Foundation, Poughkeepsie, NY, USA.

Ising H, Babisch W, Kruppa B 1998 Acute and chronic noise stress as cardiovascular risk factors. Federal Environmental Agency, Berlin, Germany.

Ising H, Babisch W, Gandert J, Scheuermann B 1988 Hörschäden bei jugendlichen Berufsanfängern aufgrund von Freizeitlärm und Musik. Zeitschrift für Lärmbekämpfung, 35:35-41

Ising H, Hanel J, Pilgramm M et al 1994 Gehörschadensrisiko durch Musikhören mit Kopfhörern. Hals-Nasen-Ohren 1994; 42:764-8.

ISO 1975a Acoustics-Method for Calculating Loudness Level. ISO-532-1975 (E), International Organization for Standardization, Geneva, Switzerland.

ISO 1975b Acoustics-Preferred Frequencies for Measurements. International Standard ISO 266-1975 (E), International Organization for Standardization, Geneva, Switzerland

ISO 1978 Laboratory Measurement of Airborne Sound Insulation of Building Elements – Part V, Field Measurements of Airborne Sound Insulation of Façade Elements and Facades", International Standard ISO-140/V, International Organization for Standardization, Geneva, Switzerland

ISO 1982 Acoustics – Description and measurement of environmental noise – Part 1: Basic quantities and procedures. International Standard ISO 1996-1, International Organization for Standardization, Geneva, Switzerland.

ISO 1987a Acoustics-Normal Equal Loudness Contours. International Standard ISO 226-1-1987 (E), International Organization for Standardization, Geneva, Switzerland.

ISO 1987b Acoustics – Description and measurement of environmental noise – Part 3: Application to noise limits. International Standard ISO 1996-3:1987(E), International Organization for Standardization, Geneva, Switzerland.

ISO 1990 Acoustics-Determination of occupational noise exposure and estimation of noise-induced hearing impairment. International Standard ISO 1999, International Organization for Standardization, Geneva, Switzerland.

ISO 1994 Quality systems – Model for quality assurance in production, installation and servicing. International Standard ISO 9002, International Organization for Standardization, Geneva, Switzerland.

ISO 1995 Laboratory Measurement of Airborne Sound Insulation of Building Elements – Part III: Laboratory Measurements of Airborne Sound Insulation of Building Elements. International Standard ISO-140/III. International Organization for Standardization, Geneva, Switzerland .

ISO 1996a Acoustics – Rating of Sound Insulation in Buildings and of Building Elements - Part 1: Airborne Sound Insulation. International Standard ISO 717-1. International Organization for Standardization, Geneva, Switzerland.

ISO 1996b Environmental management systems - specification with guidance for use. International Standard ISO 14001. International Organization for Standardization, Geneva, Switzerland

ISO 1996c Environmental management systems - general guidelines on principles, systems and supporting techniques. International Standard ISO 14004. International Organization for Standardization, Geneva, Switzerland.

ISO 1998 Measurement of Sound Insulation in Buildings and of Building Elements – Part VI: Laboratory Measurements of impact sound insulation of floors. International Standard ISO-140/VI, International Organization for Standardization, Geneva, Switzerland.

Jansen G 1986 Zur "erheblichen Belästigung" und "Gefährdung" durch Lärm. Zeitschrift für Lärmbekämpfung 33:2-7.

Jansen G 1987 Verkehrslärmwirkungen bei besonderen Personengruppen. Zeitschrift für Lärmbekämpfung 34: 152-156

Jansen G 1998 Health concepts and noise effects. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2, pp. 697-702. Noise Effects '98 PTY Ltd., Sydney, Australia.

Jansen G and Gottlob D 1996 Requirements for the protection against outdoor noise in various countries with respect to standardization and regulations. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96. Noise Control – The Next 25 Years, Book 6, pp. 3343-3346. Institute of Acoustics, St Albans, UK

Jenkins LM, Tarnopolsky A, Hand DJ 1981 Psychiatric admissions and aircraft noise from London Airport: Four-year, three hospitals' study. Psychological Medicine 11: 765-782

Job RFS 1988 Community response to noise: A review of factors influencing the relationship between noise exposure and reaction. Journal of the Acoustical Society of America 83: 991-1001.

Job RFS 1993 Psychological factors of community reaction to noise. In M. Vallet (ed.) Noise as a Public Health Problem. Vol. 3, pp. 48-59. INRETS - Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France

Job RFS 1996 The influence of subjective reactions to noise on health effects of the noise. Environment International 22: 93-104.

Kabuto M and Suzuki S 1976 A trial measurement of individual noise exposure by time-zone in a day. Japanese Journal of Industrial Health, 18: 17-22.

Kabuto M, Ohtsuka R, Suzuki S 1978 Measurement and evaluation of individual noise exposure level of Tokyo metropolitan commuters in railroad cars above ground and in subways. Japanese Journal of Public Health, 2: 59-63.

Kageyama T, Kabuto M, Nitta H, Kurokawa Y, Taira K, Suzuki S, Takemoto T 1997 A populations study on risk factors for insomnia among adult Japanese women: A possible effect of road traffic volume. Sleep 20: 963-971.

Kastka J, Buchta E, Ritterstaedt U, Paulsen R, Mau U 1995 The long term effect of noise protection barriers on the annoyance response of residents. Journal of Sound and Vibration. 184: 823-852.

Katz J. (ed.) 1994 Handbook of Clinical Audiology. Fourth edition, Williams and Wilkins Baltimore, ML, USA.

Kerry G, Lomax C, and James DJ 1997 Assessment and Relevance of methods for calculating onset rate of low altitude flight noise. In F. Augustinovicz (ed.), Inter Noise 97. Help Quiet the World for a Higher Quality Life. vol. 3, pp. 1227-30. Noise Control Foundation, Poughkeepsie, NY, USA.

Kjellberg A, Goldstein M. and Gamberale F 1984 An Assessment of dBA for Predicting Loudness and Annoyance of Noise Containing Low Frequency Components. Journal of Low Frequency Noise and Vibration 3: 10-16.

Klæboe R, Kolbenstvedt M. Lercher P. and Solberg S 1998 Changes in noise reactions– Evidence for an area-effect? In V.C. Goodwin and D.C. Stevenson (eds.) Inter Noise 98. Sound and Silence: Setting the Balance. Vol. 2, pp. 1133-36. New Zealand Acoustical Society, Auckland, New Zealand.

Koelega HS (ed.) 1987 Environmental Annoyance: Characterization, Measurement, and Control. Elsevier, Amsterdam, Netherlands.

Kremer L 1950 Die Wissenschaftliche Grundlagen der Raumakustik. Band III. Hirzel

Verlag, Leipzig

Kryter KD 1959 Scaling Human Reaction to the Sound from Aircraft. Journal of the Acoustical Society of America 31: 1415-1429.

Kryter KD 1994 The Handbook of Noise and Hearing. Academic Press, San Diego, CA, USA.

Kutscheidt E 1989 Rechtsprobleme bei der Bewertung von Geräuschimmissionen. Neue Zeitschrift für Verwaltungsrecht 3:193-199.

Kuwano S, Namba S, and Mizunami T 1998 The effect of noise on the effort to sleep. In V.C. Goodwin and D.C. Stevenson (eds.) Inter Noise 98. Sound and Silence: Setting the Balance, Vol. 2, pp. 1083-1086. New Zealand Acoustical Society, Auckland, New Zealand.

Lara Sáenz A and Stephens RWB (eds.) 1986 Noise Pollution. Wiley, Chichester, UK

Lambert J and Vallet M 1994 Study Related to the Preparation of a Communication on a Future EC Noise Policy. INRETS LEN Report No. 9420, INRETS - Institut National de REcherche sur les Transports et leur Sécurité, Bron, France.

Lang J 1986 Assessment of noise impact on the urban environment. A study on noise prediction models. Environmental Health Series 9, Regional Office for Europe, World Health Organization, Copenhagen, Denmark.

Lang J 1995 Noise abatement regulations and strategies. In: Noise - Selected presentations of an Informal Regional Consultation Meeting on Noise Pollution, 2-5 September 1991, Amman, Jordan, Eastern Mediterranean Regional Office, Regional Centre for Environmental Health Activities (CEHA), Amman, Jordan.

Lang WW 1999 Is noise policy a global issue, or is it a local issue? In: J. Cuschieri, S. Glegg, Yan Yong (eds.) Internoise 99 – The 1999 International Congress on Noise Control Engineering, 6-8 December 1999, Fort Lauderdale, Florida, USA, pp. 1939-1943.

Large JB and House ME 1989 The effect on aviation noise of the single European market. In G.C. Maling, Jr (ed.), Inter-Noise 89, Vol. 1, pp. 695-700. Noise Control Foundation, Poughkeepsie, NY, USA.

Lazarus H 1990 New methods for describing and assessing direct speech communication under disturbing conditions. Environment International 16: 373-392.

Lazarus H 1998 Noise and communication: The present state. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 157-162. Noise Effects '98 PTY Ltd., Sydney, Australia

Lercher P 1996 Environmental noise and health: An integrated research perspective. Environment International 22: 117-129.

Lercher P 1998a Context and coping as moderators of potential health effects in noise-exposed persons. In D. Prasher and L. Luxon, (Eds.), Advances in Noise Series. Vol. 1: Biological Effects, pp. 328-335, Whurr Publishers, London, UK.

Lercher P 1998b Deviant dose-response curves for traffic noise in "sensitive areas"? In V.C. Goodwin and D.C. Stevenson (eds.) Inter Noise 98. Sound and Silence: Setting the Balance, Vol. 2, pp. 1141-1144. New Zealand Acoustical Society, Auckland, New Zealand.

Lercher P, Stansfeld SA, Thompson SJ 1998 Non-auditory health effects of noise: Review of the 1993-1998 period. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 213-220. Noise Effects '98 PTY Ltd., Sydney, Australia.

Lindemann HE, van der Klaauw MM, Platenburg-Gits FA 1987 Hearing acuity in male adolescents at the age of 17 – 23 years. Audiology 26: 65-78.

Lindvall T and Radford EP (eds.) 1973 Measurement of annoyance due to exposure to environmental factors. Environmental Research 6:1-36

London Charter 1999 Charter on Transport, Environment and Health. Final version prepared following the Fourth Preparatory Meeting on "Transport, environment and Health, Vienna, 15-17 March 1999. EUR/ICP/EHCO 02 02 05/9 Rev.4 - 09009 – 16 June 1999. Regional Office for Europe, European Centre for Environment and Health, Rome Division, World Health Organization. Rome, Italy. Internet address: http://www.who.it/london_conference/teh.htm.

Lutman ME and Haggard MP (eds.) 1983 Hearing Science and Hearing Disorders. Academic Press, London, UK.

Mage, D and Walsh, M 1998: Case studies from cities around the world. In: Urban Traffic Pollution, eds. D. Schwela and O. Zali, E & Spon, London, UK.

Maschke C 1992 Der Einfluss von Nachtlärm auf den Schlafverlauf und die Katecholaminenausscheidung. Technische Universität Berlin, Germany.

Maschke C, Arndt D, Ising H, et al. 1995 Nachtfluglärmwirkungen auf Anwohner. DFG-Forschungsbericht Gr. 452/8-2. Gustav Fischer Verlag, Stuttgart, Germany.

Miedema HME 1987 Annoyance from Combined Noise Sources. In H. S. Koelega (ed.), Environmental Annoyance: Characterization, Measurement and Control, pp. 313-320, Elsevier, Amsterdam, The Netherlands.

Miedema HME 1993 Response Functions for Environmental Noise. In M. Vallet (ed.) Noise as a Public Health Problem, Vol. 3, pp. 428-433, INRETS - Institut National de Recherche sur les Transports et leur Sécurité, Arcueil Cedex, France.

Miedema HME 1996 Quantification of Annoyance Caused by Environmental Noise and Odor. TNO, Leiden, Netherlands

Miedema HME, Vos H 1998 Exposure response functions for transportation noise. Journal of the Acoustical Society of America 104: 3432-3445.

Miller JD 1978 General psychological and sociological effects of noise. In E.C. Carterette and M.P. Friedman (eds.), Handbook of Perception. Vol. VI: Hearing (pp. 641-676). Academic Press, New York NZ. USA

Moehler U Community response to railway noise: A review of social surveys. Journal of Sound and Vibration 120: 321-332.

Molino JA 1974 Equal aversion levels for pure tones and 1/3 octave bands of noise. Journal of the Acoustical Society of America 55: 1285-1289

National Environment Board of Thailand 1990 Air and noise pollution in Thailand 1989. Bangkok.

NRC-CNRC 1994 NEF Validation Study. (2) Review of Aircraft Noise and its Effects. Contract Report A-1505.5 (Final). Institute for Research in Construction, Ottawa, Canada.

OECD 1991 Fighting Noise in the 1990's. Organisation for Economic Co-operation and Development, Paris, France.

OECD 1993 Environmental Data Compendium. Organisation for Economic Co-operation and Development, Paris, France.

OECD-ECMT 1995 Urban Travel and Sustainable Development. European Conference of Ministers of Transport, Organisation for Economic Co-operation and Development, Paris, France.

Öhrström E 1993a Research on noise and sleep since 1988: Present state. In M. Vallet (ed.), Noise as a Public Health Problem, Vol. 3, pp. 331-338, INRETS - Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France.

Öhrström, E 1993b. Effects of low levels of road traffic noise during night. In M. Vallet (ed.), Noise as a Public Health Problem, Vol. 3, pp. 359-366, INRETS - Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France

Öhrström E 1997 Effects of exposure to railway noise–A comparison between areas with and without vibration. Journal of Sound and Vibration 205, 555-560.

Öhrström E, Björkman M 1988 Effects of noise-disturbed sleep–A laboratory study on habituation and subjective noise sensitivity. Journal of Sound and Vibration 122: 277-290.

Öhrström E, Skånberg AB1996 A field survey on effects of exposure to noise and vibrations from railway traffic. Part I: Annoyance and activity disturbance effects. Journal of Sound and Vibration 193: 39-47.

Ollerhead JB, Jones CJ, Cadoux RE, Woodley A, Atkinson BJ, Horne JA, Pankhurst F, Reyner L, Horne KI, Van F, Watson A, Diamond I, Egger P, Holmes D, McKean J 1992 Report of a Field Study of Aircraft Noise and Sleep Disturbance. Department of Transport, London, UK.

Pankhurst FL and Horne JA 1994 The influence of bed partners on movement during sleep. Sleep 17: 308-315.

Passchier-Vermeer W 1991 Noise from toys and the hearing of children. NIPG-TNO Report 91.052, TNO Institute of Preventive Health Care, Leiden, Netherlands.

Passchier-Vermeer W 1993 Noise and Health. The Hague: Health Council of the Netherlands [Publication No A93/02E, review prepared by TNO Institute of Preventive Health Care, Leiden]

Passchier-Vermeer W 1994 Sleep disturbance due to night-time aircraft noise, Leiden: TNO-PG Report 94.077, TNO Institute of Preventive Health Care, Leiden, Netherlands.

Passchier-Vermeer, W 1996. Effects of noise and health. Chapter 3 of a report on Noise and Health prepared by a committee of the Health Council of The Netherlands. Noise/News International: 137-150.

Passchier-Vermeer W and Rövekamp AJM 1985 Verband tussen gehoorschade en de sociale handicap door een verminderd hoorvermogen bij groepen personen die tijdens hun werk aan lawaai zijn geëxponeerd. In: Passchier-Vermeer W, et al. Preventie gehoorschade door lawaai Voordrachten ter gelegenheid van het 10-jarig jubileum van NVBA, pp.185-202. NIPG-TNO Institute of Preventive Health Care, Leiden. Netherlands.

Passchier-Vermeer W and Zeichart K Vibrations in the living environment. TNO-PG Report 98.030. TNO Institute of Preventive Health Care, Leiden. Netherlands.

Passchier-Vermeer W, Vos H, Steenbekkers JHM 1998 Popmusic through headphones and hearing loss. Report 98.036. TNO Institute of Preventive Health Care, Leiden. Netherlands.

Paulsen R and Kastka J 1995 Effects of combined noise and vibration on annoyance. Journal of Sound and Vibration 181: 295-314.
Pearsons KS 1998 Awakening and motility effects of aircraft noise. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2. pp. 427-32. Noise Effects '98 PTY Ltd., Sydney, Australia.
Pearsons KS, Barber DS, Tabachnick BG, Fidell S 1995 Predicting noise-induced sleep disturbance. Journal of the Acoustic Society of America 97: 331-338.
Pearsons KS 1996 Recent field studies in the United States involving the disturbance of sleep from aircraft noise. In F.A. Hill and R. Lawrence (eds.) Inter Noise 96. Noise Control - The Next 25 Years, Book 5, pp. 2271-2276. Institute of Acoustics, St. Albans, UK.
Persson K and Björkman M 1988 Annoyance due to Low Frequency Noise and the Use of the dBA Scale. Journal of Sound and Vibration 127: 491-497.
Plomp R 1986 A signal to noise ratio model for the speech-reception threshold of the hearing impaired. Journal of Speech and Hearing Research 29: 146-152.
Prasanchuk S (1997) Noise pollution: Its effect on health and hearing – Thailand as a case study. Presentation at the PDH Informal Consultation on the Prevention of Noise-induced Hearing Loss, 28-30 October 1997, WHO/PDH/98.5. World Health Organization, Geneva.
Razi MS, Jafer S, Hillier V, Zaidi SH, Newton V 1995 Causes of bilateral hearing loss in school children. Pakistan Journal of Otolaryngology 11: 68-86.
Reyner LA and Horne JA 1995 Gender- and age-related differences in sleep determined by home-recorded sleep logs and actimetry from 400 adults. Sleep 18: 127-134.
Ronnebaum T Schulte-Fortkamp B Weber R 1996 Synergetic effects of noise from different sources: a literature study. In F.A. Hill and R. Lawrence (eds.), Inter Noise 96. Noise Control - The Next 25 Years, Vol. 6, pp. 2241-2246. Institute of Acoustics, St. Albans, UK.
SABS 1994 Code of practice for the measurement and rating of environmental noise with respect to annoyance and speech communication (third revision). South African Bureau of Standards publication No. 0103, Pretoria, South Africa.
SABS 1996 Code of practice for calculating and predicting road traffic noise. South African Bureau of Standards publication No. 0210, Pretoria, South Africa.
SABS 1998 Code of practice for methods for environmental noise impact assessments. South African Bureau of Standards publication No. 0328, Pretoria, South Africa.
Salter L 1988 Mandated Science: Science and Scientists in the Making of Standards. Kluwer, Dordrecht, Netherlands.
Sandberg U (ed.) 1995 The effects of regulations on road vehicle noise. Report by the International Institute of Noise Control Engineering Working Party, Noise News International 6: 85-113.
Sandberg U 1999 Abatement of traffic, vehicle and tire/road noise – the global perspective. In: J. Cuschieri, S. Glegg, Yan Yong (eds.) Internoise 99 – The 1999 International Congress on Noise Control Engineering, 6-8 December 1999, Fort Lauderdale, Florida, USA, pp. 37-42.
Sargent JW and Fothergill LC 1993 The noise climate around our homes. Information Paper 21/93, Building Research Establishment, Garston, UK.
Scharf B 1970 Critical bands. In J.V. Tobias (ed.), Foundations of Modern Auditory Theory, Vol. 1, pp. 157-202. Academic Press, New York, NY, USA.
Scharf B and Hellman R 1980 How Best to Predict Human Response to Noise on the Basis of Acoustic Variables. In J.V. Tobias, G. Jansen and W.D. Ward (eds.) Noise as a Public Health Problem. ASHA Report no. 10, pp. 475-487. Rockville, ML, USA.

Schultz TJ 1978 Synthesis of Social Surveys on noise annoyance. Journal of the Acoustical Society of America. 64: 377-405.

Schwela D 1998. WHO Guidelines on Community Noise. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 2, pp. 475-480. Noise Effects '98 PTY Ltd., Sydney, Australia.

Smith AW 1998 The World Health Organisation and the prevention of deafness and hearing impairment caused by noise. Noise and Health 1: 6-12.

Smith AP 1990 Noise, performance efficiency and safety. International Archive of Occupational and Environmental Health 62: 1-5

Smoorenburg GF 1998 Effects of impulse noise on man. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98), Vol. 1, pp. 1-10, Noise Effects '98 PTY Ltd., Sydney, Australia.

Smoorenburg GF and Goldstein-Brouwers WG 1986 Spreaakverstaan in relatie tot het toonaudiograrn bij slechthorendheid ten gevolge van lawaai. IZF-TNO Report 1986 C-17, Soesterberg, Netherlands.

Stanners D and Bordeau P (Eds.) 1995 Europe's Environment the Dobris Assessment. Noise and radiation, pp.359-374, European Environment Agency, Copenhagen, Denmark.

Stansfeld SA 1992 Noise, noise sensitivity and psychiatric disorder: Epidemiological and psychological studies. Psychological Mededicine, Monograph Suppl 22, Cambridge University Press, Cambridge, UK

Stansfeld SA, Gallacher J, Babisch W, Shipley S 1996. Road traffic noise and psychiatric disorder: prospective findings from the Caerphilly Study. British Medical Journal 313: 266-267.

Stevens SS 1972 Perceived level of noise by Mark VII and decibels (E). Journal of the Acoustical Society of America 51, 575-601.

Struwe F, Jansen G, Schwarze S, Schwenzer C, Nitzsche M 1996 Untersuchung von Hörgewohn-heiten und möglichen Gehörrisiken durch Schalleinwirkungen in der Freizeit unter beson-derer Berücksichtigung des Walkman-Hörens. Düsseldorf: Institut für Arbeitsmedizin der Heinrich-Heine-Universität. In B. Babissch , G. Bambach, H. Ising, B. Kruppa, P. Plath, E. Rebentisch, F Struwe Gehörgefährdung durch laute Musik und Freizeitlärm, pp. 44 - 154. Institut für Wasser-, Boden- und Lufthygiene des Umweltbundesamtes. Berlin, Germany.

Tafalla RJ and Evans GW 1997 Noise, physiology and human performance: The potential role of effort. Journal of Occupational Health Psychology 2: 148-155.

Tempest W (ed.) 1985 The Noise Handbook. Academic Press, London, UK.

ten Wolde T 1998 European Commission's future noise policy. In V.C. Goodwin and D.C. Stevenson (eds.) Inter Noise 98. Sound and Silence: Setting the Balance, Vol 3, pp. 1719-1722. New Zealand Acoustical Society, Auckland, New Zealand

Thiessen GJ 1978 Disturbance of sleep by noise. Journal of the Acoustical Society of America, 64: 216-222.

Thompson SJ 1996 Non-auditory health effects of noise: an updated review. In F.A Hill and R. Lawrence (eds.) Inter Noise 96. Noise Control – The Next 25 Years. Vol. 4, pp. 2177-2182. Institute of Acoustics, St. Albans, UK.

UNCED 1992 Agenda 21. United Nations Conference on Environment and Development, Conches, Switzerland.

US EPA. 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Report EPA 550/9-74-004, US Environmental Protection Agency, Washington DC, USA.

Vallet M 1996 Caractéristiques et indicateurs de la gene due au bruit des avions. Synthèse. INRETS LRN Report No. 29. Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France.

Vallet M 1998 Sleep disturbance by noise. Recent orientations. In N.L. Carter and R.F.S. Job (eds.) Noise as a Public Health Problem (Noise Effects '98),, Vol. 2, pp. 421-26, Noise Effects '98 PTY Ltd., Sydney, Australia.

Vallet M and Vernet I 1991 Night aircraft noise index and sleep research results. In A. Lawrence (ed.). Inter-Noise 91. The Cost of Noise. Vol. 1. pp. 207-210. Noise Control Foundation, Poughkeepsie, NY, USA.

Vallet M, Gagneux J-M, Clairet JM, Laurens JF, Letisserand D 1983 Heart rate reactivity to aircraft noise after a long-term exposure. In G. Rossi (ed.), Noise as a Public Health Problem, Vol. 2, pp. 965-971, Centro Richerche e Studi Amplifon, Milano, Italy.

van den Berg M 1996 Noise management in the Netherlands. Noise and Vibration, September 1996. 11-12

van Hees O 1992 Gehoorafwijkingen bij beroepsmusici. Thesis, GUA, Amsterdam, Netherlands

Vaskor JG, Dickinson SM, Bradley JS 1979 Effect of Sampling on the Statistical Descriptors of Traffic Noise. Applied Acoustics 12: 111-124.

Vernon JA, Moller AR (Eds.) 1995 Mechanisms of Tinnitus. Allyn and Bacon, Needham Heights, Ma, USA.

von Gierke HE 1975 Noise - How Much is Too Much? Noise Control Engineering Journal 5: 24-34.

von Gierke HE and Harris CS 1987 Annoyance Response to Military Flight Operations and the Development of Standard Criteria for Community Annoyance. In H.S. Koelega (ed.). Environmental Annoyance, Characterization, Measurement and Control, pp. 257-269, Elsevier, Amsterdam, The Netherlands.

Vos, J 1992 Annoyance caused by simultaneous impulse, road-traffic and aircraft sounds: a quantitative model. Journal of the Acoustical Society of America 91: 3330-45.

Vos J 1996 Annoyance caused by impulse sounds produced by small, medium-large, and large firearms. In F.A Hill and R. Lawrence (eds.) Inter-Noise 96. Noise Control -- The Next 25 Years, Book 5, pp. 2231-36. Institute of Acoustics, St. Albans, UK.

Warren CHE 1972 The sonic boom exposure effects 1.2: The sonic boom generation and propagation. Journal of Sound and Vibration 20: 485-497.

WCED 1987 Our Common Future. World Commission on Environment and Development The Brundtland Commission, Oxford University Press, Oxford UK.

Westman JC and Walters JR 1981 Noise and stress. A comprehensive approach. Environmental Health Perspectives 41: 291-309

WHO 1980a Noise. Environmental Health Criteria Document No. 12, World Health Organization, Geneva, Switzerland.

WHO 1980b Glossary on Air Pollution. WHO Regional Office of Europe, Series No. 9. World Health Organization, Copenhagen, Denmark

WHO 1993 The Environmental Health Criteria Document on Community Noise. Report on the Task Force Meeting, Düsseldorf, Germany, 24-28 November 1992. WHO Regional Office for Europe. Report EUR/HFA Target 24. World Health Organization, Copenhagen, Denmark.

WHO 1994 Assessing human health risks of chemicals: Derivation of guidance values for health-based exposure limits. Environmental Health Criteria No. 170, World Health Organization, Geneva, Switzerland

WHO 1995a Concern for Europe's Tomorrow - Health and the Environment in the WHO European Region. WHO European Centre for Environment and Health. Wissenschaftliche Verlagsgesellschaft, Stuttgart, Germany.

WHO 1995b Noise - Selected presentations of an Informal Regional Consultation Meeting on Noise Pollution. 2-5 September 1991, Amman, Jordan. Eastern Mediterranean Regional Office, Regional Centre for Environmental Health Activities (CEHA), Amman, Jordan.

WHO 1998 Air Management Information System. AMIS CD ROM, 2nd edition. World Health Organization, Geneva, Switzerland.

Zaidi SH 1998 Current status and future trends of deafness and hearing impairment in the Tropics. Pakistan Journal of Otolaryngology 14: 38-45

Zaidi SH 1999 An epidemiological study of hearing impairment in the Himalayan territories of Pakistan. Hearing International Newsletter 8: 1-4.

Zeichart K 1998 Kombinatorische Wirkungen von Bahnlärm und Bahnerschütterungen. Zeitschrift für Lärmbekämpfung 45: 7-16.

Zwicker E 1960 Ein Verfahren zur Berechnung der Lautstärke. Acustica 10: 304-308.

Zwicker E 1989 On the dependence of unbiased annoyance on loudness. In G. Maling Jr (ed.) Inter Noise 89, Vol 2, pp 809-14 Noise Control Foundation, Poughkeepsie, NY, USA. .

Appendix 2 : Examples Of Regional Noise Situations

REGION OF THE AMERICAS

Latin America (Guillermo Fuchs, Argentina)

As more and more cities in Latin America surpass the 20 million inhabitants mark, the noise pollution situation will continue to deteriorate. Most noise pollution in Latin American cities comes from traffic, industry, domestic situations and from the community. Traffic is the main source of outdoor noise in most big cities. The increase in automobile engine power and lack of adequate silencing results in LAeq street levels >70 dB, above acceptable limits. Vehicle noise has strong low-frequency peaks at ~13 Hz, and at driving speeds of 100 Km/h noise levels can exceed 100 dB. The low-frequency (LF) noise is aerodynamic in origin produced, for example, by driving with the car windows open. Little can be done to mitigate these low-frequency noises, except to drive with all the windows closed. Noise exposure due to leisure activities such as carting, motor racing and Walkman use is also growing at a fast rate. Walkman use in the street not only contributes to temporary threshold shifts (TTS) in hearing, but also endangers the user because they may not hear warning signals. Construction sites, pavement repairs and advertisements also contribute to street noise, and noise levels of 85–100 dB are common.

The Centro de Investigaciones Acústicas y Luminotécnicas (CIAL) in Córdoba, Argentina has investigated noise pollution in both the field and in the laboratory. The most noticeable effect of excessive urban noise is hearing impairment, but other psychophysiological effects also result. For example, tinnitus resulting from sudden or continuous noise bursts, can produce a TTS of 20-30 dB, and prolonged exposures can result in permanent threshold shifts (PTS). By analyzing sound spectra down to a few Hertz, and at levels of up to 120 dB, discrete frequencies and bands of infrasound were found which damage hearing. With LF sounds at levels of 120 dB, TTS resulted after brief exposure, and PTS after only 30 min of exposure. The effects of noise on hearing can be especially detrimental to children in schools located downtown. Field studies in Córdoba city schools located near streets with high traffic density showed that speech intelligibility was dramatically degraded in classrooms that did not meet international acoustical standards. This is a particularly worrying problem for the younger students, who are in the process of language acquisition, and interferes with their learning process.

In general, community noise in Latin America remains above accepted limits. Particularly at night, sleep and rest are affected by transient noise signals from electronically amplified sounds, music and propaganda. Field research was carried out in four zones of Buenos Aires, to determine the effects of urban noise on the well-being, health and activities of the inhabitants. The effects of confounding variables were taken into consideration. It was concluded that night-time noise levels in downtown Buenos Aires were barely lower than daytime levels. The results showed that sleep, concentration, communication and well-being were affected in most people when noise levels exceeded those permitted by international laws. The reactions of the inhabitants to protect themselves from the effects of noise varied, and included changing rooms, closing windows and complaining to authorities.

Individual responses to noise also vary, and depend on factors such as social, educational and economic levels, individual sensibility, attitudes towards noise, satisfaction with home or neighborhood, and cognitive and affective parameters. For example, at CIAL two pilot studies were carried out with a group of adolescents to determine the influence of environmental conditions on the perception of noise. When music was played at very high sound levels (with sound peaks of 119 dBA) in a discotheque, judged to be a pleasant environment, the subjects showed less TTS than when exposed to the same music in the laboratory, which was considered to be an unpleasant environment.

At the municipal level Argentinean Ordinances consider two types of noises: unnecessary and excessive. Unnecessary noises are forbidden. Excessive noises are classified according to neighboring activities and are limited by maximum levels allowed for daytime (7 am to 10 pm) and night-time (10 pm to 7 am). This regulation has been relatively successful, but control has to be continuous. Similar actions have been prescribed at the provincial level in many cities of Argentina and Latin America. Control efforts aimed at reducing noise levels from individual vehicles are showing reasonably good improvements. However, many efforts of municipal authorities to mitigate noise pollution have failed because of economic, political and other pressures. For example, although noise control for automobiles has shown some improvement, efforts have been counteracted by the growth in the number and power of automobiles.

CIAL has designed both static and dynamic tests that can be used to set annual noise control limits. For roads and freeways where permitted speeds are above 80 Km/h, CIAL has also designed barriers which protect buildings lining the freeways. Considerable improvements have been obtained using these barriers with noise reductions of over 20 dB at buildings fronts. The most common types of barrier are concrete slabs or wooden structures, made translucent or covered with vegetation. Planted vegetation does not act as an efficient noise shield for freeway noise, except in cases of thick forest strips. In several cities, CIAL also designed ring roads to avoid heavy traffic along sensitive areas such as hospitals, schools and laboratories.

Efforts have not been successful in reducing the noise pollution from popular sports such as carting, motorboating and motocross, where noise levels can exceed 100 dB. In part, this is because individuals do not believe these activities can result in hearing impairment or have other detrimental effects, in spite of the scientific evidence. Argentinean and other Latin American authorities also have not been successful in reducing the sound levels from music centres, such as discotheques, where sound levels can exceed 100 dB between 11 pm and 6 am. However, public protest is increasing and municipal authorities have been applying some control. For instance, in big cities, discotheque owners and others are beginning to seek advice on how to isolate their businesses from apartment buildings and residential areas. Some improvements have been observed, but accepted limits have not yet been generally attained.

United States of America (Larry Finegold)

Noise Exposure.

In the United States, there have only been a few major attempts to describe broad environmental noise exposures. Early estimates for the average daily exposure of various population groups were reported in the U.S. Environmental Protection Agency's *Levels Document* (US EPA 1974), but these were only partially verified by subsequent large-scale measurements. Another EPA publication the same year provided estimates of the national population distribution as a function of outdoor noise level, and established population density as the primary predictor of a community's noise exposure (Galloway et al. 1974). Methodological issues that need be considered when measuring community noise, including both temporal and geographic sampling techniques, have been addressed by Eldred (1975). This paper also provided early quantitative estimates of noise exposure at a variety of sites, from an isolated spot on the North rim of the Grand Canyon to a spot in downtown Harlem in New York City. Another nationwide survey focused on exposure to everyday urban noises, rather than the more traditional approach of measuring exposure to high-level transportation noise from aircraft, traffic and rail (Fidell 1978). This study included noise exposure and human response data from over 2 000 participants at 24 sites.

A comprehensive report, *Noise In America: The Extent of the Problem*, included estimates of occupational noise exposure in the US in standard industrial classification categories (Bolt, Beranek & Newman, Inc. 1981). A more recent paper reviewed the long-term trends of noise exposure in the US and its impact over a 30-year time span, starting in the early 1970's. The focus was primarily on motor vehicle and aircraft noise, and the prediction was for steadily decreasing population-weighted day-night sound exposure (Eldred 1988). However, it remains to be seen whether the technological improvements in noise emission, such as changing from Chapter 2 to Chapter 3 aircraft, will be offset in the long run by the larger carriers and increased operations levels that are forecast for all transportation modes. Although never implemented in its entirety, a comprehensive plan for measuring community environmental noise and associated human responses was proposed over 25 years ago in the US (Sutherland et al. 1973).

Environmental Noise Policy in the United States

One of the first major breakthroughs in developing an environmental noise policy in the United States occurred in 1969 with the adoption of the National Environmental Policy Act (NEPA). This Congressional Act mandated that the environmental effects of any major development project be assessed if federal funds were involved in the project. Through the Noise Control Act (NCA) of 1972, the U.S. Congress directed the US Environmental Protection Agency (EPA) to publish scientific information about the kind and extent of all identifiable effects of different qualities and quantities of noise. The US EPA was also requested to define acceptable noise levels under various conditions that would protect the public health and welfare with an adequate margin of safety. To accomplish this objective, the 1974 US EPA *Levels Document* formally introduced prescribed noise descriptors and prescribed levels of environmental noise exposure. Along with its companion document, *Guidelines for Preparing Environmental Impact Statements on Noise*, which was published by the U.S. National Research Council in 1977, the

Levels Document has been the mainstay of U.S. environmental noise policy for nearly a quarter of a century. These documents were supplemented by additional Public Laws, Presidential Executive Orders, and many-tiered noise exposure guidelines, regulations, and Standards. Important examples include *Guidelines for Considering Noise in Land Use Planning and Control*, published in 1980 by the US Federal Interagency Committee on Urban Noise; and *Guidelines for Noise Impact Analysis*, published in 1982 by the US EPA.

One of the distinctive features of the US EPA *Levels Document* is that it does not establish regulatory goals. This is because the noise exposure levels identified in this document were determined by a negotiated scientific consensus and were chosen without concern for their economic and technological feasibility; they also included an additional margin of safety. For these reasons, an A-weighted Day-Night Average Sound Level (DNL) of 55 dB was selected in the *Levels Document* as that required to totally protect against outdoor activity interference and annoyance. Land use planning guidelines developed since its publication allow for an outdoor DNL exposure in non-sensitive areas of up to 65 dB before sound insulation or other noise mitigation measures must be implemented. Thus, separation of short-, medium- and long-term goals allow noise-exposure goals to be established that are based on human effects research data, yet still allow for the financial and technological constraints within which all countries must work.

The US EPA's Office of Noise Abatement and Control (ONAC) provided a considerable amount of impetus to the development of environmental noise policies for about a decade in the US. During this time, several major US federal agencies, including the US EPA, the Department of Transportation, the Federal Aviation Administration, the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the Department of Defense, and the Federal Interagency Committee on Noise have all published important documents addressing environmental noise and its effects on people. Lack of funding, however, has made the EPA ONAC largely ineffective in the past decade. A new bill, the *Quiet Communities Act* has recently been introduced in the U.S. Congress to re-enact and fund this office (House of Representatives Bill, H.R. 536). However, the passage of this bill is uncertain, because noise in the US, as in Europe, has not received the attention that other environmental issues have, such as air and water quality.

In the USA there is growing debate over whether to continue to rely on the use of DNL (and the A-Weighted Equivalent Continuous Sound Pressure Level upon which DNL is based) as the primary environmental noise exposure metric, or whether to supplement it with other noise descriptors. Because a growing number of researchers believe that "Sound Exposure" is more understandable to the public, the American National Standards Institute has prepared a new Standard, which allows the equivalent use of either DNL or Sound Exposure (ANSI 1996). The primary purpose of this new standard, however, is to provide a methodology for modeling the Combined or Total Noise Environment, by making numerical adjustments to the exposure levels from various noise sources before assessing their predicted impacts on people. A companion standard (ANSI 1998) links DNL and Sound Exposure with the current USA land use planning table. The latter is currently being updated by a team of people from various federal government agencies and when completed should improve the capabilities of environmental and community land-use planners. These documents will complement the newly revised ANSI standard on acoustical terminology (ANSI 1994)

To summarize progress in noise control made in the USA in the nearly 25 years since the initial national environmental noise policy documents were written, the Acoustical Society of America held a special session in Washington, D.C. in 1995. The papers presented in this special session were then published as a collaborative effort between the Acoustical Society of America and the Institute of Noise Control Engineering (von Gierke & Johnson 1996). This document is available from the Acoustical Society of America, as are a wide range of standards related to various environmental noise and bioacoustics topics from the ANSI.

A document from the European Union is now also available, which includes guidelines for addressing noise in environmental assessments (EC 1996). Policy documents from organizations such as ISO, CEN, and ICAO have shown that international cooperation is quite possible in the environmental noise arena. The ISO document, entitled *Acoustics - Description and Measurement of Environmental Noise* (ISO 1996), and other international standards have already proven themselves to be invaluable in moving towards the development of a harmonized environmental noise policy. The best way to move forward in developing a harmonized environmental noise policy is to take a look at the various national policies that have already been adopted in many countries, including those both from the European member states and from the USA, and to decide what improvements need to be made to the existing policy documents. A solid understanding of the progress that has already been achieved around the world would obviously provide the foundation for the development of future noise policies.

Implementation Concepts and Tools

Development of appropriate policies, regulations, and standards, particularly in the noise measurement and impact assessment areas, is a necessary foundation for implementing effective noise abatement policies and noise control programs. A well-trained cadre of environmental planners will be needed in the future to perform land-use planning and environmental impact analysis. These professionals will require both a new generation of standardized noise propagation models to deal with the Total Noise Environment, as well as sophisticated computer-based impact analysis and land-use planning tools.

A more thorough description of the current noise environment in major cities, suburbs, and rural areas is needed to support the noise policy development process. A new generation of noise measurement and monitoring systems, along with standards related to their use, are already providing considerable improvement in our ability to accurately describe complex noise environments. Finally, both active and passive noise control technologies, and other noise mitigation techniques, are rapidly becoming available for addressing local noise problems. Combined with a strong public awareness and education program, land-use planning and noise abatement efforts certainly have the potential to provide us with an environment with acceptable levels of noise exposure.

References

ANSI 1994 American National Samerican Standard Acoustical Terminology. American National Standard S1, American National Standards Institute, New York, NY, USA.

ANSI 1996)Quantities and Procedures for Description and Measurement of Environmental Sound - Part 4: Assessment and Prediction of Long-Term Community Response. American National Standard S12.9-Part 4, American National Standard Institute, New York, NY, USA
ANSI 1998 Quantities and Procedures for Description and Measurement of Environmental Sound - Part 5. Sound Level Descriptors for Determination of Compatible Land Use. American National Standard S12 9-Part 5, American National Standard Institute, New York, NY, USA
Bolt, Beranek, Newman, Inc (BBN) 1981 Noise in America: The extent of the problem. Cambridge, MA, USA.
Eldred km 1975 Assessment of community noise. Noise Control Engineering Journal 3. 88-95.
Eldred km 1988 Noise at the year 2000. In Proceedings of the Fifth International Congress on Noise as a Public Health Problem (B. Berglund et al., eds.). Stockholm: Swedish Council for Building Research.
Fidell S (1978) Nationwide urban noise survey Journal of the Acoustical Society of America 64: 198-206.
Galloway W, Eldred K, and Simpson M 1974 Population distribution of the United States as a function of outdoor noise. US Environmental Protection Agency Report No. 550/9-74-009 Washington, D.C., USA.
Scheri JR, McGatha EA (1973) A real-world assessment of noise exposure. Sound and Vibration 12. 24-30.
Sutherland LC, Braden. MH, and Colman R 1973 A programme for the measurement of environmental noise in the community and its associated human response. Vols. I and II. Report No. DOT-TST-74-5, Washington, D.C.: Department of Transportation, Office of Noise Abatement.
US EPA 1974 Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. EPA/ONAC Report 550/9-74-004, U.S. Environmental Protection Agency, Washington, D.C., USA.
von Gierke HE, Johnson LC 1996 Noise Control - Where Do We Stand Today? Noise Control Engineering Journal.

AFRICAN REGION

South Africa (Etienne Grond, South Africa)

Introduction

Cultural and developmental levels diverge greatly in South Africa, and the country can be divided into a first world sector, a developing sector and a third world sector. This contributes to huge variations in both the awareness of noise pollution and in population exposure to noise pollution. Noise-related health problems will in all probability show the same large variations.

Legal requirements

Noise control in South Africa has a history dating back about three decades. Noise control began with codes of practice issued by the South African Bureau of Standards (SABS) to address noise pollution in different sectors. Since then, Section 25 of the Environment Conservation Act (Act 73 of 1989) made provision for the Minister of Environmental Affairs and Tourism to regulate noise, vibration and shock at the national level. These regulations were published in 1990 and local authorities could apply to the Minister to make them applicable in their areas of jurisdiction. However, a number of the bigger local authorities did not apply for the regulations since they already had by-laws in place, which they felt were sufficient. By the middle of 1992 only 29 local authorities had applied the regulations and so the act was changed to make it obligatory for all authorities to apply the regulations. However, by the time the regulations were ready to be published, the new Constitution of South Africa came into effect and this listed noise control as an exclusive legislative competence of provincial and local authorities. This meant that the national government could not publish the regulations. However, provincial governments have agreed to publish the regulations in their respective areas. The regulations will apply to all local authorities as soon as they are published in the provinces, and will give local authorities both the power and the obligation to enforce the regulations.

The Department of Environmental Affairs and Tourism also published regulations during 1997 to make Environmental Impact Assessments mandatory for most new developments, as well as for changes in existing developments. This means that any impact that a development might have on its surrounding environment must be evaluated and, where necessary, the impact must be mitigated to acceptable levels. The noise control regulations also state that a local authority may declare a "controlled area," which is an area where the average noise level exceeds 65 dBA over a period of 24 h period. This means that educational and residential buildings, hospitals and churches may not be situated within such areas.

Occupational noise exposure is regulated by the Department of Manpower, under the Occupational Health and Safety Act (Act 85 of 1993). These regulations states that workers may not be exposed to noise levels of higher than 85 dBA and that those exposed to such levels must make use of equipment to protect their hearing. The problem, however, is that most workers tend not to make use of the provided equipment, either because the equipment is not comfortable, or because they are not aware of the risks high noise levels pose to their hearing. A further problem is that small industries often do not supply the workers with the necessary equipment, or supply inferior equipment that is less costly.

Codes of practice

The codes of practice issued by the SABS were for the most part replaced by IEC (International Electrotechnical Commission) standards and adopted as SABS ISO codes of practice. They are still being used in South Africa and are regularly updated. A relevant list can be found in the references. The SABS has also published a number of recommended practices (ARP). These include the ARP 020: "Sound impact investigations for integrated environmental management" that is currently being upgraded to a code of practice. Such codes of practice can be referred to as requirements in legislation and will be known as SABS 0328: "Methods for environmental noise impact assessments." The codes of practice published in South Africa cover hearing protection; measurement of noise; occupational noise; environmental noise; airplane noise; and building acoustics, etc.

Courses

Local authorities responsible for applying regulations published by the Department of Environmental Affairs and Tourism must employ a noise control officer who has at least three years tertiary education in engineering, physical sciences or health sciences, and who is registered with a professional council. Alternatively, a consultant with similar training may be employed. Most of the universities in South Africa provide the relevant training, with at least part of the training in acoustics. Universities and technical colleges also provide a number of special acoustics courses. Over the last couple of years awareness of environmental conservation has expanded dramatically within the academic community, and most universities and colleges now have degree courses in environmental management. At the very least, these courses include a six-month module in acoustics, and usually also include training in basic mathematics; the physics of sound; sound measuring methodologies; and noise pollution.

Community awareness and exposure to noise pollution

This topic should be discussed with respect to three separate population sectors: the first-world sector (developed), the developing sector and the third-world sector (rural).

Developed sector

This sector of the population is more-or-less as developed as their European and American counterparts. They have been exposed to noise pollution for a considerable time and, for the most part, are aware of the health consequences of high noise levels. People in this group are also aware of the existence of legal measures by which noise pollution can be addressed. Not surprisingly, most of the complaints and legal action regarding noise pollution are received from this group. Information about noise-related health problems is very limited, but because this group is highly aware of the risks posed by high noise levels, future studies will probably show that people in this category have the fewest health problems. The majority of people in this group are less exposed to high noise levels at work, and they live in more affluent neighborhoods with large plots and separating walls. Their houses tend to be built with materials that are noise reducing. They also live further away from major noise-producing activities, such as highways, airports and large industries.

Developing sector

This sector of the population has the greatest exposure to high noise levels, both at home and in the workplace. Overall, they are relatively poor and cannot afford to live in quiet areas, or afford large plots or solid building materials. A large component of this sector resides in squatter communities where building are made of any material available, from plastic to corrugated sheets and wood. The buildings are right next to each other and there is almost no noise attenuation between residencies.

People in this category usually live close to major access routes into the cities, because they make use of public transportation and taxis to get to their places of work. Often, too, they live close to their places of work, which are usually big industries with relatively high levels of noise pollution. These people usually work in high noise areas, and because of their lack of awareness of the effects of high noise levels, often do not make use of available hearing protection equipment. Because of a lack of funds, these people also cannot get out of high noise areas and go to recreational areas for relaxation and lower noise levels. Not much information is available on the adverse health problems in this sector. However, workers in this sector should undergo regular medical examinations and the results can be obtained from the industries involved.

Rural sector

As the name suggests, people in this sector live in rural surroundings and for the most part are not subjected to noise levels that could be detrimental to their health. However, they are almost totally unaware of the risks posed by high noise levels. Some of these people work on farms and work with machinery that emits relatively high noise levels, but because of their lack of awareness they do not make use of hearing protection equipment. One advantage they do have is that they return to homes in quiet surroundings and their hearing has a chance to recover. To date, no studies have been carried out to determine the state of their hearing and it would be impossible to state that they have no health problems related to high noise levels.

References

Environment Conservation Act (Act No. 73 of 1989) Noise Control Regulations, Ministry of Environmental Affairs and Tourism, Pretoria, South Africa.

Relevant SABS codes of practice:

SABS 083-1996. The measurement and assessment of occupational noise for hearing conservation purposes.

SABS 0103-1994. The measurement and rating of environmental noise with respect to annoyance and speech communication (third revision).

SABS 0115-1974. The measurement of noise and the determination of disturbance from aeroplanes for certification purposes

SABS 0117-1974. The determination and limitation of disturbance around an aerodrome due to noise from aeroplanes (Amendment no 1 - 1984).

SABS 0205-1986. The measurement of noise emitted by motor vehicles in motion.

SABS 0210-1996. Calculating and predicting road traffic noise (Amendment no 1 - 1997).

SABS 0211-1987 The measurement of noise inside motor vehicles.

SABS 0218/1-1988 Acoustical properties of buildings Part 1: The grading of buildings according to their airborne-sound insulation properties (under revision).

SABS 0218/2-1988 Acoustical properties of buildings Part 2: The assessment of building plans and buildings with respect to their acoustical properties (under revision).

SABS 0234-1991. Determination of sound power levels of multi-source industrial plants for the evaluation of the sound pressure levels in the environment. - Engineering method (Incorporating ISO 8297:1994)

ARP 020-1992. Sound impact investigations for integrated environmental management. (To be superseded and replaced by SABS 0328. Methods for environmental noise impact assessments).

EASTERN MEDITERRANEAN REGION (Shabih H. Zaidi)

Scope

In the Eastern Mediterranean region some countries have highly developed industries, while others have none. In other cases, the agricultural economy is inseparably mixed with high-technology industries, such as the oil industry, which can be seen in nearly the whole of the Arabian Peninsula. Other examples of where agriculture and industry are intertwined can be seen in Pakistan, Jordan and Egypt. The main focus of this paper is community noise, but because industry is so widely distributed, some discussion of industrial noise is inevitable. The scope of this paper is to document the available scientific data on community noise in the WHO Regional Office of the Eastern Mediterranean (EMRO) region, including preventive strategies, legislation, compensation and future trends.

Sources of Noise Pollution

Sources of noise pollution in the Eastern Mediterranean region include noise from transportation, social and religious activities, building and civil works, roadside workshops, mechanical floor shops and others. During civil works and building booms, noise levels in all countries of the Eastern Mediterranean region could easily reach 85dBA during the daytime over an 8 h work period. In Pakistan, unprotected construction work goes on at all times of the day and night and uses outdated machinery; and the noise is compounded by workers shouting. On a typical building site noise levels reach 90–100 dBA

In Karachi, the main artery for daily commuters is a long road that terminates at the harbor. In the densest area of this road there are a hundred small and large mechanical workshops, garages, metal sheet workers, dent removers, painters, welders and repair shops, all of which create a variety of noises. In the middle of this area at the Tibet Centre the LAeq,8h is 90dBA (Zaidi 1989). A similar picture is seen elsewhere in cities like Lahore, Peshawar, etc. Fortunately, the same is not true for other newly built cities in the EMRO region, such as Dubai, or Tripoli, where strict rules separate industrial zones from residential areas.

A special noise problem is Karachi harbour. This port serves the whole of Pakistan as well as Afghanistan and several Asian states, such as Kyrgyzstan, Kazakhstan and Uzbekistan. The noise level at the main wharf of Karachi Port ranges between 90–110 dBA on any given day. Other special sources of noise are the Eastern Mediterranean airports, and indeed most of the airports in the Middle East. Most northbound air traffic originates in Pakistan, Dubai, Sharjah etc. and flights usually depart after midnight so as to arrive in Europe during the daytime. A study is currently underway in Karachi to identify the damage caused by these nocturnal flights to those living under the flight path (SH Zaidi, GH Shaikh & AN Zaidi, personal communication).

Sadly, violence has become part of Eastern culture and is a significant source of noise pollution. Wars generate a lot of noise, and although noise-induced hearing loss is a secondary issue compared with the killing, after the wars many people are hearing impaired. This has been seen following conflicts in Baluchistan, Peshawar and Afghanistan, where perforated ear drums, profound hearing loss and stress-related psychosomatic illnesses are common in the refugee camps. The noise levels during a recent mass demonstration in Karachi, which included the firing of automatic weapons, reached 120 dBA at a distance of 50 m from the scene.

The Effects of Noise on Health

There is good evidence that environmental noise causes a range of health effects, including hearing loss, annoyance, cardiovascular changes, sleep disturbance and psychological effects. Although the health effects of noise pollution have not been documented for the entire EMRO region, data are available for Pakistan and can be used to illustrate the general problem. In this report, noise exposure is mainly expressed as LAeq,24h values.

Noise-induced hearing loss (NIHL).

It is believed that exposure to environmental noise in the EMRO countries is directly related to the living habits, economic prosperity and outdoor habits of people. It has been estimated that no more than 5% of the people are exposed to environmental sound levels in excess of 65dBA over a 24-h period. Similarly, for indoor noise, it is believed that the average family is not exposed to sound levels in excess of 70 dBA over a 24-h period. However, it is difficult to generalize for all countries in the EMRO region, because of ancient living styles and different cultural practices, such as taking siestas between 13:00–16:00 and stopping work at 20:00.

Exposure to noise while travelling to schools, offices or workplaces may vary tremendously between cities in the region. In Karachi, for example, traffic flow is undisciplined, erratic and irrational, with LAeq,8h values of 80–85 dBA. In Riyadh, by contrast, traffic flow is orderly with LAeq levels of 70 dBA during a normal working day. In Karachi, noise levels show significant diurnal variation, reaching levels in excess of 140 dB during the peak rush hour at around 5.00 p.m. (Zaidi 1989). At the Tibet Centre, located at a busy downtown junction, noise levels were 60–70 dB at 9 am, but reached levels in excess of 140 dB between 5-7 p.m. A study conducted on a day that transportation workers went on strike established that road traffic is the most significant source of noise pollution in this city; in the absence of buses, rickshaws, trucks and other public vehicles the LAeq level declined from 90dB to 75dB (Zaidi 1990). Motor engines, horns, loud music on public buses and rickshaws generate at least 65% of the noise in Karachi (Zaidi 1997, Shams 1997). Rickshaws can produce noise levels of 100–110 dBA and do not have silencers. On festive occasions, such as national holidays or political rallies, motorbikes running at high speeds along the Clifton beach in Karachi easily make noise exceeding 120 dBA. (Zaidi 1996).

Another study conducted at 14 different sites in Karachi showed that, in 11 of the sites, the average noise level ranged between 79–80 dB (Bosan & Zaidi 1995). The maximum noise levels at all these sites exceeded 100 dB. Speech interference, measured by the Preferred Speech Interference Level and the Articulation Index, was significant (Shaikh & Rizvi 1990). The study results indicated that two people facing each other at a distance of 1.2 m would have to shout to be intelligible, and the Articulation Indexes demonstrated that communication was unsatisfactory. Of perhaps greater concern are the results of a survey of 587 males between the ages of 17 and 45 years old, who worked as shopkeepers, vehicle drivers, builders and office assistants. Audiograms showed that 14.6% of the subjects had significant hearing impairment at 3 000–4 000 Hertz (Hasan et al., 2000).

Noise pollution from leisure activities can vary from country to country in the EMRO region. The Panthans in northern Pakistan, for example, like to shoot in the air on festive occasions, such as weddings, without using any noise protection devices. A minimum of 1 000 shots are fired on such occasions; and at a traditional tribal dance called the "Khattak" the noise level recorded during a particularly enthralling performance in a sports arena was 120dBA. The hunting of wild boar is a common sport in the hinterlands of Sindh. With the rifle shots and the noise made by the beaters, noise levels can easily reach 110 –120 dBA. In some EMRO countries, the younger crowd has taken up the Western habit of listening to Pop music for many hours. Discos and floorshows are confined to a few countries, such as Egypt. Open-air concerts are usually held in stadiums. The noise level recorded at a particularly popular concert was 130 dBA at a distance of 20 m from the stage and 35 m from the amplifiers.

In a study of road traffic at 25 different sites in Peshawar, the third most populous city in Pakistan, 90 traffic constables were taken as cohorts to investigate the extent of NIHL. Of these, 50 did not have any previous history of noise exposure and were taken as controls. Detailed evaluation and audiological investigations established that constables exposed to a noise level of 90 dBA for 8 hours every day suffered from NIHL. Compared to the control subjects, the constables had significant hearing impairment at 3 000 Hz, measured by Pure Tone Audiometry (Akhter 1996).

A similar study of traffic constables in Karachi showed that 82.8% of the constables suffered from NIHL (Itrat & Zaidi 1999). The study also showed that 33.3% of rickshaw drivers, and 56.9% of shopkeepers who worked in noisy bazaars, had hearing impairment. If these findings can be extrapolated to the total populations, there are 1 566 traffic constables (out of a total of 1 890 constables), and 4 067 rickshaw drivers (out of a total of 12 202 drivers) who suffer from NIHL. As has been reported by other researchers, the study also found evidence of acclimatization in the subjects: following an initial, rapid decline, hearing loss stabilized after prolonged noise exposure.

Annoyance.

The citizens of Karachi commonly complain that noise causes irritability and stress. The main sources have been identified as traffic noise, industrial noise and noise generated by human activity. Unfortunately no data are available for the level of annoyance caused by noise exposure in the EMRO region. From limited research around the world, it can be estimated that 35–40% of employees in office buildings are seriously annoyed by noise at sound levels in excess of 55–60 dBA. In countries such as Pakistan, Iran, Jordan and Egypt that level is often seen in most offices. Annoyance is a non-tangible entity and cannot be quantified scientifically. It is a human reaction and perhaps its parameters could include irritability, apprehension, fear, anger, frustration, uneasiness, apathy, chaos and confusion. If such are the parameters, then on a scale of 0–10, with 10 being the greatest annoyance, many EMRO countries could easily score 6 or higher.

Effects of noise on sleep and the cardiovascular system.

In the Eastern Mediterranean region no specific data are available on the effects of noise on sleep or the cardiovascular system. However, factory workers, traffic constables, rickshaw drivers and shopkeepers frequently complain about fatigue, irritability and headaches; and one of the most common causes of poor performance in offices is sleep disturbance. The rising incidence of tinnitus in cities like Karachi is also related to noise exposure, and tinnitus itself can lead to sleep deprivation. Although the effects of noise on the cardiovascular system have been well documented for other countries (Berglund & Lindvall 1995), data are lacking for the EMRO region. However, the prevalence of cardiovascular diseases are on the rise in the EMRO countries, particularly hypertension. While most of the increase in these diseases is due to a rich diet and lack of exercise, the relationship between noise and cardiovascular changes is worth investigating.

The risk to unborn babies and newborns.

Although evidence from other countries indicates that noise may damage the hearing of a fetus, there are no data from the EMRO countries to confirm this. With newborn babies, however, noise from incubators is a major cause of hearing loss in the EMRO region, particularly as 20–27% of them are born underweight (Razi et al. 1995). Once exposed to noise in an incubator, the chances of hearing impairment rapidly rises compared with cohorts in developed countries. Several other factors have also been identified as causing deafness and hearing impairment in newborns in the Eastern Mediterranean region (Zaidi 1998; Zakzouk et al. 1994). They are:

a. Discharge from the ears.

b. Communicable infections.

c. Ototoxicity.

d. Noise.

e. Consanguinity.

f. Iodine deficiency.

Noise Control

Although noise control legislation exists in several EMRO countries, it is seldom enforced, particularly in Pakistan and some neighboring countries. Noise control begins with education, public awareness and the appropriate use of media in highlighting the effects of noise. In Calcutta, for instance, public orientation and mass media mobilization have produced tangible results, and this can easily be done in other countries. Three strategies have been devised for noise control, all of which are practicable in EMRO region countries. They are control at the source, control along the path and control at the receiving end.

There are many ways noise can be controlled at the source. For example, most of the equipment and machinery used in EMRO countries is imported from the West. Noise control could begin by importing quieter machinery, built with newer materials like ceramics or frictionless parts. And at the local level, the timely replacement of parts and proper maintenance of the machines should be carried out. Vehicles like the rickshaw should be banned, or at least be compelled to maintain their silencers, and all vehicles must be put to a road worthiness test periodically. This already occurs in some EMRO countries, but not all. Horns, hooters, music players and other noise making factors must also be controlled. The use of amplifiers and public address systems should also be banned, and social, leisure and religious activities should be restricted to specific places and times.

Along the sound path, barriers can be used to control noise. There are three kinds of barriers available, namely, space absorbers made out of porous material, resonant absorbers and panel absorbers. Architects, for example, use hollow blocks of porous material. The air gaps between building walls not only keep the buildings cool in hot weather, but also reduce the effects of noise. Ceilings and roofs are often treated with absorbent material. In large factories, architects use corrugated sheets and prefabricated material, which are helpful in reducing noise levels. In Pakistan, some people use clay pots in closely ranked positions on rooftops to reduce the effect of heat as well as noise. For civic works and buildings, special enclosures, barriers and vibration controlling devices should be used. Public halls, such as cinemas, mosques and meeting places should have their walls and floors carpeted, and covered with hangings, mats etc. An effective material is jute, which is grown in many countries, mainly Bangladesh, and it is quite economical. Some of the old highways and most of the busy expressways need natural noise barriers, such as earth banks, trees and plants.

References.

Akhter NH 1996 Noise induced hearing loss in traffic police constables of Peshawar. Journal of College of Physicians and Surgeons Pakistan 6. 265-268.

Burglund B and Lindvall T 1995 Community Noise. Archives of the Centre for Sensory Research, volume 2, issue 1, pp. 56.57. Stockholm University and Karolinska Institute, Stockholm.

Bosan Altaf, Zaidi SH Nobel Tracy 1995 The problem of noise, Pakistan Journal of Otolaryngology 11, 128-131.

Hasan S, Zaidi AN, Tahira S, Zaidi SH 2000 Audiological profile of NIHL in IMPACT Ear Camps. Pakistan Journal of Oto-Rhino-Laryngology, in print.

Irat J, Zaidi SH 1999 Deafness in Pakistan, Pakistan Journal of Otolaryngology 15: 78-83.

Razi MS, Jaffer S, Hillier V, Zaidi SH, Newton V 1995 Causes of bilateral hearing loss in school children. Pakistan Journal of Otolaryngology 11: 68-86

Shams ZI 1997 The hazards of noise pollution. Daily Dawn, 30th September 1997.

Shaikh GH, Rizvi SSH 1987 Road transport in Karachi city. Pakistan Journal of Science and research. 30: 197.

The environmental protection agency Sindh. The study of noise pollution in Karachi. Executive Report. Karachi Pakistan. ACE (pvt.) Ltd. Karachi.

Zaidi SH 1989 Noise level and the sources of noise pollution in Karachi. Journal of Pakistan Medical Association. 39: 62-65.

Zaidi SH 1990 Noise level in Karachi on a transporter's strike day. Journal of Pakistan Medical Association, 40. 299-300.
Zaidi SH 1996 Noise Ototoxicity. Pakistan Journal of Otolaryngology, 12: 194.
Zaidi SH 1997 Noise induced hearing loss in Pakistan. Hearing International, 6: 12-13.
Zaidi SH 1998 The causes of deafness and Hearing Impairment in the Tropics: Keynote speech delivered at the Centennial Congress of Liverpool School of Tropical Medicine in Sept 1998. Pakistan Journal of Otolaryngology 14: 102-107.
Zakzouk SM, Bafaqeh SA, Al-Mahmmod H, Essa A 1994 Demographic factors and hearing impairment in Saudi Arabian Children., Journal of Laryngology and Otology 108 294-298.

SOUTH-EAST ASIAN REGION. (Sudhakar B. Ogale)

Introduction

The ability to hear sound is a sensory function vital for human survival and communication. However, not all sounds are wanted. Unwanted sounds, for which the term "noise" is normally used, often originate from human activities such as road traffic, rail traffic, aircraft, discos, electric power generators, festivals, firecrackers and toys. In general, however, data on noise pollution in South east Asian countries are not available. For example, there are no comprehensive statistical data regarding the incidence and etiology of hearing impairment. Consequently, it is difficult to estimate the exact percentage of the population affected by community noise.

Excessive noise is the major contributor to many stress conditions. It reduces resistance to illness by decreasing the efficiency of the immune system, and is the direct cause of some gastrointestinal problems. Noise also increases the use of drugs, disturbs sleep and increases proneness to accidents. An increased incidence of mental illness and hospital admissions, increases in absenteeism from work and lethargy from sleep disturbance all result from noise pollution and cause considerable loss of industrial production.

Noise Exposure in India

India is rapidly becoming industrialized and more mechanized, which directly affects noise levels. However, no general population study regarding the magnitude of the noise problem in India has been performed.

Road Traffic Noise

Exposure. A study by the Indian Institute of Road Traffic (IRT) reported that Delhi was the noisiest city in India, followed by Calcutta and Bombay (IRT 1996; Santra & Chakrabarty 1996). The survey examined whether road-traffic noise affected people with respect to annoyance, sleep disturbance, interference with communication and hearing impairment. It showed that 35% of the population in four major cities have bilateral sensory neural hearing loss at noise emission levels above 82 dBA. This is of particular concern in light of a second study, showing that $L_{Aeq,24h}$ levels at 24 kerbside locations in Calcutta were 80-92 dBA (Chakrabarty et al. 1997). The mean noise emission levels of four different vehicle categories are presented in Table A2.1.

Table A2.1: Mean noise emission levels of vehicles

Type of vehicle	Mean sound pressure level
2 wheelers (motor cycle)	82 dBA
3 wheelers (auto rickshaw)	87 dBA
Motor car (taxi, private cars)	85 dBA
Heavy vehicles (trucks)	92 dBA

Control Measures. Only recently has noise pollution been considered an offence in India, under the Environmental (Protection) Act 1986. Several measures are being taken to reduce traffic-noise exposure. These include:

a. Planting trees, shrubs and hedges along roadsides

b. Mandatory, periodic vehicle inspections by road traffic control

c. Reintroduction of silent zones, such as around schools, nursing homes and hospitals that face main roads

d. Regulation of traffic discipline, and a ban on the use of pressure horns.

e. Enforcement of exhaust noise standards.

f. Mandating that silencers be effective in three-wheeled vehicles.

g. The use and construction of bypass roads for heavy vehicles.

h. Limiting night-time access of heavy vehicles to roads in residential neighbourhoods

i. Installation of sound-proof windows.

j. Proper planning of new towns and buildings.

Air Traffic Noise

Many airports were originally built at some distance from the towns they served. But due to growing populations and the lack of space, buildings are now commonly constructed alongside airports in India

Exposure. A survey revealed that aircraft produced a high level of noise during take-off, with sound pressure levels of 97-109 dBA for the Airbus, and 109 dBA for Boeing aircraft (SB Ogale, unpublished observations). During landing, the aircraft produced a sound pressure level of 108 dBA. Although exposure to aircraft noise is considered to be less of a problem than exposure to traffic noise, the effects of air-traffic noise are similar to those of road traffic, and include palpitations and frequent awakenings at night.

Control measures. The use of ear muffs must be made obligatory at the airport. This can reduce noise exposure to a safe level. An air-traffic control act should also enforce the use and introduction of low-noise aircraft, and mandate fewer night-time flights.

Rail Traffic Noise

Very little attention has been paid to the problems of railway noise.

Exposure. In Bombay, where the majority of residential buildings are situated on either side of railway tracks, residents are more prone to suffer from acoustic trauma. More than 14% of the population in Bombay suffer from sleep disturbances during night, due to high-speed trains and their whistling. A study on surface railways (SB Ogale, unpublished observations) revealed that platform noise was 71–73 dBA in the morning and 78–85 dBA in the evening. The noise from loudspeakers mounted in the platform was 87–90 dBA. At a distance of 1 m from the engine, the whistle noise was 105–108 dBA for a train with an electric engine, up to 110 dBA for a train with diesel engine and 118 dBA for steam engine trains. Vacuum brakes produced noise levels as high as 95 dBA. This suggests that unprotected railway staff on platforms are at risk of permanent noise induced hearing loss.

Festival noise

Festival noise in India was first surveyed in Bombay in late 1970, during the Ganpati festival period. A similar study (Santra et al. 1996) was conducted soon after in Calcutta at the Durga Pooja festival during evening hours (18.00–22:00). The music from loudspeakers produces sound pressure levels of more than 112 dBA. During the festival period the residents experienced a noisy environment for 8–10 h at a stretch, with noise level of 85–95 dBA. This level is above the 80 dBA limit set by WHO for industrial workers exposed to noise for a maximum period of 8 hours.

Control measures. In a religious country, it is politically difficult to restrict religious music, even in the interests of public health. A ban on all music from loudspeakers after 22.00 would decrease the sound pressure levels to below the permissible legal limit. A preventive programme is advocated to measure noise levels with sound level metres.

Fire crackers and toy weapons noise

Exposure. A study conducted by Gupta & Vishvakarma (1989) at the time of Deepawali, an Indian festival of fireworks, determined the auditory status of 600 volunteers from various age groups, before and after exposure to firecrackers. The study also measured the acoustical output of representative samples of toy weapons and firecrackers, and the noise intensity level at critical spectator points. The average sound level at a distance of 3 m from the noise source was 150 dBA, exceeding the 130 dBA level at which adults are at risk for hearing damage. On average, 2.5% of the people surveyed during Deepawali had persistent sensory neural hearing loss of 30 dBA, with those in the 9–15 year old age group being most affected.

Control Measures. A judicious approach in the manufacture and use of toy weapons and firecrackers is encouraged, in addition to legal restraints. Fireworks should be more a display of light, rather than sound.

Generator Noise

Diesel generators are often used in India to produce electric power. Big generators produce sound pressure levels exceeding 96 dBA (SB Ogale, unpublished observations)

Conclusions

No comprehensive statistical data are available for community noise in India, however, the main sources of environmental noise are road traffic, air traffic, rail traffic, festivals, firecrackers and diesel generators. The adverse effects of noise are difficult to quantify, since tolerance to noise levels and to different types of noise varies considerably between people. Noise intensity also varies significantly from place to place. It should also be noted that noise data from different countries are often not obtained by the same method, and in general models have been used which are based on data from a limited number of locations. Noise control measures could be taken at several levels, including building design, legal measures, and educating the people on the health dangers of community noise. In India, what is needed now is noise control legislation and its strict enforcement, if a friendly, low-noise environment is to be maintained.

Noise Exposure in Indonesia

According to a report by the WHO, the noise exposure and control situation in Indonesia is as follows (Dickinson 1993).

Exposure. No nationwide data are available for Indonesia. However, during the last three decades there has been rapid growth in transportation, industry and tourism in Indonesia.

Control Measures. With the large majority of people having little income, protection of the physical environment has not been a first-order priority. The following recommendations have been made with respect to community noise (Dickinson 1993):

a. The cities of Indonesia have relatively large populations and each provincial government will need the staff and equipment to monitor and manage the environment.

b. Sound level meters with noise analysis computer programmes should be purchased.

c. Training courses and adequate equipment should be provided.

IRT 1996 Indian Council of Medical Research Bulletin Vol. 26, No. 8, August 1996, New Delhi.
Prasanchuk S (1997) Noise pollution. Its effect on health and hearing -- Thailand as a case study. Presentation at the PDH Informal Consultation on the Prevention of Noise-induced Hearing Loss. 28-30 October 1997, WHO/PDH/98.5. World Health Organization, Geneva, Switzerland.
Santra SC, Chakrabarty D 1996 Need for rationalization of noise standards in Indian perspectives. Presented at the First National Workshop on Development and Use of Environmental Reference Materials, 14-16 February 1996, Central Pollution Control Board, New Delhi.
Santra SC, Chakrabarty D, Mukherjee A, Roy B 1996 Noise status of Calcutta metropolis A resume. Man and Environment. Annual Report. pp. 19-22.

d. Noise management planning for airports should be promoted.

e. Reduction measures should be taken for road-traffic noise.

Noise Exposure in Bangladesh

Exposure. In Bangladesh no authentic statistical data on the effects of community noise on deafness or hearing impairment are available (Amin 1995).

Control Measures. Governments have meager resources, a vast population to contend with and high illiteracy rates; consequently, priorities are with fighting hunger, malnutrition, diseases and various man-made and natural calamities. The governments are unable to give the necessary attention towards the prevention, early detection and management of noise disabilities in the country. Close cooperation is needed between the national and international organizations, to exchange ideas, skills and knowledge (Amin 1995).

Noise Exposure in Thailand

Exposure. Noise from traffic, construction, and from factories and industry has become a big problem in the Bangkok area. The National Environmental Board of Thailand was set up two decades ago and has been active in studying the pollution problems in Thailand. Indeed, a committee on noise pollution control was set up to study the noise pollution in Bangkok area and its surroundings. Although regulations and recommendations were made for controlling various sources of noise, the problem was not solved due to a lack of public awareness, the difficulty of proving that noise had adverse effects on health and hearing, and the difficulty of getting access to control noise. A general survey revealed that 21.4% of the Bangkok population is suffering from sensory neural hearing loss (Prasanchuk 1997). Noise sources included street noise, traffic noise, industrial noise and leisure noise.

Control Measures. In 1996, regulations for noise pollution control set LAeq,24h levels at 70 dBA for residential areas, and less than 50 dBA to avoid annoyance. The National Committee on Noise Pollution Control has been asked to study the health effects of noise in the Bangkok area and its surroundings, and determine whether these regulations are realistic and feasible.

References.

Amin 1995 Community Noise. Proceedings of the International Symposium on Deafness and Hearing Impairment in Developing Countries, Manchester, 6-8 July 1995.
Chakrabarty D, Santra SC, Mukherjee A, Roy B, Das P 1997 Status of road traffic noise in Calcutta metropolis, India. Journal of the Acoustical Society of America 101: 943-949
Dickinson P (1993) Noise assessment and management in Indonesia. Report SEA/EH 461, Regional Office for South-East Asia, World Health Organization, New Delhi, India.
Gupta D, Vishvakarma SK. 1989 Toy weapons and fire crackers. Laryngoscope 99: 330-334.

WESTERN PACIFIC REGION.

In this section, information on noise pollution and control will be given for three countries in the Western Pacific Region, namely Australia, the People's Republic of China and Japan. From a noise pollution point of view China may be viewed as a developing country, whereas Japan and Australia, with their high level of industrialization, represent developed countries.

Australia (Andrew Hede & Michinori Kabuto)

Exposure. Australia has a population of 18 million with the majority living in cities that have experienced increasing noise pollution from a number of sources. The single most serious source of noise is road traffic, although in major cities such as Sydney, Melbourne and Perth, large communities are exposed to aircraft noise as well. Other important sources of noise pollution are railway noise and neighbourhood noise (including barking dogs, lawn mowers and garbage collection). A particular problem in Australia is that the climate encourages most residents to live with open windows, and few houses have effective noise insulation.

A study of road-traffic noise was conducted at 264 sites in 11 urban centres with populations in excess of 100 000 people (Brown et al. 1994). Noise was measured one metre from the façade of the most exposed windows and at window height. From the results, it was estimated that over 9% of the Australian population is exposed to LA10,18h levels of 68 dB or greater, and 19% of the population is exposed to noise levels of 63 dB or greater. In terms of LAeq values for daytimes, noise exposure in Australia is worse than in the Netherlands, but better than in Germany, France, Switzerland or Japan.

Control. In the mid-1990's, when a third runway was built at Sydney Airport, the government funded noise insulation of high-exposed dwellings. Increasingly, too, major cities are using noise barriers along freeways adjacent to residential communities. In most states barriers are mandatory for new freeways and for new residential developments along existing freeways and major motorways. There has been considerable testing of noise barriers by state agencies, to develop designs and materials that are cost effective.

Brown AL et al. (1994) Exposure of the Australian Population in Road Traffic Noise. Applied Acoustics 43, 169-176.
OECD (1991) Fighting Noise in the 1990's. Organization for Economic Cooperation and Development. Paris, France.

China (Chen Ming)

Introduction

Urban noise pollution has become a contemporary world problem. Urban noise influences people's living, learning and working. People exposed to noise feel disagreeable and cannot concentrate on work. Rest and sleep are also disturbed. People exposed to high-intensity noise do not hear alarm signals and cannot communicate with each other. This can result in injury and, indeed, with the modernization of China, construction accidents related to noise are increasing. According to statistics for several cities in China, including Beijing, Shanghai, Tientsin and Fuzhou, the proportion of total accidents that were noise related was 29.7% in 1979, 34.6% in 1980, 44.8% in 1981 and 50% in 1990. It is therefore very important to control noise pollution in China.

Long-term exposure to urban environmental noise can lead to temporary hearing loss (assessed by temporary threshold shift), permanent hearing loss (assessed by permanent threshold shift) or deafness. Microscopy studies have shown that in people exposed to noise for long periods, hair cells, nerve fibers and ganglion cells were absent in the cochleae, especially in the basal turns. The primary lesion is in the 8–10 mm region of the cochlea, which is responsible for detecting sound at a frequency of 4 000 Hz. People chronically exposed to noise may first complain about tinnitus and, later on, about hearing loss. This is especially true for patients who have bilateral hearing loss at 4 000 Hz, but who have relatively good hearing other frequencies. Non-auditory symptoms of noise include effects on the nervous system, cardiovascular system and blood system. These symptoms were rarely observed in China in the past, but today more and more people complain about hearing damage and non-auditory physiological effects.

Urban environmental noise has thus become a common concern of all members of society. A key to resolving the complex noise issue lies in the effective control of urban noise sources. Control measures include reducing noise at its source, changing noise transmission pathways, building design, community planning and the use of personal hearing protection.

Urban environmental noise sources can be divided into industrial noise, traffic noise, building architecture noise and community district noise sources. Only the last three types are of concern here.

Traffic Noise

There are four sources of traffic noise: road traffic, railway transport, civil aviation and water transport; of these, road traffic is the main source of urban noise. The sound emission levels of heavy-duty trucks are 82–92 dBA and 90–100 dBA for electric horns; air horns are even worse, with sound emission levels of 105–110 dBA. Most urban noise from automobiles is in the 70–75 dB range, and it has been estimated that 27% of all complaints are about traffic noise. When a commercial jet takes off, speech communication is interrupted for up to 1 km on both sides of the runway, but people as far away as 4 km are disturbed in their sleep and rest. If a supersonic passenger plane flies at an altitude of 1 500 m, its sound pressure waves can be heard on the ground in a 30–50 km radius.

Building Noise

As a result of urban development in China, construction noise has become an increasingly serious problem. It is estimated that 80% of the houses in Fuzhou were built in the past 20 years. According to statistics, the noise from ramming in posts and supports is about 88 dB and the noise from bulldozers and excavators is about 91 dB, 10 m from the equipment. About 98% of industrial noise is in the 80–105 dB range, and it is estimated that 20% of all noise complaints is about industrial noise.

Community Noise

The main sources of community noise include street noise, noise from electronic equipment (air conditioners, refrigerators, washing machines, televisions), music, clocks, gongs and drums. Trumpets, gongs, drums and firecrackers, in particular, seriously disturb normal life and lead to annoyance complaints.

In conclusion, urban noise pollution in China is serious and is getting worse. To control noise pollution, China has promulgated standard sound values for environmental noise. These are summarized in table A2.2.

Table A2.2: LAeq standard values in dB for environmental noise in urban areas.

Applied area	day	night
Special residential quarters[1]	45	35
Residential and cultural education area[2]	50	40
Type 1 mixed area[3]	55	45
Type 2 mixed area[4] or commercial area	60	50
Industrial area	65	55
Arterial roads[5]	70	55

1 Special residential quarters: quiet residential area
2 Residential and cultural education area: residential quarters, cultural, educational offices
3 Type 1 mixed area: mixture of commercial area and residential quarters
4 Type 2 mixed area: mixture of industrial area, commercial area, residential quarters and others
5 Roads with traffic volume of more than 100 cars per hour

The peak sound levels for frequent noises emitted during the night-time are not allowed to exceed standard values by more than 10 dBA. Single, sudden noises during the night-time are not allowed to exceed standard values by more than 15dBA.

References

Liu Tian Gi et al.: Noise pollution and control. Environmental protection. Chemical industrial publishing company 1996. 6. First publication P137-154.
National environmental protection leader group. GB 3096-82. Urban environmental noise

standard. The national standard of the People's Republic of China. 1982, 8. 1.
Feng Gen Quan: The main result of field investigation for industrial continuous noise. Foreign Medicine. Otorhinolaryngology. 1978, 2:12.
Beijing Medical Quarantine Station. The investigation analysis of the noise hazard condition in nine provinces and cities. The noise work investigation cooperation group in nine provinces and cities (internal material). 1982.
Cheng Ming: The diagnostic criteria of occupational deafness and experience of hearing conservation in China. Noise as public health problem. New advance in noise research, part 1. Swedish Council for building research. Stockholm, Sweden 1990, pp. 137-44.

Japan (Michinori Kabuto)

Environmental Quality Standards

Noise standards for both general and roadside areas were set in Japan in 1967, through the "Basic Law for Environmental Pollution." This law was updated in September 1999. Each standard is classified according to the type of land use and the time of day. In ordinary residential areas, the night-time standard is 45 dB LAeq, but in areas that require even lower noise exposure, such as hospitals, this is lowered to 40 dB LAeq. In contrast, the daytime levels for commercial and industrial areas is as high as 60 dBA. Standards for roadside areas are 70 dB LAeq for daytime and 65 dB LAeq for nighttime. Between 1973–1997 noise standards for aircraft noise, super-express train noise and conventional railway train noise were also implemented. Standards for aircraft noise were set in terms of the weighted equivalent continuous perceived noise level (WECPNL). For residential areas, the WECPNL standard is 70 dBA, and is 75 dBA for areas where it is necessary to maintain a normal daily life.

For super-express trains, the Environmental Agency required noise levels to be below 75 dBA in densely populated residential areas, such as along the Tokaido and Sanyo Shinkansen lines, as well as in increasingly populated areas, such as along the Tohoku and Joetsu Shinkansen lines. The standards were to be met by 1990, but by 1991 this level had been achieved at only 76% of the measuring sites on average. Noise countermeasures included the installation of new types of sound-proof walls, and laying ballast mats along densely populated stretches of the four Shinkansen lines. Noise and vibration problems can also result from conventional trains, such as occurred with the opening of the Tsugaru Strait and Seto Ohashi railway lines in 1988. Various measures have since been taken to address the problems.

Complaints About Community Noise.

In Japan, complaints to local governments about environmental problems have been summarized annually and reported by Japan Environmental Agency. Thirty-seven percent of all complaints was due to factory (machinery) noise; 22% to construction noise; 3% to road traffic noise; 4% to air traffic noise; 0.8% to rail traffic noise; 9% to night-time business; 6% to other commercial activities; 2.5% to loudspeaker announcements, 9% to domestic noise; and 8% was due to miscellaneous complaints.

Sources of Noise Exposure and their Effects

Road-traffic noise. The number of automobiles in Japan has increased from 20 million in 1971 to 70 million in 1994, a 3.5-fold increase. One-third of this increase was due to heavy-duty vehicles. Since 1994, out of a total of 1 150 000 km of roads in Japan, only 29 930 km have been designed according to noise regulations. According to 1998 estimates by the Environmental Agency, 58% of all roads passed through residential areas. Daytime noise limits were exceeded in 92% of all cases, and night-time limits were exceeded in 87% of all cases. The study also estimated that 0.5 million houses within 10 m of the roads were exposed to excessive traffic noise. In a recent lawsuit, the Japanese Supreme Court ruled that people should be compensated when exposed to night-time noise levels exceeding 65 dB LAeq. This would apply to people living alongside 2 000 km of roads in Japan.

A recent epidemiological study examined insomnia in 3 600 women living in eight different roadside areas exposed to night-time traffic. Insomnia was defined as one or more of the following symptoms: difficulty in falling asleep; waking up during sleep; waking up too early; and feelings of sleeplessness one or more days a week over a period of at least a month. The data were adjusted for confounding variables, such as age, medical care, whether the subjects had young children to care for, and sleep apnea symptoms. The results showed that the odds ratio for insomnia was significantly correlated with the average night-time traffic volume for each of the eight areas and suggested that insomnia could be attributed solely to night-time road traffic.

From the most noisy areas in the above study 19 insomnia cases were selected for a further in-depth examination. The insomnia cases were matched in age and work with 19 control subjects. Indoor and outdoor sound levels during sleep were measured simultaneously at 0.6 s intervals. For residences facing roads with average night-time traffic volume of 6 000 vehicles per hour, the highest sound levels observed were 73–93 dBA. The odds ratios for insomnia in each of the quartiles for LAmax,1min; L50,1min; L10,1min and LAeq,1min generally showed a linear trend and ranged between 1 (lowest quartile) and 6.7 (highest quartile). It was concluded that insomnia was likely to result when night-time indoor LAeq, 1min sound levels exceeded 30 dBA.

Air-traffic noise. At the larger Japanese airports (Osaka, Tokyo, Fukuoka), jet airplanes have rapidly increased in number and have caused serious complaints and lawsuits from those living nearby. Complaints about jet-fighter noise are also common from residents living in the vicinity of several U.S. airbases located in Japan. In the case of Kadena and Futenma airbases on Okinawa, a recent study by the Okinawa Prefecture Government suggested that hearing loss, child misbehaviour and low birth-weight babies were possible health effects of the noise associated with these bases (RSCANIH 1997). Using measurements taken in 1968 during the Vietnam War, it was estimated that the WECPNL was 99–108 dBA at the Kadena village fire station. Similar WECPNL estimates of 105 dBA were also obtained for Yara (Kadena-cho) and Sunabe (Chatan-cho) bases. These levels correspond to a LAeq,24h value of 83 dB, and are of serious concern in light of recommendations by the Japan Association of Industrial Health that occupational noise exposure levels should not exceed 85 dB for an 8-h work day if hearing loss is to be avoided.

Audiogrammes of subjects living in areas surrounding Kadena airport indicated that they had progressive hearing loss at higher frequencies. Eight subjects had hearing impairment in the 3–6 kHz range, which strongly suggested that the hearing loss was due to excessive noise exposure. Since the examiners confirmed the subjects had not been exposed to repeated intense noise at their residences or workplaces, the most likely cause of their hearing loss was the intense aircraft noise during take-offs, landings and tune-ups at Kadena airport.

The effects of noise were examined in children from nursery schools and kindergartens in towns surrounding Kadena airport. The children were scored with respect to seven variables: cold symptoms, emotional instability, discontentment-anxiety, headache-stomachache, passivity, eating problems and urination problems. Confounding factors, such as sex, age, birth order, the number of parents living together, the mother's age when the child was born, reaction to noise and the extent of noise exposure, were taken into account. The results showed that children exposed to noise had significantly more problems with respect to their behaviour, physical condition, character and reaction to noise, when compared to a control group of children that had not been exposed to airport noise. This was especially true of for children exposed to a WECPNL of 75 or more. Thus, small children acquire both physical and mental disorders from chronic exposure to aircraft noise.

Chronic exposure to aircraft noise also affects the birth-weight of children. The birth-weights of infants were analyzed using records from 1974 to 1993 in the Okinawa Prefecture. Confounding factors such as the mother's age, whether there were single or multiple embryos, the child's sex, and the legitimacy of the child were considered. The results showed that 9.1 % of all infants born in Kadena-cho, located closest to Kadena airport, had low birth-weights. This was significantly higher than the 7.6 % rate seen in other municipalities around Kadena and Futemma airfields, and much higher than the 7 % rate in cities, towns and villages on other parts of Okinawa Island.

Rail-traffic noise. Commuter trains and subway cars expose Tokyo office workers to much higher noise levels than do other daily activities (Kabuto & Suzuki 1976). Exposure to indoor noise may vary according to railway line or season (there are more open windows in good weather), but the levels range from 65–85 dBA. In general, these values exceeded the LAeq,24h level of 70 dBA for auditory protection (US EPA 1974).

Neighbourhood noise. Neighbourhood noise, including noise from late-night business operations, noise caused by loudspeaker announcements, and noise from everyday activities, have accounted for approximately 39% of all complaints about noise in recent years. At present, noise controls for late-night business operations have been enforced by ordinances in 39 cities and prefectures, and in 42 cities for loudspeaker announcements.

References

Japan Environmental Agency Government of Japan (1994): Quality of the Environment in Japan 1994. Global Environment Department, Environment Agency, Tokyo.

Kabuto M and Suzuki S (1976) A trial measurement of individual noise exposure by time zone in a day. Japanese Journal of Industrial Health, 18:17-22.

Kabuto M, Ohtsuka R, Suzuki S (1978) Measurement and evaluation of individual noise exposure level of Tokyo metropolitan commuters and railroad cars above ground and in subways. Japanese Journal of Public Health 2: 59-63

Kageyama, T., Kabuto, M. Nitta H, Kurokawa Y, Taira K, Suzuki S, Takemoto T (1974): A population study on risk factors for insomnia among adult Japanese women: A possible effects of road traffic volume. Sleep 20: 963-971.

RSCAINH (1997) Summary of the Interim Report of the Field Study on Public Health around U.S. Bases in Okinawa, Research Study Committee of Aircraft Noise Influences in Health, Okinawa Prefecture Government, Okinawa Public Health Association.

US EPA (1974) information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Rep. No. 550/9-74.004

Appendix 3 : Glossary

Acoustic	Pertaining to sound or to the sense of hearing (CMD 1997)
Acoustic dispersion	Change of speed of sound with frequency (ANSI 1994)
Acoustic trauma	Injury to hearing by noise, especially loud noise (CMD 1997)
Adverse effect	(of noise) A change in morphology and physiology of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to the harmful effects of other environmental influences. This definition includes any temporary or long term lowering of physical, psychological or social functioning of humans or human organs (WHO 1994)
Annoyance	A feeling of displeasure associated with any agent or condition known or believed by an individual or a group to be adversely affecting them" (Lindvall and Radford 1973; Koelega 1987). Any sound that is perceived as irritating or a nuisance (ANSI 1995)
Anxiety	A feeling of apprehension, uncertainty, and fear without apparent stimulus, and associated with physiological changes (tachycardia, sweating, tremor, etc.) (DIMD 1985). A vaguer feeling of apprehension, worry, uneasiness, or dread, the source of which is often nonspecific or unknown to the individual (CMD 1997).
Audiometry	Testing of the hearing sense (CMD 1997). Measurement of hearing, including aspects other than hearing sensitivity (ANSI 1995)
Auditory	Pertaining to the sense of hearing (CMD 1997)
Auditory threshold	Minimum audible sound perceived (CMD 1997)
A-weighting	A frequency dependent correction that is applied to a measured or calculated sound of moderate intensity to mimick the varying sensitivity of the ear to sound for different frequencies

Ambient noise	All-encompassing sound at a given place, usually a composite of sounds from many sources near and far (ANSI 1994)
Articulation index	Numerical value indicating the proportion of an average speech signal that is understandable to an individual (ANSI 1995)
Bel	Unit of level when the base of the logarithm is ten, and the quantities concerned are proportional to power; unit symbol B (ANSI 1994)
Cardiovascular	Pertaining to the heart and blood vessels (DIMD 1985)
Cochlea	A winding cone-shaped tube forming a portion of the inner ear. It contains the receptor for hearing (CMD 1997)
Cognitive	Being aware with perception, reasoning, judgement, intuition, and memory (CMD 1997)
Community noise	Noise emitted from all noise sources except noise at the industrial workplace (WHO 1995a)
Cortisol	A glucocortical hormone of the outer layer of the adrenal gland (CMD 1997)
Critical health effect	Health effect with lowest effect level
C-weighting	A frequency dependent correction that is applied to a measured or calculated sound of high intensity to mimick the varying sensitivity of the ear to sound for different frequencies
dB	Decibel, one-tenth of a bel
dBA	A-weighted frequency spectrum in dB, see A-weighting
dBC	C-weighted frequency spectrum in dB, see C-weighting
dBlin	Unweighted frequency spectrum in dB
Decibel	Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power; unit symbol dB (ANSI 1994)

Ear plug	Hearing protector that is inserted into the ear canal (ANSI 1994)
Ear muff	Hearing protector worn over the pinna (external part) of an ear (ANSI 1994)
Effective perceived noise level	Level of the time integral of the antilogarithm of one tenth of tone-corrected perceived noise level over the duration of an aircraft fly-over, the reference duration being 10 s (ANSI 1994)
Emission	(of sounds). Sounds generated from all types of sources
Epinephrine	A hormone secreted by the adrenal medulla (inner or central portion of an organ) in response to stimulation of the sympathetic nervous system (CMD 1997)
Equal energy principle	Hypothesis that states that the total effect of sound is proportional to the total amount of sound energy received by the ear, irrespective of the distribution of that energy in time
Equivalent sound pressure level	Ten times the logarithm to the base ten of the ratio of the time-mean-square instantaneous sound pressure, during a stated time interval T, to the square of the standard reference sound pressure (ANSI 1994)
Exposure-response curve	Graphical representation of exposure-response relationship
Exposure-response relationship	(With respect to noise:) Relationship between specified sound levels and health impacts
Frequency	For a function periodic in time, the reciprocal of the period (ANSI 1994)
Frequency-weighting	A frequency dependent correction that is applied to a measured or calculated sound (ANSI 1994)
Gastro-intestinal	Pertaining to the stomach and intestines (CMD 1997)
Hearing impairment, hearing loss	A decreased ability to perceive sounds as compared which what the individual or examiner would regard as normal (CMD 1997)
Hearing threshold	For a given listener and specified signal, the minimum (a) sound pressure level or (b) force level that is capable of

evoking an auditory sensation in a specified function of trials (ANSI 1994)

Hertz	Unit of frequency, the number of times a phenomenon repeats itself in a unit of time; abbreviated to Hz
Hysteria	A mental disorder, usually temporary, presenting somatic (pertaining to the body) symptoms, stimulating almost any type of physical disease. Symptoms include emotional instability, various sensory disturbations, and a marked craving for sympathy (CMD 1997)
Immission	Sounds impacting on the human ear.
Impulsive sound	Sound consisting of one or more very brief and rapid increases in sound pressure
Incubator	An enclosed crib, in which the temperature and humidity may be regulated, for care of premature babies (CMD 1997)
Isolation, insulation	(With respect to sound.) Between two rooms in a specified frequency band, difference between the space-time average sound pressure levels in the two enclosed spaces when one or more sound sources operates in one of the rooms (ANSI 1994). (With respect to vibrations.) Reduction in the capacity of a system to respond to excitation, attained by use of resilient support (ANSI 1994).
Ischaemic Heart Disease	Heart disease due to a local and temporary deficiency of blood supply due to obstruction of the circulation to a part (CMD 1997)
Loudness level	Of a sound, the median sound pressure level in a specified number of trials of a free progressive wave having a frequency of 1000 Hz that is judged equally loud as the unknown sound when presented to listeners with normal hearing who are facing the source; unit phon (ANSI 1994)
Level	Logarithm of the ratio of a quantity to a reference quantity of the same kind; unit Bel (ANSI 1994)
Maximum sound level	Greatest fast (125 milliseconds) A-weighted sound level, within a stated time interval (ANSI 1994)

Mental Health	The absence of identifiable psychiatric disorder according to current norms (Freeman 1984). In noise research, mental health covers a variety of symptoms, ranging from anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood and anxiety, and social conflicts, to more general psychiatric categories like neurosis, phychosis and hysteria (Berglund and Lindvall 1995).
Morphological	Pertaining to the science of structure and form of organisms without regard to function (CMD 1997)
Nausea	An unpleasant sensation usually preceding vomiting (CMD 1997)
Neurosis	An emotional disorder due to unresolved conflicts, anxiety being its chief characteristic (DIMD 1985)
Noise	Undesired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device (ANSI 1994).
Noise induced temporary threshold shift	Temporary hearing impairment occurring as a result of noise exposure, often phrased temporary threshold shift (adapted from ANSI 1994)
Noise induced permanent threshold shift	Permanent hearing impairment occurring as a result of noise exposure, often phrased permanent threshold shift (adapted from ANSI 1994)
Noise level	Level of undesired sound
Norepinephrine	A hormone produced by the adrenal medulla (inner or central portion of an organ), similar in chemical and pharmacological properties to epinephrine, but chiefly a vasoconstrictor with little effect on cardiac output (CMD 1997)
Oscillation	Variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference (ANSI 1994)

Ototoxic	Having a detrimental effect on the organs of hearing (CMD 1997)
Paracusis	Any abnormality or disorder of the sense of hearing (CMD 1997)
Pascal	Unit of pressure, equal to one newton per square meter, abbreviated to Pa
Peak sound pressure	Greatest absolute instantaneous sound pressure within a specified time interval (ANSI 1994)
Peak sound pressure level	Level of peak sound pressure with stated frequency weighting, within a specified time interval (ANSI 1994)
Perceived noise level	Frequency-weighted sound pressure level obtained by a stated procedure that combines the sound pressure levels in the 24 one-third octave bands with midband frequencies from 50 Hz to 10 kHz (ANSI 1994)
Permanent threshold shift, permanent hearing loss	Permanent increase in the auditory threshold for an ear (adapted from ANSI 1995) (see also: noise induced permanent threshold shift)
Presbyacusia, presbycusis	The progressive loss of hearing ability due to the normal aging process (CMD 1997)
Psychiatric disorders	Mental disorders
Psychosis	Mental disturbance of a magnitude that there is a personality disintegration and loss of contact with reality (CMD 1997)
Psychotropic drug	A drug that affects psychic function, behaviour or experience (CMD 1997)
Reverberation time	Of an enclosure, for a stated frequency or frequency band, time that would be required for the level of time-mean-square sound pressure in the enclosure to decrease by 60 dB, after the source has been stopped (ANSI 1994)
Sensorineural	Of or pertaining to a sensory nerve; pertaining to or affecting a sensory mechanism and/or a sensory nerve (DIMD 1985)

Signal	Information to be conveyed over a communication system (ANSI 1994)
Signal-to-noise ratio	Ratio of a measure of a signal to the same measure of the noise (ANSI 1995) (see also: noise - in its extended meaning)
Silencer	Duct designed to reduce the level of sound, the sound-reducing mechanisms may be either absorptive or reactive, or a combination (ANSI 1994)
Sound absorption	Change in sound energy into some other form, usually heat, in passing through a medium or on striking a surface (ANSI 1994)
Sound energy	Total energy in a given part of a medium minus the energy that would exist at that same part with no sound waves present (ANSI 1994)
Sound exposure	Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event (ANSI 1994)
Sound exposure level	Ten times the logarithm to the base ten of the ratio of a given time integral of squared, instantaneous A-weighted sound pressure, over a stated time interval or event, to the product of the squared reference sound pressure of 20 micropascals and reference duration of one second (ANSI 1994)
Sound intensity	Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered (ANSI 1994)
Sound level meter	Device to be used to measure sound pressure level with a standardized frequency weighting and indicated exponential time weighting for measurements of sound level, or without time weighting for measurement of time-average sound pressure level or sound exposure level (ANSI 1994)
Sound pressure	Root-mean-square instantaneous sound pressure at a point, during a given time interval (ANSI 1994), where the *instantaneous* sound pressure is the total instantaneous pressure in that point minus the static pressure (ANSI 1994)

Sound pressure level	Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases of 20 • Pa (ANSI 1994)
Sound reduction index	Single-number rating of airborne sound insulation of a partition (ANSI 1994)
Sound transmission class	Single-number rating of airborne sound insulation of a building partition (ANSI 1994)
Speech interference level	One-fourth of the the sum of the band sound pressure levels for octave-bands with nominal midband frequencies of 500, 100, 2000 and 4000 Hz (ANSI 1994)
Speech intelligibility	That property which allows units of speech to be identified (ANSI 1995)
Speech perception	Psychological process that relates a sensation caused by a spoken message to a listener's knowledge of speech and language (ANSI 1995)
Speech comprehension	(a) Highest level of speech perception. (b) Knowledge or understanding of a verbal statement (ANSI 1995)
Speech transmission index	Physical methgod for measuring the quality of speech-transmission channels accounting for nonlinear distortions as well as distortions of time (ANSI 1995)
Stereocilia	Nonmotile protoplasmic projections from free surfaces on the hair cells of the receptors of the inner ear (CMD 1997)
Stress	The sum of the biological reactions to any adverse stimulus, physical, mental or emotional, internal or external, that tends to disturb the organism's homeostasis (DIMD 1985)
Temporary threshold shift, temporary hearing loss	Temporary increase in the auditory threshold for an ear caused by exposure to high-intensity acoustic stimuli (adapted from ANSI 1995) (see also: noise induced temporary threshold shift).
Tinnitus	A subjective ringing or tinkling sound in the ear (CMD 1997). Otological condition in which sound is perceived by

	a person without an external auditory stimulation. The sound may be a whistling, ringing, buzzing, or cricket type sounds, but auditory hallucinations of voices are excluded (ANSI 1995).
Vibration	Oscillation of a parameter that defines the motion of a mechanical system (ANSI 1994)

For references see Appendix A.

Appendix 4 : Acronyms

AAP	American Academy of Pediatrics
AI	Articulation Index
AMIS	Air Management Information System (WHO, Healthy Cities)
ANEF	Australian Noise Exposure Forecast
ANSI	American National Standard Institute, Washington DC, USA
ASCII	American Standard Code for Information Interchange
ASHA	American Speech-Language-Hearing Association, Rockville, MD, USA
ASTM	American Society for Testing and Materials, West Conshohocken, PA, USA
CEN	Comité Européen de Normalisation, Brussels, Belgium (European Committee for Standardization)
CFR	Code of Federal Regulations (United States)
CIAL	Centro de Investigaciones Acústicas y Luminotécnicas, Córdoba, Argentina (Centre of acoustical and light-technical investigations)
CMD	Cyclopedic Medical Dictionary
CNRC	Conseil National de Recherches du Canada (National Research Council)
COPD	Chronic Obstructive Pulmonary Disease
CSD	Commission for Sustainable Development
CSIRO	Commonwealth Scientific and Industrial Research Organization
CVS	Cardiovascular System
DNL	Day-Night Average Sound Level (United States)
EC DG	European Commission Directorate General
ECE	Economic Commission for Europe
ECMT	European Conference of Ministers of Transport
EHIAP	Environmental Health Impact Assessment Plan
EIAP	Environmental Impact Assessment Plan
EMRO	WHO Regional Office of the Eastern Mediterranean
ENIA	Environmental Noise Impact Analysis
EPNL	Effective Perceived Noise Level measure
EU	European Union
FAA	Federal Aviation Administration (United States)
FFT	Fast Fourier Transform technique
GIS	Geographic Information System
Hz	Hertz, the unit of frequency
ICAO	International Civil Aviation Organization
ICBEN	International Commission on the Biological Effects of Noise
IEC	International Electrotechnical Commission
ILO	International Labour Office, Geneva, Switzerland
INCE	Institute of Noise Control Engineering of the United States of America
INRETS	Institut National de REcherche sur les Transports et leur Sécurité, Arcueil, France (National Research Institute for Transport and their Safety)
ISO	International Standards Organization
I-INCE	International Institute of Noise Control Engineering
L10	10 percentile of sound pressure level

L50	Median sound pressure level
L90	90-percentile of sound pressure level
LA	Latin America
LAeq,T	A-weighted equivalent sound pressure level for period T
LAmax	Maximum A-weighted sound pressure level in a stated interval
L_{dn}	Day and night continuous equivalent sound pressure level
Leq,T	Equivalent sound pressure level for period T
LEQ(FLG)	Descriptor used for aircraft noise (Germany)
LNIP	Low Noise Implementation Plan
Lp	Sound pressure level
MTF	Modulation Transfer Function
NASA	National Aeronautics and Space Administration (United States)
NC	Noise Criterion
NCA	Noise Control Act (United States)
NCB	Balanced Noise Criterion procedure system
NEF	Noise Exposure Forecast
NEPA	National Environmental Policy Act (United States)
NGO	Non Governmental Organization
NIHL	Noise Induced Hearing Loss
NIPTS	Noise Induced Permanent Threshold Shift
NITTS	Noise Induced Temporary Threshold Shift
NNI	Noise and Number Index
NR	Noise Rating
NRC	National Research Council (United States, Canada)
OECD	Organisation for Economic Co-operation and Development, Paris, France.
ONAC	Office of Noise Abatement and Control of the US EPA
OSHA	Occupational Safety and Health Administration
Pa	Pascal, the unit of pressure
PAHO	Pan American Health Organization
PHE	Department for Protection of the Human Environment, WHO, Geneva
PNL	Perceived Noise Level
PSIL	Preferred Speech Interference Level
PTS	Permanent Threshold Shift
RASTI	Rapid Speech Transmission Index
RC	Room Criterion
SABS	South African Bureau of Standards
SEL	Sound Exposure Level
STC	Sound Transmission Class
STI	Speech Transmission Index
TTS	Temporary Threshold Shift
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development (Rio de Janeiro, June 1992)
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe

UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
USA	United States of America
WCED	World Commission on Environment and Development (Brundtland Commission)
WECPNL	Weighted Equivalent Continuous Perceived Noise Level
WHO	World Health Organization
WWF	World Wildlife Fund

Appendix 5 : Equations and other technical information

Basic acoustical measures

Sound Pressure Level

The time-varying sound pressure will completely define a sound in a given location. The sound pressure range is wide within which human listeners can receive (10^{-5} - 10^{2} N/m^2). Therefore, it is practical to measure sound pressure level on a logarithmic scale. Sound intensity level is defined as 10 times the logarithm (to the base 10) of the ratio of the sound intensity of a target sound to the sound intensity of another (reference) sound. Sound intensity is proportional to the squared sound pressure because the static mass density of the sound medium as well as the speed of sound in this medium are invariant. The sound pressure level (L_p) of a sound may be expressed as a function of sound pressure (p) and is, thus, possible to measure:

$$L_p = 10 \log_{10} (p/p_{ref})^2$$

For the purpose of measuring sound pressure level in a comparative way, the reference pressure, p_{ref}, has an internationally agreed value of $2 \cdot 10^{-5}$ N/m^2 (earlier 20 μPa). Sound pressure level is then expressed in decibel (dB) relative to this reference sound.

Sound Pressure Level of Combined Sounds

Whereas sound intensities or energies or pressures are additive, non-correlated time-varying sound pressure levels have first to be expressed as mean square pressure, then added, and then transferred to a sound pressure value again. For example, if two sound sources are combined, each of a sound pressure level of 80 dB, then the sound pressure level of the resulting combined sound will become 83 dB:

$$L_p = 10 \cdot \log_{10} (10^8 + 10^8) = 10 \cdot \log_{10} (2 \cdot 10^8) = 10 \cdot (\log_{10} 2 + \log_{10} 10^8) = 10 \cdot (0.3 + 8) = 83$$

It is only sounds with similar sound pressure levels that when combined will result in a significant increase in sound pressure level relative to the louder sound. In the example given above, a doubling of the sound energy from two sources will only result in a 3-dB increase in sound pressure level. For two sound sources that emit non-correlated time-varying sound pressures, this represents the maximum increase possible. The sound pressure level outcome, resulting from combining two sound pressure levels in dB, is displayed in Figure A.5.1.

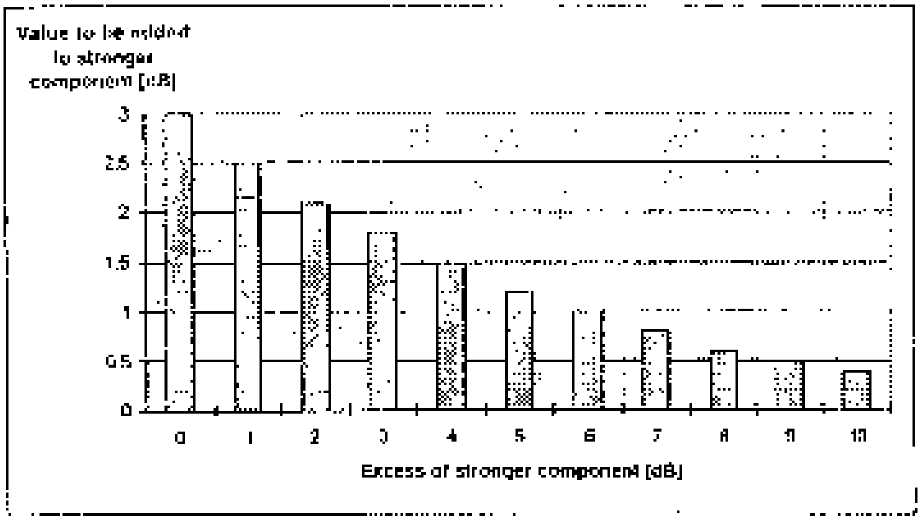

Figure A.5.1: Estimate of combined sound levels

Equivalent Continuous Sound Pressure Level

Average sound pressure level is determined for a time period of interest, T, which may be an interval in seconds, minutes, or hours. This gives a dB-value in Leq that stands for equivalent continuous sound pressure level or simply sound level. It is derived from the following mathematical expression in which A-weighting has been applied:

$$L_{Aeq,T} = 10 \log_{10}\{(1/T) \int_0^T 10^{L(t)/10} \, dt\} \text{ [dBA]}$$

Because the integral is a measure of the total sound energy during the period T, this process is often called "energy averaging". For similar reasons, the integral term representing the total sound energy may be interpreted as a measure of the total noise dose. Thus, Leq is the level of that steady sound which, over the same interval of time as the fluctuating sound of interest, has the same mean square sound pressure, usually applied as an A-frequency weighting. The interval of time must be stated

Sound exposure level

Individual noise events can be described in terms of their sound exposure level (SEL). SEL is defined as the constant sound level over a period of 1 s that would have the same amount of energy as the complete noise event (Ford 1987). For a single noise event occurring over a time interval T, the relationship between SEL and LAeq,T is,

$$SEL = L_{Aeq,T} + 10 \log_{10} (T/T_0)$$

In this equation T_0 is 1 s.

Day and night continuous sound pressure level

There are different definition in different countries. One definition is (von Gierke 1975, Ford 1987)

L_{dn} = LAeq,16h + LAeq,8h 10 dBA

Where LAeq,16h is the day equivalent sound pressure level and LAeq,8h is the night equivalent sound pressure level.

Sound Transmission into and within buildings

An approximate relationship between sound reduction index (R), the frequency (f), the mass per unit area of the panel (m) in kg/m^2, and the angle of incidence (θ) is given by

$$R(\theta) = 20 \log(f\, m\, \mathrm{COS}(\theta)) - 42.4, \text{ (dB)}$$

This relationship indicates that the sound reduction index will increase with the mass of a panel and with the frequency of the sound as well as varying with the angle of incidence of the sound. It is valid for limp materials but is a good approximation to the behaviour of many real building materials at lower frequencies.

The sound reduction index versus frequency characteristics are usually complicated by a coincidence dip which occurs around the frequency where the wavelength of the incident sound is the same as the wavelength of bending waves in the building façade material. The frequency at which the coincidence dip occurs is influenced by the stiffness of the panel material. Thicker, and hence stiffer materials, will have coincidence dips that are lower in frequency than less stiff materials. Figure A.5.2 plots measured sound reduction index values versus frequency for 4 mm thick glass and illustrates the coincidence dip for this glass at a frequency centered just above 3 kHz.

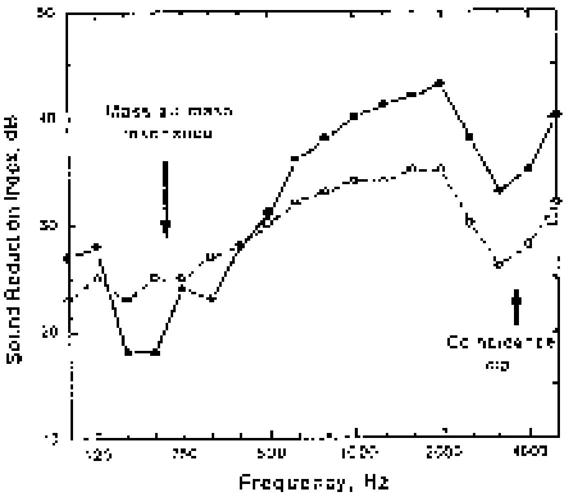

Figure A.5.2: Sound reduction index versus frequency for single and double layers of 4 mm glass (air separation 13 mm).

As also illustrated in Figure A.5.2 for two layers of 4 mm glass, the low frequency sound reduction can be severely limited by the mass-air-mass resonance. This resonance is due to the combination of the masses of the two layers and the stiffness of the enclosed air space. As the Figure A.5.2 example shows, this resonance can often dramatically reduce the low frequency sound reduction of common double window constructions.

The sound reduction of various building constructions can be calculated as the difference between the average sound levels in the two rooms ($L_1 - L_2$) plus a correction involving the area of the test panel (S) in m^2 and the total sound absorption (A) in m^2 in the receiving room,

$R = L_1 - L_2 + 10 \log\{S/A\}$ [dB].

For outdoor-to-indoor sound propagation, the measured sound reduction index will also depend on the angle of incidence of the outdoor sound as well as the position of the outdoor measuring microphone relative to the building façade,

$R = L_1 - L_2 + 10 \log\{4S\ COS(\theta)/A\} + k$ [dB].

When the outdoor incident sound level L_1 is measured with the outdoor microphone positioned against the external façade surface, measured incident sound pressures will be 6 dB higher due to pressure doubling. This occurs because the incident sound and reflected sound arrive at the microphone at the same time. If the external microphone is located 2 m from the façade, there will not be exact pressure doubling but an approximate doubling of the measured sound energy corresponding to a 3 dB increase in sound level. The table below indicates the appropriate values of k to be used in the above equation, depending on the location of the outdoor microphone, to account for sound reflected from the façade.

$k = 0$. dB	L_1 does not include reflected sound.
$k = -3$. dB	L_1 measured 2 m from façade and includes reflected energy.
$k = -6$. dB	L_1 measured at the façade surface and includes pressure doubling effect.

Appendix 6 : Participant list of THE WHO Expert Task Force meeting on Guidelines For Community Noise, 26-30 April 1999, MARC, London, UK

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Section title: Wind turbine studies & reports

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DIRECT TESTIMONY OF JON BOONE

BEFORE THE PUBLIC SERVICE COMMISSION OF MARYLAND

APPLICATION BY SYNERGICS WIND ENERGY LLC FOR A

CERTIFICATE OF PUBLIC CONVENIENCE & NECESSITY

TO CONSTRUCT A 47 MW WIND POWER FACILITY

IN GARRETT COUNTY, MARYLAND

July 25, 2005 CASE NO. 9008

Renewable energy (hydropower, for example) can have horrendous impacts on fish and wildlife. But I can think of no proposed project more devastating to fish, wildlife, and the local economy than plunking a wind farm in the middle of Nantucket Sound.
-- Ted Williams, Audubon Magazine (May 5, 2004).

Q PLEASE STATE YOUR NAME AND ADDRESS?

A. Jon Boone

503 East Alder Street

Oakland, Maryland 21550

Q. WHAT IS THE PURPOSE OF AND RATIONALE FOR YOUR TESTIMONY IN THIS CASE?

A. I oppose this application for a CPCN and recommend that the PSC deny it. There is strong and I believe compelling evidence Synergics' project at Roth Rock will cause much more trouble than it is worth. Although the Applicant promises to the make the air cleaner by displacing toxins from the combustion of fossil fueled power-generating facilities, such windplants in the uplands of the eastern United States will have the same nugatory effect on air pollution and global warming as the removal of a few drops of water would have in emptying a large tub that is continuously being filled. Belief that more forty-story wind plants here will reduce fossil fuel combustion below current levels is demonstrably false, given our increasing demand for electricity. That generous subsidies for windpower are *not* indexed to reductions in fossil fuel emissions—the raison d'etre of windpower– is a clear recognition of its limitations. Consequently, this windplant will obligate the state's rate and tax payers to spend more without receiving any of the promised health benefits in exchange.

More than 2000 wind turbines spread over nearly 300 miles of forested ridgeline like the ones proposed here would not displace one 1600 MW coalplant. The industry as a whole produces nominal electricity to avail itself of massive tax avoidance mechanisms for a few investors at the expense of tax and rate payers. It is best seen as an Enronesque delivery system for tax shelters, for it was Enron that pioneered the tax shelter as a commodity and, before its demise, owned and operated the nation's largest stock of windplants (most of which General Electric purchased during Enron's bankruptcy). Moreover, this particular multi-million dollar capital project will not bring many local jobs or add much local revenue. It will kill significant wildlife and mock Garrett County's Heritage Plan, which calls for the protection of Backbone Mountain as a natural heritage resource. It will reduce property values in the viewshed and cause significant disturbances for those who live nearby.

In short, it represents yet another extraction industry seeking to exploit the people and resources of Appalachia while delivering no meaningful product, relying upon unsubstantiated claims, an uninformed public and press, and the gullibility of those seeking easy solutions to complex problems. Many who live in Garrett County resent the pillage of our mountains, the destruction of wildlife, and the devaluation of property that will follow in the wake of this project. I read nothing in the developer's application and supplemental emendations or in subsequent testimony from Synergics' team that assuages my concerns about the havoc this project would visit upon the county. I'm now convinced industrial-scaled wind projects sited on Appalachian ridgetops are anathema to informed environmentalism, as well as responsible economics and public policy.

Those involved with public policy implementation should work hard to make informed decisions that reveal, then limit or eliminate, negative consequences. The history of environmentalism is essentially the effort to restrain corporate excess and mitigate the unanticipated undesirable effects of wishful thinking. The history of the Public Service Commission began in just this spirit, with the goal of protecting energy consumers. Unfortunately, the PSC budget today is derived from the industries it regulates, raising the specter of conflict of interest.

My intention with this commentary is not only to challenge the claims this Applicant has made about his product, but also challenge the Public Service Commission to do so as well. It will serve the public to know what consequences, if any, obtain for promises made and not fulfilled, as well as to learn how any benefits, if substantiated, compare with a range of costs. The PSC should carefully investigate and evaluate all aspects of this application, aware of the "horse and barn door" difficulties inherent in correcting problems that may emerge down the road. Generally, if something seems too good to be true, it almost always is. Informed, rational public policy should not be about wishful thinking, political cronyism, or the timely delivery of production tax credits.

Q WHAT IS YOUR BACKGROUND?

A. As a life-long environmentalist, I know the dangers of heavy reliance upon fossil fuel combustion. A few years ago, I hoped windpower, since it does not directly emit greenhouse gases into the air, might fulfill its promise to reduce the region's coal mining and significantly improve air quality. But after an earlier MDPSC windplant application experience (Case No. 8938) , where I focused primarily on wildlife concerns, I have done more research, from which I gained much wider context about the industry and its potential to displace fossil fuels in the production of electricity—knowledge the PSC should have sought in the first place before deciding anything.

Nearly 30 years ago, I helped found the North American Bluebird Society to undo the damage resulting from well-meaning but ill-considered decisions made 100 years previously. During my lifetime, I have witnessed countless examples of this kind of damage. Seventy years ago, hydroelectric dams exemplified renewable, "clean" energy initiatives; today, they are known to be so environmentally destructive that many are being dismantled--at taxpayer expense. The indiscriminate use of DDT cost us dearly, although it did help in the fight against malaria. The encouraging effort to restore the Bald Eagle and Peregrine Falcon after the chemical's broad usage was banned has cost millions of public dollars. And now here we are with the swash, buckle, and spin of the windpower industry, with its often pretentious environmentalism and relatively feckless energy production.

My interest in birds and nature began in childhood, and I have nourished that interest with considerable reading and observation over many years. I know the avifauna of the targeted area as well as anyone, spending much time there in recent years studying the nesting behavior of, to give but one example, the state-endangered Mourning Warbler. Although my interest in birds is that of a passionate amateur, I nonetheless have written about the nesting cycle of the Golden-crowned Kinglet (finding the first kinglet nest in Maryland) as well as a number of other articles on the history and effectiveness of field guides. I also lecture on the subject of Garrett County birds, and often take groups of people around the countryside for intimate looks at the way birds make their living in various county habitats. I knew and corresponded with Roger Tory Peterson, the famed naturalist, and I am now a consultant for the Roger Tory Peterson Institute in Jamestown, New York. I continue to be informed and inspired by perhaps this country's most renowned ornithologist, Chandler S. Robbins, who has studied migratory birds in the mountains of Maryland for nearly 60 years.

My work on this subject is a public service. My sole interest is enlightened public policy. Neither I nor any members of my family own property in the proposed viewshed of this project --and the facility would not be visible at our place of residence. Although I belong to Friends of Backbone Mountain, a Garrett County group of about 200 people dedicated to the protection of Backbone Mountain as a natural heritage resource, I accept no funding from any source on this wind issue. While I consult with members of Friends of Backbone Mountain, I am not bound by any directives from the organization. By profession. I am a retired university administrator and now am a painter, often using the forms of nature to inspire my work. In recent years, I've written extensively on the Dutch artist, Johannes Vermeer. This is the second windpower application I have reviewed.

Q. WHAT ARE YOUR SPECIFIC AREAS OF CONCERN ABOUT THIS HEARING AND THE APPLICATION?

A. I'm uneasy about the precedent-setting nature of these early wind applications. The intervenors in this case should help broaden the scope and rigor of review beyond the rather cursory analysis of previous cases. That the PSC sanctioned an expedited review in the earlier cases, short-circuiting a considered examination of the many issues at play in a new technology, and chose not to notify nearby property owners individually, the people most affected by propinquity to a massive windplant, are matters of major concern. At the very least, the public meeting for this hearing in Garrett County should provide ample time for comment and be held in a venue appropriate to accommodate the many people who will want to be heard. As the only resident of Garrett County involved directly in this hearing, I hope to bring a citizen's perspective, while seeking clear responses about this project's costs to and benefits for the public.

Either directly or with supporting documents, the Applicant has stated his windplant (1) will lessen dependence on foreign oil; improve air quality by mitigating the production of fossil-fueled power plants; improve the health of Maryland residents; (2) provide electrical power for 13,000 to 33,000 homes (with a 40 MW facility); and (3) add significant revenues to Garrett County's economy. In addition, the Applicant has stated (4) his technology would not pose significant risk to wildlife, nor (5) alter the landscape in perceptible ways, nor decrease the value for surrounding properties, nor introduce disturbances that might jeopardize the right of neighbors to quietly enjoy their property. Conversely, he barely mentions the extraordinary subsidies that taxpayers provide, although these are clearly the motivating reason for the application. Finally, the developer contends that (6) decommissioning of the turbines is a non-issue.

Each of these claims, as well as any increased taxpayer or ratepayer obligations that may result due to the project, should be scrutinized and interrogated with great care to determine their validity.

Q. ARE YOU CONCERNED ABOUT CONTINUED RELIANCE ON FOSSIL FUELS? IF SO, WHY DON'T YOU WHOLEHEARTEDLY ENDORSE RENEWABLE WIND ENERGY?

A. Yes! Power to supply our demand for electricity now comes primarily from the combustion of fossil fuels like coal, with poisonous consequences. Because windpower does not emit toxins into the air and its source of energy is recurrent, it offers the promise of a clean, renewable alternative to fossil fuels, along with a reduction in the significant environmental problems fossil fuels cause. Indeed, the understandable desire to reduce the toxins that reliance on fossil fuel combustion cause, as well as the wish to eliminate such draconian extraction techniques for coal as strip mining and mountaintop removal, has enabled windpower advocates to make strong gains in recent years

The quest for renewable energy has had a long contrapuntal history. A few hundred years ago, timber seemed inexhaustible, but our demand made short work of the supply. Coal, too, is renewable, but again, our demand will at some time overrun supply—and our meager lifespan won't extend the tens of millions of years necessary to replenish it. A few generations ago, hydroelectric dams were all the rage. Although these do produce a lot of electricity from a renewable source, they are so environmentally damaging that many are now being dismantled, at taxpayer expense.

The central problem with harnessing any form of energy is that enormous energies are wasted in the process of producing and channeling a relatively small amount (a phenomenon described by the Second Law of Thermodynamics). Hydroelectric dams, for example, transformed whole ecosystems, but the resulting supply of electricity was only a small percentage of the total energy within the ecosystem before the dams were built. This "loss" of energy was really the loss of valuable natural dynamics that previously functioned to maintain wetlands and mitigate erosion.

Windpower, too, has this inherent difficulty. There are significant losses—direct and indirect-- in the process of producing wind energy at industrial scales, which I will detail throughout this commentary. But because time seems to be running out on fossil fuels and the lure of non-polluting windpower is so seductive, otherwise sensible people are now promoting windpower initiatives at any cost with nearly idolatrous fervor, without investigating potential negative consequences-- and with no apparent knowledge of even recent environmental history.

Q. WHY DON'T YOU THINK WINDPLANTS SUCH AS THE PROPOSED WILL LESSEN DEPENDENCE ON FOREIGN OIL IN THE REGION, AS CLAIMED?

A. Wind only generates electricity. Electricity generation is only part of our energy production. *Sixty percent of the nation's energy use does not involve the making of electricity.* Allegheny Power, the major electricity provider in the region including Western Maryland, reports that oil accounted for 1% of the resources used to generate its power in 2004. Nationwide, this figure is less than 5%. Coal and gas-fired power plants do pollute the air with toxic hydro-carbons. But the sheer volume of automobile exhaust combined with home heating demand are major contributors to the problem. It is folly to suggest that thousands of wind turbines blanketing the mountains of the region would do anything of significance to mitigate these other energy forces evidently contributing to the warming of the planet. It would take 100 windplants like the one Synergics proposes, spread over nearly 300 miles of ridgetop, to generate as much electricity as one 1600 megawatt coal plant. Even if industrial wind generated ten percent of the nation's electricity, it would not staunch the fossil fuel emissions involved in accelerating global warming, given our nation's increasing energy consumption and given that wind can only intermittently (about 30 percent of the time) address the electricity portion of the problem.

Q. DO YOU THINK WINDPLANTS SUCH AS THE PROPOSED WILL REDUCE/DISPLACE THE MINING/BURNING OF FOSSIL FUELS IN THE REGION, AS CLAIMED?

A. It would take thousands of these clean-energy, landscape-marring machines to generate only a slice of the region's power needs. Consider a recent Department of Energy Study. It shows that nationwide, moving to 10 percent renewable energy would still see coal burning increase substantially because of rapidly growing electrical demand.
-- -Tom Horton, staff environmental writer of the weekly column, On the Bay, The Baltimore Sun: "Wind farms a problem, too," February 27, 2004

Wind technology in the uplands of this region stands little chance of displacing fossil fuel extraction efforts or reducing its consumption, given our increasing rate of electricity demand. Wind machinery has problems accessing and controlling its source of power. Because of the intermittent nature of wind velocity, sometimes it is not strong enough to generate power and other times it is too strong to be commercially tapped. The industry has attempted to increase its effectiveness by making taller machines and targeting them on high ridges with excellent wind potential. Nonetheless, because of its intermittency, wind technology will require back-up from other, often "dirty" power sources for the time it does not operate or works at sub-optimal levels.

A wind turbine is designed to generate optimal electrical power relative to its size, shape, ability to withstand stresses, rotor sweep and efficiency, and location, among other conditions. The wind needs to blow eight to fourteen miles an hour before a turbine will produce electricity, and a turbine is programmed to shut down when the wind velocity exceeds 50 or 55 miles per hour to prevent harm to its gears. If the wind were to blow at a sufficiently consistent velocity all the time and the turbine never broke down, the turbine would be operating at 100 percent of its capacity potential over a year's time--its **Rated Capacity**. However, because the wind is intermittent and volatile, and the turbines at various times require maintenance, they *actually* will produce electricity only some of the time. Using a combination of considerations, such as meteorological testing, weather history, the history of turbine effectiveness, among others, energy experts assign a **Capacity Factor** for each turbine model, which predicts the amount of electricity a turbine will actually produce in a year. *No existing windplants located in the PJM region have achieved a capacity factor of more than 30 percent. (Attachment A)* This means that 70 percent of the time they are not producing electricity. Consequently, a windplant rated at 47 MWs, for example, will generate electricity in the neighborhood of 12-15 MWs (25-30 % of its rated capacity).

Other power sources, such as coal or nuclear, also don't work all of the time either, and must be supplemented by power sources that are working. The electricity grid has a complex monitoring system for predicting and maintaining its supply. Electricity must balance the rate of production with the rate of consumption at all times. *A fundamental problem with supplying electricity is that electricity cannot be stored at industrial levels.*

Once generated, electricity must be delivered and consumed immediately. However, power sources like coal and nuclear are rarely volatile when producing their yield and produce electricity at about 75-80 percent of their rated capacities. The volatile, extremely unpredictable nature of wind resource makes its technology different from other power sources not only in degree but in kind.

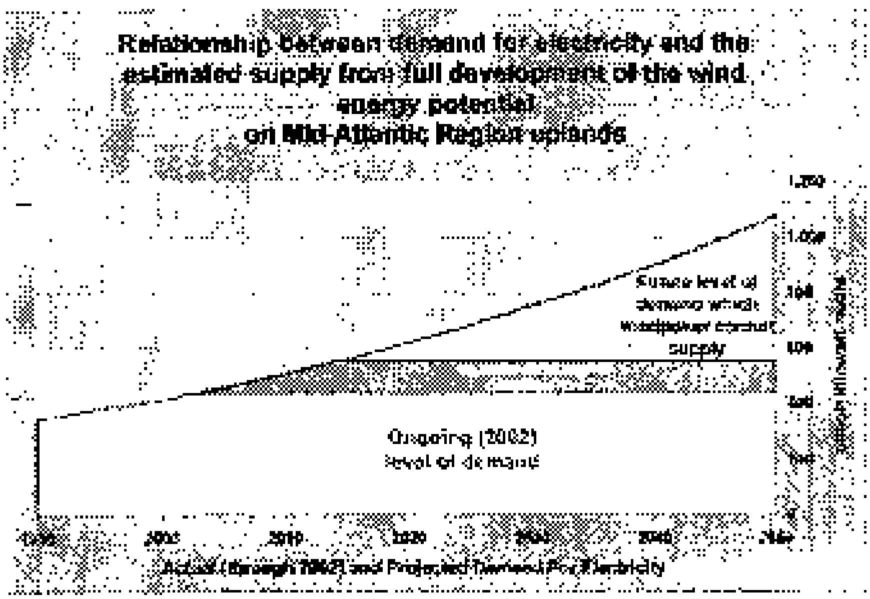
The intermittent nature of wind energy might not pose a problem to the region's electricity grid at present levels. However, increasing the percentage of wind energy to higher levels would require significant and expensive technological modifications to the grid and to the various transmission systems out to the end user. It would also present major challenges for the grid's management.

This may not be a substantial concern until wind energy becomes a major contributor to the electricity grid, adding, say, two or three percent to the total electricity supply. A "Wind Report 2004" by E-On/Netz, one of Germany's largest electric grid operators, confirms this analysis, adding many other "price" caveats: given the intermittent and volatile nature of the wind, both the mechanics of grid operation and transmission technology would have to be retooled—at substantial cost—to back up wind generation. In fact, if wind energy increased to provide, say, just a small percentage of the power for the PJM grid, primarily fossil-fueled generating plants would have to fire up to levels of 80 percent to function as a "shadow" back up service. This report also confirms that wind utilization rates rarely achieve 30 percent, that is, they don't work more than 70 percent of the time (*Attachment P*).

Since other windplants struggle to achieve a 30 percent capacity factor, it is unclear how Synergics has arrived at its claim of 38 percent (down from an earlier claim of nearly 60 percent—the theoretical maximum!). The developer still does not disclose how this capacity will be achieved, and has refused to provide any wind energy measurement data. The PSC should require these wind measurement data to be made public.

With a generous 30 percent capacity factor, *more than 2000 giant 2.5 MW turbines are needed to equal the annual production of one 1600 MW coal plant* (i.e., Mt. Storm, West Virginia). Even if we placed huge wind machines at *all* the good wind sites possible in the uplands east of the Mississippi River (a region with only 5% of the wind energy potential of the continental US) *(Attachment B)*, this would still not reduce the mining or burning of coal, given that our demand for electricity will likely nearly double in 30 years. In fact, *wind technology works least when the need is greatest – summer peak demand, when the wind is typically not very active. At the nearby Mountaineer wind facility, the capacity factor during summer months averages less than 15 percent – half of the average annual capacity factor.*

Consider the following graph showing the relationship between demand for electricity and the potential of windpower to meet it in the uplands of the Mid-Atlantic region.



This region comprises all or most of six states and Washington, DC. It's ridges have less than one percent of the nation's wind energy potential. Moving from left to right, the upward curve on the graph represents the demand for electricity which is expected to increase in the region at a conservative projection rate of two percent each year into the foreseeable future. Present supply comes from the PJM Interconnection, the world's largest grid operator, which taps a variety of power sources— primarily fossil fuels, with negligible contributions from wind.

However, *if* (and this is a most improbable if) the wind industry could immediately exploit *all* the wind potential available in the region's uplands, *saturating* it with 30,000 huge turbines functioning at a capacity factor of 30 percent (see the table below), then it could produce enough electricity to supply about one-fourth of the *present* level of demand. In the graph, this hypothetical supply from wind is represented in blue atop the ongoing level of demand. But note, in about 15 years, our increased rate of demand will absorb any yield produced by windpower, necessitating additional energy sources to supply it. Unless wind turbines fill up the Chesapeake Bay and are constructed off the ocean's shore, the projected additional future power sources will not come from wind, for the industry will be tapped out on land. As the graph rather dramatically shows, wind energy development of the region's uplands --at its realistic maximum-- will not result in a net reduction of greenhouse gases or cut the present rate of the burning of coal and other fossil fuels. The very best case scenario for windpower in the Mid-Atlantic region is that future wind energy development will only slightly lessen the rapidly increasing rate in the growth of demand for electricity from "dirty" power sources.

The claim Synergics makes about its potential wind energy production may seem impressive. However, a million hamsters churning treadmills will also produce electricity. But what's the point? In this larger scheme, Synergics' comparatively minuscule power production would immediately be engulfed by increasing demand. The boast that its plant would be an important first step in the direction of a comprehensively effective windpower system is therefore unsupportable.

STATE	RENEWABLE ENERGY SOURCES[1] Geothermal Potential (million kWh)	Landfill Gas Potential (million kWh)	Clean Biomass Potential (million kWh)	Wind Potential[2] (million kWh)	TOTAL OF RENEWABLE ENERGY SOURCES (million kWh)	% TOTAL FROM WIND	NUMBER OF INDUSTRIAL WIND TURBINES TO GENERATE WIND POTENTIAL[3]
DC	0	0	0	0	0	0	0
Delaware	0	123	[illegible]	4,963	5,480	89%	1,718
Maryland	0	915	2,[illegible]	3,640	[illegible]	65%	1,431
New Jersey	0	1,275	480	[illegible]	17,102	80%	3,468
Pennsylvania	0	1,743	6,959	67,994	79,611	85%	17,223
Virginia	0	1,050	11,429	13,293	25,132	51%	3,391
West Virginia	0	[illegible]	3,303	9,764	15,087	65%	2,477
TOTAL	0	4,250	30,307	118,797	151,494	77%	29,529

1. Source information is from a national report entitled - Generating Solutions. How States Are Putting Renewable Energy Into Action. A Report of the US PIRG Education Fund and the State Public Interest Research Groups. February 2002. ["This report examines 21 states and their potential for electricity generation from renewable resources using state-of-the-art technology." Estimates of amount of electricity possible for energy sources were based on studies by government (mainly National Renewable Energy Laboratory), industry and the Union of Concerned Scientists (UCS).] Amount of electricity is shown as Million kilowatt-hours. See, http://www.uspirg.org/reports/generatingsolutions2_02.pdf

2. Union of Concerned Scientists estimate based on a state breakout of data developed for Doherty, Julie P., "U.S. Wind Energy Potential: the Effect of the Proximity of Wind Resources to Transmission Lines," Monthly Energy Review. Energy Information Administration. February 1995. Includes class 3 and higher windy land area within 20 miles of existing transmission lines, excluding all urban and environmentally sensitive areas, 50% of forest land, 30% or agricultural land, and 10% of range land

3. Number of modern industrial wind turbines is calculated by dividing each state's Wind Potential by the average amount of electricity annually generated by a 1.5-MW turbine. An "average" 1.5-MW turbine produces only about 30% of its rated capacity each year (i.e., Capacity Factor = .30), so its annual output would be about 4 million kilowatt-hours (1,500 kw * .30 * 8760 hrs/yr).

4.

Q. DO YOU THINK THE PROPOSED PROJECT WILL IMPROVE AIR QUALITY AND THE PUBLIC HEALTH?

A. No. Unfortunately, the demand for electricity will be so great over the next thirty years that additional coal plants are likely to be built. Florida Power and Light, the nation's third largest electric utility company, now owns over one-half of the wind energy facilities in the US. Moreover, AES Corporation, which operates a coal-burning power plant at Cumberland, Maryland, has recently joined with US WindForce (which has several approved and planned projects in West Virginia and Maryland), lending its financial backing to wind energy development in the region. US WindForce is the most ambitious developer of wind energy in the Alleghenies. Here is a weblink to the announced collaboration with AES, an international owner of mostly fossil fueled powerplants: http://www.aes.com/aes/index?page=news&reqid=609530&print=Y

Such "equity investments" between wind and coal will likely grow in number, as the former industry reaps the cachet of association with a major electricity producer while the latter gathers in the use of wind's generous tax avoidance shelters and its reputation as a green energy source. The irony of these partnerships should not be lost on the PSC.

Unless we have a major change of political direction, fossil fuel combustion, and the toxins it emits into the air, will increase in the future, contributing to such dire statistics as the rate of asthma doubling every five years. The wind industry will not itself alter this circumstance. Only when the public insists upon implementing appropriate standards and newer equipment to increase efficiency, as well as conservation measures that reduce per capita consumption demand, will air quality improve. Indeed, because of some of these measures residual to the last Administration, which mandated newer, more efficient coal-burning technology, air quality in the region has actually improved in recent years.

Altogether, the wind industry in the uplands of the eastern US is not an answer to the concerns about global warming, energy independence, air pollution, or public health.

Q. DO YOU THINK THE PROPOSED SYNERGICS WINDPLANT WILL POWER 13,00-33,000 HOMES, AS INITIALLY CLAIMED BY THE APPLICANT IN VARIOUS ACCOUNTS?

A. No. And here's why. Let's return to the concept of the capacity factor mentioned earlier, examining whether, as the original application indicated, a proposed 40 megawatt windplant would generate enough electricity to power 13,000 homes, let alone 33,000. A megawatt (MW) is one million watts or one thousand kilowatts (KW). According to the Department of Energy, the average home consumes 12,000 KW hours of electricity annually* (not the low 9000 average KW hours Synergics postulates). Using this estimate, one can rather easily obtain a reasonable annual projection for the number of homes this windplant can power. The following example assumes the Applicant's initial 24 turbine windplant with 400-foot tall turbines, each rated with a potential of 1.65MW and a generous capacity factor of 30 percent:

1.65 MW x 30% efficiency = .50 MW (or 500 KW)
500 KW x 24 hours x 365 days = 4, 380,000 KW hours per year per turbine
4,380,000 KW x 24 turbines = 105,120,000 KW hours annual plant output
105,120,000 KW / 12,000 KW hours average household use per year* -- 8760 homes powered annually.

Consequently, a 40 MW windplant would power less than 9,000 homes annually. With 19- 420 foot turbines, each at a rated capacity of 2.5 MW, generating 15 MWs annually, as would be the case in Synergics' revised scheme, and using the same calculus, only about 10,400 homes could be "powered" by Synergics' proposed facility. Even this overstates the case significantly, however. Because electricity from wind is inherently intermittent and volatile, it would really "serve" those homes where the occupants were willing to have electricity only when the wind was blowing in the right speed range—or for them to invest in an expensive battery storage system. Seen in this light, windpower would service *no* homes in any conventional sense of that term's use. A 47 MW windplant may produce about 15 million watts annually for the grid, but this is not the same as saying it will service any particular sector. And it is a figure which should be seen in context. The *Mid-Atlantic region requires from the PJM grid about 470 billion KW hrs to supply many millions of households, with residential usage increasing two percent each year – far more than the tiny fraction of a percent Synergics would contribute to the grid. Synergic's possible contribution of 125 million KW hrs for 10,400 households would be so statistically negligible as to be meaningless in terms of cleaner air and improved health—less than two-tenths of one percent.*

*The wind industry often uses a decade-old low end projection of 9,000 showing only direct household use. The conservative 12,000 projection assumes that the average household requires a reasonable baseline of public, community-related infrastructure electricity to operate in society – hospitals, schools, courthouses, traffic lights, etc—in order to function.

Q. DO YOU BELIEVE THE PROPOSED PROJECT WILL ADD SIGNIFICANT REVENUES TO THE LOCAL ECONOMY OF GARRETT COUNTY, AS CLAIMED?

A. No. Promised "windfall" revenue is tantalizing. However, Garrett County relies heavily upon tourism attracted to the region's scenic natural beauty. The lure of additional revenue without any apparent cost often blinds authorities to the problems created by development which will diminish the natural beauty at the heart of the economy.

Garrett County has no ordinances for taxing a windplant in ways commensurate with the capital value of the proposed windplant. This developer's claims about what his windplant will pay in taxes are in need of clarification; for there are assurances Garrett County would receive about $750,000 in the first year alone. The PSC staff should evaluate these claims, examining, among other things, how the equipment section of the county's business personal property tax applies. Nowhere is it made clear what the assessed value of each turbine will be for tax purposes. The developer suggests a 30 year life, which seems meaningless in light of the federal depreciation schedule allowed.

For the first two windplants operating in Somerset County, PA, the average per turbine tax payment in 2003 was only $528, a combined property tax payment of $7, 388 (fide County Commissioner Pamela Tokar-Ickes) on machines that cost nearly $50 million to install . Moreover, another Florida Power and Light windplant in Thomas, West Virginia (Mountaineer Wind) has purportedly paid $93,000 over several years after a capital outlay of over $70 million—and this after much delay and a lot of negative press (Judy Rodd, Citizens for Responsible Windpower, Personal Communication). These companies had promised to contribute many hundreds of thousands of dollars in local taxes. Synergics will not be taxed as a public utility. Indeed, it is not clear what taxes it would be obliged to pay. With knowledgeable tax accountants, a developer will undoubtedly look to protect its investors, not a local economy hundreds of miles away from its corporate offices. What penalties apply if Garrett County does not receive promised revenues? Evidently, none.

Since this project will lease private land, the county will receive little additional property tax. Wind leases are typically written to favor the developer, restricting the owner's use of the land for up to 35 years and devaluing it significantly (a major problem for those in need of emergency funds). Turbine leases also may allow abandoning all equipment to the property owner, providing little or no indemnification for any decommissioning, removal, or restoration costs. And they often include noise and other "nuisance" easements, holding the developer harmless from legal responsibility if his machines create such nuisances.

Income generated from turbine lease agreements varies widely. Synergics claims that lease income will range from $4,000-$6,000 annually per turbine, although it is not clear how this estimate was derived. It is also not clear what effect five fewer turbines will have on promised wind leases. An examination of a lease from another wind company reveals provision for an initial, one-time payment (from $500 to $1,000) to reserve a turbine lease and pledges a minimum annual rental income of about $1500 per turbine against a small percentage of the power the turbines actually produce, generating at maximum about $2500 per turbine. The PSC should interrogate this claim carefully to protect wind lessors, especially in light of Synergics' reduction in the capacity factor of its machines. Moreover, if a wind lessor does not reside locally, the local economy will not benefit from any increased income tax.

Very few permanent jobs will likely be created-- perhaps a couple of low wage maintenance employees. According to a report by the National Renewable Energy Lab on windplant jobs, the national average is one maintenance employee for every 12-15 turbines. A 20 turbine windplant in Meyersdale, Pennsylvania now employs only two maintenance employees. The claim here that four permanent jobs will be created appears generous. But even if it were true, this is a very small return relative to a $40 -50 million capital project.

During construction, a few local security guards and some local earth moving crews may be hired for a few months, while the bulk of construction will probably be completed by non-local labor, since many huge turbines are actually manufactured in Europe(often as subcontracts to US firms like GE) with warranties likely serviced by the manufacturer and its employees. A recent study by the Iowa Department of Natural Resources on the "Top of Iowa" windplant showed that, of the 200 total construction jobs, only 20 were local—and all disappeared within six months.

Synergies has overstated the general local economic benefits by counting the full price of goods and services, rather than value added. Generally, a large part of the price paid to a local supplier has to be paid by that supplier to another agent, in this case likely to be a party outside the local area. This price is part of the local supplier's cost of acquiring the goods (for example, the purchase of fuel, wiring, cement) the local supplier is reselling to the windplant. The only portion of the price paid by the windplant that should be tallied is the difference between the local supplier's cost and the price he charges—that is, the value added portion—which in any case would be extremely small in Garrett County, as most goods will be purchased elsewhere for this wind facility.

Q. DO YOU BELIEVE THE APPLICANT'S CLAIM THAT HIS TECHNOLOGY IS SAFE FOR WILDLIFE BASED UPON HIS EXPERTS' RISK ASSESMENT?

A. Science is the disinterested search for the objective truth about the material world. -- Richard Dawkins

Theories crumble, but good observations never fade.-- Harlow Shapley

The less one knows about the universe, the easier it is to explain.----Leon Brunschvicg

Good public policy requires those who make claims about the safety of their product to substantiate those claims *before* introducing it into the environment, deferring to what Rachel Carson called the precautionary principle. Industry funded research is always suspect. Experts who work for an industry should submit their research and resulting conclusions for independent, peer-reviewed analysis. Science insists upon conclusions which account for all the evidence, not selective pieces which fit the convenience of a developer's agenda. *Post* construction studies are extremely problematic.

This is surely the principal reason that the US Fish and Wildlife Service guidelines call for a three year preconstruction analysis before a permit such as that which Synergics seeks is granted. And the presumption seems to be that if those studies show significant risk, then the project would be denied. As is the case presently at Altamont Pass, California, where windplants have killed thousands of birds annually for many years (prompting a law suit by the Center for Biological Diversity), who is going to shut down a $40 million + capital facility after it is up and running, even if later studies verify it kills significant wildlife?

Others at this hearing will likely bring forward critical commentary about the claims of wildlife safety that this developer and his team make. I will limit my remarks to the following.

If this project really were a grand first step in the mitigation of fossil fuel emissions, making the air cleaner and our society less "vulnerable from imported energy sources" (although it will do neither), the prospect it will likely kill thousands of birds and bats (and create hardship for other wildlife as well) might be justifiable, although the small population of some of these species makes them extremely vulnerable.

The Roth Rock firetower area is the only place where Mourning Warblers have been consistently found to nest in the state in recent years. Three years ago, I located four nests there, some through serendipity, others by watching the adults carry food. One of those nest locations was destroyed a few years ago because Synergics cleared three acres of forest habitat to erect a meteorological device. Last season, I heard only two singing Mourning Warblers in the area, but did not seek out their nesting sites. Although I'm aware this is a bird that frequents cut-over, disturbed habitat, I'm also aware it does not tolerate intrusion; it is a most cautious bird characterized by its "skulking" behavior. I have little doubt that a windplant at the scale proposed here will eliminate the Mourning Warbler as a nesting species at this locale, especially since even the revised proposal would erect wind turbines in the midst of the bird's known nesting locations. Perhaps, as Paul Kerlinger, Synergics' avian expert suggests, it won't affect the species' regional or global population levels. But it very likely will purge the Mourning Warbler as a resident nester in the state. And if this happens, how does Synergics propose to compensate the state for this resource loss?

Dr. Kerlinger's avian risk study mocks the scientific method. Scientists are not just experts; they work in an analytic process characterized by rigorously evaluated *if* this, *then* that experimental "conditionals" constructed from hypotheses. Analysis of this kind is supposed to have predictive power because it comprehensively considers the many variables individually-- and then works to understand how they integrate to create "regularities"--patterns with a certain outcome. These predictable outcomes—and the processes used to achieve them—are then scrutinized by other scientists for validation in a process known as independent peer review. A particular experiment, however honestly and intelligently conducted, can yield the "wrong" answer for a variety of reasons. This is why experiments must be checked by other scientists, using other instruments, other conditions, even other ideas.

On the basis of only two walks in the woods at a time (July) well after spring and before fall migration when most nesting birds are generally quiet because they are feeding young out of the nest, Kerlinger makes predictive assessments about the quantity and quality of bird-life in the area. His technical area of expertise resides in birds of prey, not passerines like *Oporornis* warblers. Moreover, his recitation both of the literature and personal contacts used as part of his evaluation protocol is highly selective. In a way favorable to his client, he mischaracterizes conversations he had with representatives of the Maryland Ornithological Society and with Chandler S. Robbins, the area's most knowledgeable ornithologist who has been studying birds there for over 50 years. He invokes the "broad front theory" of migration to justify his statements that birds won't fly low enough or don't follow the contours of the ridge sufficient to collide with his employer's large turbines, in full knowledge there are significant exceptions to the application of this theory. In conditions of fog and low clouds (which abound in the spring and fall around the Garrett County mountains), night migrating neotropical songbirds in large numbers are sometimes forced to fly low enough to encounter 420 foot tall structures atop a 3200 foot ridge. Rather than modifying the broad front theory to accord with all observations, however, Kerlinger continues to invoke it as some sort of sacred text, somehow uncontaminated by reality. This is the antithesis of the scientific method. His tactics here seem similar to those Cinderella's step-sisters employed to create the illusion their outsized feet really did fit that damned slipper.

The radar study to which Kerlinger refers in his testimony as evidence supporting the broad front theory's explanatory power is not the only such study extant. Yet he does not mention these other studies. Recent radar reconnaissance at proposed industrial windplant locations atop the mountains of Vermont (see the Direct Testimony to the State of

Vermont Public Service Board [Docket No. 6911] of Adam Kelly, Vice President of Research and Development, DeTect, Inc. explaining how DeTect used radar to investigate bird activity atop East Mountain, Vermont on behalf of the Vermont Agency of Natural Resources, Department of Fish and Wildlife) and West Virginia (see the recent Arnett study submitted by other intervenors) demonstrate that hundreds of thousands of migratory birds and bats fly low enough to collide with huge turbines, placing them at risk—especially in times of fog and low clouds. This is the case with buildings, cell towers, even fire towers which are along a migratory route. The taller the turbines, the larger the threat. These studies also give evidence that ridges here in the Allegheny Highlands may in fact channel migrating birds and bats, a phenomenon which Dr. Robbins has previously testified he has witnessed. In 2003, a developer-funded mortality study that Kerlinger conducted over a several week period at a West Virginia windplant revealed that over 2,000 birds and bats had been killed during fall migration in that span Independent experts have doubled that mortality figure to more than 4,000, concluding that Kerlinger's accounting methodology was deficient.

In previous windplant testimony, Kerlinger initially said (inaccurately) the Backbone ridge had relatively few migrating birds passing over, and then used an apples to orangutans comparison, citing statistics (only two or three birds killed per turbine) derived from western turbines averaging about 150 feet tall and located in fields not known for significant avian migration—stating these should be comparable to 400 foot turbines located on prominent forested ridges in areas well known as a major avian flyway. This kind of comparison is no basis for credible prediction, which is the purpose of scientific analysis.

Given the evidence of bodies on the ground in California and West Virginia, wind industry pundits like Kerlinger have now begun to admit that wildlife mortality may be higher than they had expected. But not high enough for him to recommend against building windplants in risky areas, since, although the wildlife mortality at these sites may be significant, and may indeed eliminate one species from nesting in the state, it may not be "biologically significant," threatening any species with extinction, as if the scientific community had agreed to a clear definition of the meaning of "biologically significant." These protean rationales are clearly intended to suit the needs of a desperate client rather than provide a scientific explanation of complex wildlife dynamics.

I believe strongly that the many windplants targeted for Garrett County and the surrounding area (*Attachment C*) represent a staggering challenge—a semi-annual gauntlet-- for migratory wildlife, which in their cumulative aspect may one day be responsible for slaughtering millions of birds and bats

The montane forest fragmentation for this project alone will create hardship for a variety of wildlife and plants, as Kerlinger admitted in 2002 in his assessment of a much smaller but similarly situated windplant in Searsburg, VT: "Fragmentation of forests via wind turbine erection can impact interior nesting birds in an adverse manner. The size and number of wind power developments in the future are also of concern with respect to habitat loss and fragmentation. This may become the primary ecological consideration in future wind power developments in these habitats." [An Assessment of the Impacts of Green Mountain Power Corporation's Wind Power Facility on Breeding and Migrating Birds in Searsburg, Vermont, July 1996-July 1998, http://www.nrel.gov/docs/fy02osti/28591.pdf)].

Kerlinger's observation about the threat from fragmentation is not unique. The scientific literature extensively documents concerns for wildlife due to the harm such forest fragmentation as Synergics contemplates will cause. Forest fragmentation has basically two components: the loss or reduction of habitat and the breaking of remaining habitat into smaller, more isolated patches. Among the negative effects of fragmentation on particular species are: the elimination of some species due to chance events; increase in isolation among species populations due to a reduction of their ability to move about the landscape; reduction in local population sizes sometimes leading to local extinctions; and disruption of ecological processes. For the forest as a whole, roads and maintenance of roads and infrastructure are known to have a number of negative effects, ranging from barriers to immigration and emigration, corridors for introduction of native predators and competitors, as well as avenues allowing the spread of non-native, invasive species.

The clearing of wide corridors for miles along the crests of forested mountain ridges to construct and operate utility-scale wind turbines will be a major contributor to forest fragmentation and loss of forest interior habitat (existing more than 100 meters from a clearing) within our region. High elevation forest interiors like Roth Rock offer optimum habitat conditions for the survival of certain species-- and it is the type of habitat most easily destroyed by development, a fact Dr. Kerlinger should know very well. To provide some sense of the devastation that will obtain with Synergics' project, I am attaching some photographs (*Attachment N*) that document various stages in the construction of the Cefn Croes windplant in Wales, with 39-1.5 MW turbines on an upland plateau. For a more complete documentation of this project, consult:
http://www.users.globalnet.co.uk/~hills/cc/gallery/index.htm#photos

To my knowledge, Kerlinger has never submitted his avian wind risk assessments for independent peer reviewed evaluation. The PSC, however, should be very suspicious about such sponsored "research." The PSC should work to develop a process for independently assessing conflicting claims made by experts involving very specialized knowledge. This is not something that should be adjudicated in an adversarial forum. "Truth" does not necessarily lie in the middle between two points of view.

Adequate preconstruction study does not mean that, because such study is made, therefore windplants should be built. Rather, any studies should be made to determine whether or not they should be built at all. Consider the FDA model for risk assessment. I will continue to demand more preconstruction studies not only as predictors of risk; but also as a means of assessing whether the risk is defensible. This is where a peer review panel of independent experts should come in--since the resultant cost-benefit analysis would require a fairly high level of sophistication and expertise over many areas of knowledge.

Q. IS IT TRUE THAT YOU HAVE REFUSED TO RELEASE IMPORTANT RADAR STUDIES THAT MIGHT DEMONSTRATE HOW SAFE WIND TECHNOLOGY IS FOR MIGRATORY WILDLIFE, AS THE APPLICANT AND HIS REPRESENTATIVES HAVE STATED?

A. Synergics' representatives continue to maintain that I and others are refusing to release important field studies that might demonstrate how safe wind technology is for migratory wildlife. This is a lie. Here is the truth.

Since I was one of those responsible for getting those studies done in the first place, the charge is more than ironic. The company involved, Clipper Windpower, insisted on a non-disclosure condition which it alone imposed on those studies. Clipper had agreed to do this study only at the request of the PSC hearing examiner in order to induce the various intervenors to settle. As an intervenor in the Clipper hearing, I was aghast at the idea of such "secrecy." Nonetheless, Clipper insisted that it would not agree to fund those studies unless *all* intervenors signed agreements that the *studies not be released until after the wind turbines were operating*. I reluctantly agreed to do so only after I became convinced that, if we did not, the PSC would likely approve Clipper's application anyhow---and no studies would be done at all. The need for data seemed paramount at the time, even if it were revealed after the fact.

The Applicant has known for many months that *all* the intervenors would be pleased to release those studies in the following way: Clipper must admit in writing that it insisted on the non-disclosure nature of the studies; the reports must be released *for independent peer review* in their entirety, including all data, without restriction; and they must not be used to excuse the need for additional research to map the complex mosaic involved in wildlife migration over the Allegheny ridgetops. I published these conditions in all the local papers months ago. To date, I have not had any response from Clipper —and certainly not from Synergics.

I'm confident these reports will demonstrate, as similar recent research already has, that massive windplants constructed atop mountains in areas well known for wildlife migration pose an unacceptable risk to birds and bats. At the same time, this important issue should not distract from other threats posed by this industry --devaluation of property, destruction of heritage views, and noise/light disturbances to nearby residents

Q. DO YOU THINK THE ROTH ROCK PROJECT WILL ALTER THE VIEWSHED IN THE TARGETED AREA?

A. The photo below depicts the Meyersdale windplant sited atop a prominent ridge.

375 Foot Turbines Over Meyersdale, PA

As Synergics own simulated photographs show, this project will transform the viewscape —and it will do so for many miles. Still photographic representations do not do the visual experience full justice, however. One must see a windplant to observe that the turbine blades are often in motion at differing angles and speeds - - and hear pulsing noise, like jet engines roaring on a runway, over distances more than a mile away. These turbines will simply take the 3200 foot ridge away from the viewing experience. Contrary to this developer's assertion that his machines will disappear into the mountains at distances beyond four miles, they will be a very visible presence for many miles more, as is the case at Meyersdale. But Synergics' turbines, with the diameter of their rotors longer than a football field and total height of over 416 feet, will be even more visible than the turbines at Meyersdale. The sweep of the blades will be 50 percent or more greater than the 1.65 MW turbines Synergics initially proposed, creating an incredible visual vortex, with an aspect much like a wind amusement park. Although some people find these turbines attractive, most have no a priori concept of the scale and scope involved. Imagine, by way of comparison to the visual intrusion, that someone, through a series of boom boxes, was loudly and perpetually playing rap music (or any form of generally unpopular music) throughout the Pleasant Valley viewshed. Most people, even politicians, understand the need to restrain such an exuberant expression of one's personal aesthetics. Such civic restraint should also apply in the visual arena. Synergics' proposed turbines are not like a new tie or suit or even automobile. They will be quite literally an in-your-face presence to thousands of people, many of whom will find them repellent.

Q. BUT WHAT DOES IT MATTER IF THE RIDGETOP'S APPEARANCE IS SIGNIFICANTLY ALTERED WITH INDUSTRIAL DEVELOPMENT?

A. I'm a strong advocate of wind farms on the high seas. But there are appropriate places for everything. We wouldn't put one of these in Yosemite, and I think environmentalists are falling into a trap if they think the only wilderness areas worth preserving are in the West. The most important are the ones close to our cities, where the public has access to them. And Nantucket Sound is a wilderness, which people need to experience. I always get nervous when people talk about privatizing the commons. In this case, the benefits of the power extracted from Nantucket Sound are far outweighed by the other values our communities derive from it.
—Robert Kennedy Jr., E Magazine (November/December 2003).

In April, 2003, Garrett County adopted a Heritage Plan that, among many other features, recognizes Backbone Mountain as a key natural heritage resource. The Plan assures that the most significant features of the county's past and rural way of life - heritage resources-- will be preserved and bequeathed in stewardship to future generations. This is not to say development cannot take place along the Backbone ridge, for some already has. But the clear intent of the Plan would prohibit industrial development that greatly altered the mountain's appearance. [*Attachment D*: I've excerpted the Heritage Plan and attached it to this testimony. The entire document is available from the Garrett County Office of Planning and Zoning and may be read at the county library.]

The mountains of Maryland are one of the state's compelling natural resources, with vistas inspiring reminders of the importance of wilderness and the special place natural beauty has in our culture. As the state's most prominent, longest mountain, Backbone represents this idea perfectly, and this is the reason for its special status within the county Heritage Plan. However, this project, as proposed, would be a jarring, discordant visual assault, with more towers scrapping the sky in this rural county than there are in Baltimore City (there are only several buildings in the city which exceed the height of these turbines). The scale of this project would visually take the mountaintop away. This is not personal aesthetic judgment, but rather one focusing upon heritage considerations and the public's right to determine modifications to that heritage. Synergics' turbines are not bucolic Dutch windmills and its development infrastructure is not a "farm."

In July, 2004, the Maryland Heritage Areas Authority (MHAA), a unit within the Department of Housing and Community Development, approved the Heritage Plan, formally recognizing Garrett County as a Recognized Heritage Area (RHA). The next stage of this process involves crafting a detailed management plan that will describe how the county will implement and support the RHA. When this step is concluded and approved, the county will be designated a Certified Heritage Area (CHA) and will be eligible for state technical and financial assistance to support the CHA, such as grants for operating assistance, capital and non-capital project support, and marketing, as well as low interest loans and tax credits.

The Heritage Plan, while rooted in historic preservation, is nonetheless a practical recognition of the importance of heritage tourism. "Garrett County receives over 500,000 visitors annually from outdoor-related activities and other related tourism activities." (Page 4.15 of the Heritage Plan) People are attracted to unspoiled views of nature and want to participate in it. Industrial strength windplants threaten this idea.

Elizabeth Cole, an administrator for the Project Review and Compliance Section of the DHCD, has already notified Synergics (her letter accompanied the application) about the need to identify and evaluate historic properties that "may be affected by the project and to develop measures to avoid, reduce or mitigate any adverse effects on significant historic properties." Doing this requires a range of activity. Under Section 106 of the National Historic Preservation Act of 1966, this is a formal requirement for all such applications requiring federal or state permits. Garrett County's Heritage Plan adds yet another dimension to this process.

In its 2003 decision granting a CPNC for Clipper Windpower (Case No. 8938), the PSC made a number of incorrect assumptions about that project's impact on the Garrett County landscape, agreeing with the developer that his turbines "will blend in with the landscape in the background beyond 4 miles [and that] The visual impact will not be significant because the project will be intermittently shielded by terrain and vegetation which will reduce visibility from highways and roads." Moreover, the PSC also inaccurately concluded that "The project will have minimal visual impact on existing residences in the vicinity of the project site because the area has been extensively logged and farmed and the existing landscape has been modified by electrical power lines, communication towers, and roads." And "Each turbine will be framed in the front and back by existing vegetation." All these claims are false for that project-- and for the Synergics project as well, in light of the visibility of the smaller Meyersdale, Pennsylvania windplant.

Q. WHAT DO YOU RECOMMEND THE PSC DO ABOUT RATIONALIZING THE SYNERGICS PROPOSAL WITH THE GARRETT COUNTY HERITAGE PLAN?

A. The PSC *and* the Power Plant team within DNR should understand the implications of this project for Garrett County's Heritage Plan -- not just for Garrett County but also for the residents of the entire state and even the tri-state region. Backbone Mountain's majesty should be protected as a reminder of the importance of nature in our lives. There are many design standards and guidelines staff can use for this process. In order to give others involved with this hearing an understanding of the craft involved, I'll list some of them in the next paragraph. But all should be mindful of the difficulties for any design prophylactic to soften and mitigate the effects of such a Goliath facility. The inherent incompatibility of mammoth industrial wind factories targeted for areas that pride themselves on their natural beauty makes for a hard, perhaps impossible, fit. Industrial scaled turbines are probably beyond any reasonable scheme's abilities to integrate that scale into a visual harmony with the environment, let alone disguise their intrusion into a historic view.

At a minimum, siting guidelines for wind turbines require mapping areas of high wind potential together with sensitive natural areas (including national/state/regional parks and scenic areas; gardens and designed landscapes; recreational and wild lands; and lands that promote biodiversity and scientific interest). Buffer zones should be established around areas of high sensitivity. Regional capacity studies should be done that include the cumulative effects on natural heritage sites, visual impact, wildlife/habitat, and local recreational and economic opportunities. See: Scottish Natural Heritage: Guidance for Onshore Wind Farms (www.snh.org.us/pdfs/polstat/ar-ps01.pdf) and Scottish Natural Heritage: Cumulative Effect of Windfarms (www.snh.org.us/pdfs/polstat/cew.pdf).

Attached is a draft *(Attachment E)* of a Wind Energy Conversion System Ordinance recently approved by Shawano County supervisors in Shawano County, WI. A citizens advisory committee crafted this ordinance after holding more than 50 meetings in the last year and a half before bringing the ordinance to the Planning, Development and Zoning Committee. Shawano County had been targeted for industrial wind development, and the citizens there, aware of problems with the technology, demanded preconstruction regulations and testing protocols that would protect its public viewshed, mitigate noise and other nuisances, clarify local tax revenues, indemnify against inadequate decommissioning funds, and a range of other important considerations. The PSC and the state's Power Plant Research Program should consider this ordinance carefully, reviewing it for siting standards Maryland could adopt before granting any CPCN to the wildcat wind industry.

Since industrial windplants sited along the uplands of the East won't really achieve the claims made for them, perhaps the PSC should encourage developers to consider smaller scaled, locally distributed auxiliary wind energy systems. These offer the prospects of local conservation as well as give design standards a chance to work. Here, individuals and small businesses would be encouraged to build windpower systems at an appropriate scale through tax credits and other subsidies, rather than making them available mainly to industrial wind developers. Small turbines (towers less than 120 feet) could provide power directly to users and any excess power could enter the grid. See: Siting a Wind Turbine on Your Property (www.state.vt.us/psb/application_forms/PSB_wind.pdf).

There is also the reality of rich wind potential in the deep oceans, and I believe, if it really wants to engage the issue of fossil fuel consumption in a meaningful way, the wind industry must get serious about tapping this vast resource, after first doing the necessary studies to ensure the safety of wind technology for marine life. Here is where the taxpayer supported subsidies for wind could perhaps be justified, for the promise of the industry might actually then be aligned with its ability to really deliver on it—without encountering the difficulties inherent with onshore development.

Q. DO YOU BELIEVE SYNERGICS' PROJECT WILL DEVALUE PROPERTY IN THE AREA?

A. Yes. While looming windplants are a relatively recent phenomenon in the East, there is increasing evidence that the closer one resides to them, the lower one's property value falls. The premiums paid for the serenity of natural views can no longer be justified in an area surrounded by huge turbines. The Pleasant Valley viewshed is one of the most beautiful natural areas in the state, filled with family farms and framed by misty mountains. Those who feel that a single wind structure is beautiful should visit Meyersdale to see how the 2750 foot mountain there seems to disappear with 375 ft. wind machines on top (one can see these 15 miles away on a clear day). Note, too, the four acres of clear-cut around each turbine (*Attachment F*).

One of the most validated real estate precepts is the idea that significant natural views have premium value, and intrusions which restrict that view erode value. Realtors doing business near windplants in the western United States and in Europe understand that property will sell for between ten and thirty percent less than previous market value, depending upon how close it is to the windplant. The few "studies" which appear to support the claim that windplants don't devalue property are extremely flawed in fact and methodology, often surveying people and evaluating property miles away from a wind site, then "averaging" these results with properties adjacent to windplants.

Q. WHAT DO YOU THINK ABOUT THE REPP STUDY THAT THE APPLICANT HAS PRESENTED, WHICH SEEMS TO INDICATE THAT WINDPLANTS DO NOT DIMINISH PROPERTY VALUES?

A. The Renewable Energy Policy Project (May, 2003) study that Synergics offers on behalf of the claim that its project will not diminish property values contains serious methodological flaws:

1. The study covers just ten projects, only one of which comes close to the size and scope of Synergics' project—and this site (Madison County, NY—the Fenner Site), with 20 1.5 MW turbines situated on farm fields—not atop prominent ridgelines-- interestingly showed significant decreases in property values.

2. The time frame of the study was so short that even the study's authors were compelled to state the data was insufficient to offer compelling conclusions.

3. The study did not verify whether individual properties had a direct view of the windplants, making the use of the term "viewshed" something of a misnomer in this context, since the viewshed properties were actually all properties within a five mile radius of the turbines regardless of whether they had a direct line of sight. To mitigate this problem, the researchers conducted phone interviews with tax assessors and other local authorities to get estimates on the number of properties in the defined viewshed that *might* have had views of the turbines.

However, under scrutiny, many of these estimates proved inaccurate.

4. The analysis used in this study did not incorporate distance from a wind facility as a variable or weighting factor, so that a viewshed property sale five miles away from a windplant counted the same as one a quarter mile away. It is at least plausible that if windplants do have an effect on property values, it would be strongest close to the turbines and decline with distance. Simple geometry suggests that the majority of properties in the area of a five mile circle are likely to be fairly distant from the wind development: 64% of the area of this circle is three miles or more from the center – and only 4% lies within the first mile. Though properties are not necessarily distributed evenly about the landscape, and property values conceivably can be affected by other things in the vicinity, the REPP study confuses substantially the proportion of properties that either have only a distant view of wind turbines or no view at all.

5. The study relied on average rates of sale prices before and after the windplant construction and between viewshed properties and properties in a comparison group. Therefore, if one calculates that sale prices among viewshed properties increased $50/month faster than sale prices in the comparison group, then it makes a difference whether the statistical uncertainty in the point estimate is plus or minus $25/month or $500/month. The former leads to a conclusion that the wind development unlikely had a negative effect on property values while the latter intimates that the data are inconclusive -- there could be a large negative impact, a large positive impact or no impact at all. These "smoothed" average sale prices against a very small time variable creates a regression analysis that is, for prediction purposes, almost beside the point, suggestive of nothing.

The REPP "study," although its basic methodological approach holds considerable promise, is severely flawed. To say, as Synergics does, that the study demonstrates its proposed windplant will have no effect on property values, that it may in fact enhance them, is disingenuous. George Sterzinger, the executive director of the REPP, admitted as much in response to critics who stressed the study contained no proof that windplants were the reason for changes in property values. "We have no idea," he said, noting that the REPP did not have time or money to answer that question (Cape Cod Times, June 20, 2003). Sterzinger further agreed that the study's findings have to be applied carefully to different situations.

There are very few windplants in the world, let alone in the United States, with turbines over 400 feet tall placed on such a prominent ridgeline. Consequently, there will be no "comparable" facility "yardstick" by which appraisers can measure the impact in Garrett County for predictive purposes. And without knowing about the various nuisances this kind of windplant will produce, the problems for credible prediction increase even more

Q. CAN YOU CITE STUDIES DEMONSTRATING THAT WINDPLANTS SUCH AS SYNERGICS IS PROPOSING WILL LIKELY DEVALUE PROPERTY?

A. In 2001-2002, the Moratorium Committee of Kewaunee County, Lincoln Township, Wisconsin compared property sales prices to assessed values before and after the construction of two wind energy facilities, each having relatively small .65 MW turbines An assessor reported that property sales (vs. 2001 assessed values) declined by 26% within one mile and by 18 % more than one mile of the wind project. The Moratorium Committee also sent anonymous survey forms to 310 property owners, of whom 223 responded. These responses were then grouped based upon proximity to the windplants.

The survey results found that 74% of respondents would not build or buy within ¼ mile, 61% within ½ mile and 59% within 2 miles of the windplants. In fact, a large percentage stated that they would not buy a home within 5 miles of the turbines. The windplant's offer to purchase neighboring homes for demolition--to create an "additional buffer for the windmills"--came immediately following the release of a noise study showing the Lincoln wind turbines increased the ambient noise level significantly, depending on wind conditions, etc [See *Attachment G* for the Lincoln Township Moratorium Committee' Report]

.A 1996 Danish report, *Social Assessment of Wind Power-Visual Effect and Noise from Windmills- Quantifying and Valuation*, contained a survey of 342 people living close to windplants. The accompanying survey found 13% of people in the area considered wind facilities a nuisance and would be willing to pay 982 DKK per year to have them leave. A survey of house sale prices showed a 16,200 DKK lower price near a single wind turbine and a 94,000 DKK lower price near windplants versus similar houses located in other areas

In October, 2003, the Beacon Hill Institute, as part of a study of the proposed Cape Wind project in which hundreds of 430 foot turbines were to be located five miles off shore from Cape Cod in Nantucket Sound, contacted 45 real estate professionals operating in towns around the Sound, asking them about the anticipated effects of the wind power project on property values. Forty-nine percent of these realtors expected property values within the region to fall if the Cape Wind power plant was erected, while most of the rest said they didn't know. [Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, pp. 16-17]

The BHI study also surveyed 501 home owners in the six towns that would be most affected by the Cape Wind project . Sixty-eight percent of these said that the turbines would worsen the view over Nantucket Sound 'slightly' or 'a lot'.[BHI study, page 14] On average, they believed that Cape Wind would reduce property values by 4.0%. Those with waterfront property believed that it would lose 10.9% of its value. The study concluded that, based on the loss of property value expected by home owners, the total loss in property values resulting from the construction of Cape Wind would be $1.35

billion, a sum substantially larger than the approximately $800 million cost of the project itself.[BHI study, page 4]

As the study noted, any reduction in property values would, in turn, lead to a fall in property tax collections in the affected towns; the drop in these tax collections would be $8 million annually. If the tax rates were raised to maintain revenue, this would shift some of the property tax burden off waterfront residents (whose property values would fall the most) and on to the (less affluent) island residents.[BHI study, pages 4, 5]

In the home owner survey, in response to the statement: "It is important to protect an uninterrupted view of Nantucket Sound," 76% strongly agreed, 18% somewhat agreed, 3% were neutral, 2% somewhat disagreed, and 1% strongly disagreed [BHI study, page 28] It's worth noting that of the home owners surveyed, 94% did *not* have homes with a view of the Sound; [BHI study, page 32] 76% were not members of a conservation or environmental organization.[BHI study, page 34]. Their main reasons for living in the area were the 'beauty of the region,' 'the beaches,' and 'the ocean views.'[BHI study, page 31].

Russell Bounds, one of Garrett County's leading realtors in large property transactions, has already lost sales in the area of proposed windplants (*Attachment H*). He has stated that huge industrial windplants "would be devastating not only to the real estate values in the Pleasant Valley viewshed, especially to neighboring properties, but would also negatively affect the entire county economy, since so much of that economy is tied up with tourism drawn by the county's natural views."(Personal communication, February 27, 2005.) Mr. Bounds has recently testified that, over the last several years, he has had at least 25 people who expressed interest in buying land in the area targeted by wind developers. However, when he advised them about the plans for the wind facilities, not one of those people expressed any further interest.

In a May 16 statement of concern I sent the PSC about this case, I submitted as an attachment a DVD, Life Under a Windplant, made this past January documenting life near large wind installations for residents in Meyersdale, Pennsylvania, as well as for residents along the outskirts of Berlin, a small town a few miles north of Meyersdale. [Since I have already made this available to all parties on the Service List of this case, I will not include it formally in this presentation, although you may refer to it as *Attachment I*.] The DVD features interviews with three people—Todd Hutzell (738 Main Street, Rockwood, Pa 15557), Rodger Hutzell (327 Ridge Road, Meyersdale, PA 15552), and Karen Ervin (561 Ridge Road), who all live nearly a mile from the 20-375 foot turbines Meyersdale Wind facility; with Helen Gallagher (343 Meyers Ave. Meyersdale, Pa 15552), who lives nearly three miles away; with Susan Wilson (2250 Juniper Lane, Rockwood, PA 15557); and with Russell Bounds, the aforementioned Garrett County realtor. It also shows views of the Meyersdale facility from various vantages, as well as views of the 340 foot tall Somerset Wind facility located in farm fields outside Berlin, with images of two properties there that were sold in 2002 for considerably less than market value.

According to witnesses and deed records, Somerset Wind LLC (incorporated in Delaware with offices in Texas--an Enron spawn), in order to discourage lawsuits brought by owners who felt that Somerset's wind turbines were disturbing the quiet enjoyment of their property, bought these properties near Berlin for fair market value—one in May, 2002 from Keith Sarver, 308 Beachley Hill Road, for $101,049, reselling it in August to Robert and Tomalee Will, (who had leased their land to the wind company in the first place) for $20,000--*20 percent of the previous sale price!* The other property was owned by David Sass, 322 Beachley Hill Road. In May, 2002, Somerset Wind purchased the Sass property for $104,447, selling it in August to Jeffrey Ream, for $65,000—*62 percent of the purchase price!*

The prices Somerset Wind in Pennsylvania paid for these properties were comparable to prices paid for similar properties in the area and in line with the price previous buyers had paid. Although the properties were assessed for tax purposes at around $20,000 (as of 1997), they initially had sold for fair market value at $80,000 and $74,000 respectively—in 1998 and 1997. The quotes of the prices listed in the documentary are those listed in the deeds, which are public records. And the reason the developer bought the properties in the first place was to forestall a lawsuit brought on because of the very real nuisances that the windplant created.

The new owners, moreover, signed a "memorandum of non-disturbance easement agreement," which absolves the wind company from liability for what the owners might regard as wind turbine-caused nuisances such as "noise, lights, air movement, odor, dust, vibration, traffic, obstruction of view, [and] light or air currents."

Let's be clear about the difference between the assessed value for tax purposes of these properties and the fair market value involved in the purchase. It is virtually a universal verity that tax assessments for property lag well behind the current market value. The price Somerset Wind paid for both properties was well within the average range of comparable market prices. Clearly, Somerset Wind was willing to pay this price to head off a nuisance suit. And the price it sold the properties for should be instructive as to the company's assessment of their worth, given such proximity to the windplant and the exculpatory non-disturbance easement agreements in the new deed.

Both the Meyersdale windplant site and the project area proposed by Synergics involve a forested prominent ridgetop; both sites have similar ridge shape, orientation and elevation differences to east and west sides; both sites have Class 3-5 wind; both sites have residences located within a mile of the ridgetop. The Meyersdale windplant installed 20 1.5 MW wind turbines manufactured by NEG Micon, which involve 72m rotor diameters and have the nacelle mounted on an 80-m hub height; whereas Synergics plans to install on a much more elevated ridge 19- 2.50 MW wind turbines with an 80 -85m hub height and 82-100 m rotor diameters—much larger machines that likely have no substantial functional history.

The burden of proof that problems at the proposed Roth Rock facility would not be similar to or worse than the Meyersdale windplant rests with the Applicant.

Q. WHAT NUISANCES ARE OFTEN ASSOCIATED WITH WINDPLANTS LIKE THE ONE SYNERGICS PROPOSES?

A. Tall wind turbines in concert with each other, especially those sited on prominent ridgetops, create profound noise reverberations extending out for more than a mile, sounding like "a boot tumbling in a dryer" or the revving of jet engines on a runway. It is very difficult to predict noise levels in the mountains compared to flat land. Noise levels will be amplified in some areas and diminished in others depending on the shape of the terrain, the wind direction, the changes in wind velocity, and so on. The impact on people also depends on whether wind turbines operate in synchronization and whether the noise "beats" or throbs. This also depends on wind direction and velocity. Who will get bombed? Who knows? That is likely very hard to predict. The travel of sound waves and their behavior is similar to the way water waves travel. Most of us have seen how water behaves when waves enter into a gap or a split or channel of rocks in the ocean. The waves travel inward and pile up-and-up as they become restricted by the channel. The more the channel narrows, the greater the piling of the wave. Sound behaves in the same way. The more it piles up, the louder it gets. A letter from Meyersdale resident Bob Laravee, who lives 3,000 feet from the windplant, documents how he measured the noise over a 48 hour period (*Attachment J*). The results "showed an average reading of about 75 decibels during that period." "According to the EPA, noise levels above 45dB(A) disturb sleep and most people cannot sleep above noise levels of 70 dB(A)."

The noise reproduced in *Life Under a Windplant* has not been altered in any way; Laravee's measurements give some context to the DVD's recorded noise. Noise from European windplants is a notorious and well-documented nuisance there. The wind industry is very aware of this problem but often tries to "hide" it by taking visitors by day directly under the turbines where there is typically little noise or by conducting tours from May-September when wind speeds are typically lower.

Turbine noise is so irritating and disconcerting that it often causes people to seek medical attention, as Rodger Hutzell had to do. Wind leases typically contain "noise easements" to protect the company from liability. Somerset Wind insisted upon such conditions for those who leased their properties for wind turbines, e.g., such as those leases which Don and Jamye Paul and Richard and Barbara Holland signed, whose properties help comprise the windplant near Berlin.

A leading acoustical researcher of the noise problem, G.P. van den Berg of the University of Groningen in the Netherlands, believes loud aerodynamic sounds are generated when the moving propeller blade passes the turbine tower mast, creating sound pressure fluctuations. Such fluctuations may not be great from an individual turbine, but when several turbines operate "nearly synchronously, the pulses... may occur in phase," significantly magnifying the sound. Van den Berg also notes a "distinct audible difference between the night and daytime wind turbine sound at some distance [more than one mile] from the turbines" – a finding consistent with the experiences of Meyersdale residents. (Both quotes were taken from G.P. van den Berg, Effects of the Wind Profile at Night on Wind Turbine Sound: *Journal of Sound and Vibration* (November 2004) 277 955-970.)

The PSC and the DNR Power Plant team should insist upon acoustical field research to assess this noise phenomenon at the Meyersdale windplant, requiring independent measurements and interviewing nearby residents. The PSC and the DNR Power Plant experts should recognize the need to verify Synergics' claim that its windplant would average 45 dB. This "average" would not mean much if it were applied, say, to residents living next door to Merriweather Post Pavilion during a rock concert. And it will not mean much to the residents of Garrett County, either – who are used to the enjoyment of a quiet landscape. Perhaps appropriate staff from the PSC and DNR, along with Synergics, should attend the First International Conference on Wind Turbine Noise in Berlin, Germany on October 17 and 18, 2005. Organized by INCE/Europe in collaboration with the European Acoustics Association, the conference will address: "Wind Turbine Noise: Perspectives for Control" (*Attachment O*).

Attached (*Attachment K*), please find a noise testing protocol for windplants that was recently approved as part of the Shawano County wind ordinance. Both the PSC and the Power Plant Research group should strongly consider adopting this standard to protect citizens from windplant noise. To repeat, this county in Wisconsin had been targeted for industrial wind development, and the citizens there, aware of problems with the technology, vowed to protect the public by establishing regulations and testing protocols that the wind industry and enabling agencies now must follow.

Q. ASIDE FROM NOISE, WHAT OTHER NUISANCES ARE OFTEN ASSOCIATED WITH WINDPLANTS LIKE THE ONE SYNGICS PROPOSES?

The Applicant has admitted that *interference with television reception* may occur, stating that it was a problem relatively easy to fix --but did not say how or at whose expense. The following weblink contains a March, 2004 BBC report, "The Impact of Large Buildings and Structures (Including Wind Farms) on Terrestrial Television Reception"--see: http://www.bbc.co.uk/reception/factsheets/docs/buildings.pdf. "Wind turbines affect reception up to a maximum distance of 5km" is one of the key sentences in the report.

Lightning and power surges. Wind turbines themselves may cause irregularities in the power supply as wind speed changes. Within the power grid, supply and demand must always be balanced; there is no storage of electricity on this scale. When the wind dies, there is less power (brown-out) until a plant using a more reliable resource powers up to increase production. When the wind gusts, there may be power surges. Residents living near the installation in Meyersdale, which came on-line in December 2003, have had to replace stove elements and small appliances due to power surges which started at that time. Residents of Lincoln Township, Wisconsin, near a wind installation noticed an increase in power surges associated with lightning strikes in their area after the turbines

went on-line in June 1999. [Two computers protected by surge protectors and a TV set, all in different houses, were simultaneously "fried" one evening when lightning struck a nearby wind turbine tower.]
Shadow Flicker and Strobe Lighting. When turning with the sun behind them, turbine blades cast moving shadows across the landscape and into houses in ways that may affect surrounding properties at a considerable distance; these are commonly described as a strobe effect within houses that can be difficult to block out. "Some people lose their balance or become nauseated from seeing the movement. As with car or sea sickness, this is because the three organs of position perception (the inner ear, eyes, and stretch receptors in muscles and joints) are not agreeing with each other: the eyes say there is movement, while the ears and stretch receptors do not. People with a personal or family history of migraine, or migraine-associated phenomena such as car sickness or vertigo, are more susceptible to these effects. The strobe effect can also provoke seizures in people with epilepsy." (Nina Pierpoint, PhD, MD in a personal conversation. Dr. Pierpoint was formerly a clinical professor of pediatrics at Columbia, University and is now in private practice in Malone, New York).

Shoddy site construction practices can also cause serious erosion problems, especially if built along steep slopes. There is much documentation about how *turbine blades throw bolder-sized ice* that has accumulated on the blade surface during winter. There are documented--and very dangerous—fires caused by malfunctioning turbine equipment.

Q. HAVE YOU HEARD THE APPLICANT CHARGE THAT LOCALS WHO OPPOSE WINDPLANTS ARE NYMBYS?

A. Yes. One of the most persistent hypocrisies from corporate wind and its supporters is the accusation that locals who resist the industry are selfishly holding back progress—the NOT IN MY BACKYARD factor. However, many politicians who vote to enable industrial wind do so fully aware that windplants will be built in someone else's back yard, realizing they would not survive the political backlash if one were constructed in their own district. Wind investors—and most politicians who enable them—live hundreds of miles away from the results of their handiwork. While there are many areas of good wind potential available, the industry focuses on rural, often economically depressed areas which don't have much money or political influence. In Maryland, for example, the Chesapeake Bay has the best overall wind potential (*Attachment L*).

Yet this particular wind developer, surely aware of the political repercussions that would ensue, avoids Bay installations—his own backyard-- preferring instead to target Appalachia with the traditional methods of neo-colonialism. He has publicly stated that the choice people will have about an improved environment is between his project in the hinterlands of Maryland and dirty coalplants. He does not demonstrate how this is a one-and-not-the-other situation, of course, while also neglecting to mention how much revenue he expects his company will make. The sanctimonious concern for environmental improvement, which will not obtain with this windplant, obscures the evident desire for profit.

As I have shown in this testimony, there are many legitimate reasons for locals to be concerned about the effects of a massive windplant in their neighborhood.

Q. WOULD YOU DISCUSS YOUR CONCERNS ABOUT TAXPAYER/RATEPAYER SUBSIDIES FOR THE WIND INDUSTRY?

A. In *Life Under a Windplant*, Karen Ervin of Meyersdale continually asks, "Who Benefits?" from the massive windplant around her town. Not her. And not her town.

On a per kilowatt hour basis, wind is among the most heavily subsidized sources of industrialized power in the nation. In response to a long term and very sophisticated lobbying effort, Congress has re-authorized substantial subsidies for wind energy development, including an accelerated double declining capital depreciation schedule and extraordinary investment and production tax avoidance shelters. Taxpayers must underwrite losses to the public treasury to support these subsidies, while the state's electricity consumers are likely to pay more in their utility bills, since Maryland and nineteen other states have passed renewable portfolio standards requiring each state to purchase a percentage of its electricity from renewable power sources. In Maryland, it's 7.5 percent. The Maryland Public Interest Research Group (MaryPIRG) estimates that the wind industry will generate nearly seventy percent of this targeted goal. In effect, this legislation obligates utility companies doing business in the state to purchase much of that electricity from the wind and hydro-electric industries — both of which cause environmental destruction.

Such government support will provide a stable, predictable, fairly long term investment armature--all perfectly legal--to minimize risk. What companies like Synergics require to make the strategy work is a lot of land. If that commodity is brought on line, any other risks to the company would doubtless be handled through insurance. Insurance is available to wind energy companies to protect them even if their turbines supply insufficient power to meet contractual obligations.

One should not mind a company making money in this way, provided it delivers on what it promises. But since the promises Synergics makes are for meaningfully cleaner air, less pollution, less reliance on foreign oil, the company simply cannot deliver on them. Its pretentious environmentalism and sanctimonious concern for the public health too often diverts attention from the *business* of wind energy.

How much money is involved? Let's examine three of the financial mechanisms wind developers such as Synergics can use to artificially enhance their bottom line and shelter income by avoiding usual corporate tax obligations--(1) the federal five year double declining accelerated capital depreciation schedule; (2) the federal production tax credits, good for ten years, at a current rate of 1.8 cents per kW hour produced; and (3) the state's Renewable Portfolio Standards.

1. Assuming that the assessed capital cost of Synergics' plant will be $40 million, the company can depreciate its capital value as follows: $8 million in the first year (20 %); $12.8 million in the second year (32%); $7.68 million in the third year (19.2%); $4.608 million each in the fourth and fifth years (11.52 percent); and $2.304 million in the sixth

year (5.76 percent). This front-loaded depreciation schedule has enormous tax sheltering advantages, especially to wealthy corporations in search of one. And if Synergics sells its facility to another company after the accelerated depreciation allowance had been used, the new owner would also be able to put these generous depreciation benefits to work as well. The incentive here to "trade back and forth" is enormous. Who guards consumers against this kind of caprice?

2. Federal production tax credits remain front and center for wind developers and their investors, today giving the industry tax credits worth 1.8 cents for each kilowatt hour it produces. If Synergics' 47 MW windplant produces about 125 million KW hours annually (each 2.50 MW turbine would yield about 6.5 million KW hours a year, assuming a 30% capacity factor), it would generate about $23 million in tax credits over the ten year period allowed by the production tax legislation. If indeed this windplant powered about 10,400 homes a year, the total subsidy, underwritten by taxpayers, would be about $2,200 for each household powered! Of course, if Synergics' windplant, if built, actually realizes a 38 percent capacity factor, these numbers would be modified accordingly.

3. Maryland's RPS law virtually guarantees wind companies doing business in the state a customer, and will create an artificial demand for thousands of massive wind turbines in the region. Of the various "renewable sources" of power, the only practical industrial source of renewable energy in the foreseeable future is wind, principally because hydroelectric energy is not going to expand in the region. Landfill gas is relatively limited in quantity and availability. The cost of electricity produced by wind is regulated by "market forces" outside the regulatory authority of the PSC—within fairly generous bounds set by the RPS standards. Any seller becomes insulated from market forces when a government dictates that buyers must buy the seller's product or service. This is precisely what happens when a state law like the RPS mandates that a certain portion of an electric utility's electricity be produced from a particular source. The government-preferred seller no longer has to compete with others offering products or services that would satisfy the same buyer's requirement but at a lower price. Moreover, in this case the cost of electricity would be regulated by "market forces"outside the regulatory authority of the PSC—within fairly generous bounds set by the RPS standards. "Market rates" means whatever the market will bear (in this case an artificial market). Market rates contrasts with "regulated rates" that are set by regulators like the PSC.

No one knows the true long term costs per KWhr of electricity from today's wind turbines. All claims about these costs are based on untested assumptions, particularly because there has not been enough long term experience with today's large wind machines to know:

How long they will last (i.e., their useful lifetime)?
How much electricity they will produce (i.e., capacity factor)?
How much their performance will deteriorate over time?
What their maintenance, repair and replacement costs will be as facilities age?

Yet, all of these factors must be known to make a valid claim about the actual costs of electricity from wind turbines. In fact, none of the turbines now being installed (especially 2.50 MW turbines) have been in operation long enough to provide actual data. Synergics is assuming that its turbines will last 30 years and that its capacity factor is accurate for the targeted site, which would yield a particular "overnight" kilowatt hour capital cost. If, however, its turbines last only 10 years (or were abandoned after 10 years because all the tax benefits had been captured, performance had deteriorated, or maintenance costs became prohibitive), the overnight capital cost would be twice as much. This simple example deals only with the useful life of a wind turbine. It ignores all the other factors that would actually have to be taken into account, such as cost of capital; maintenance, repair and replacement costs; cost of other equipment and facilities such as substation, transmission, control and data acquisition, and more. Also, if the capacity factor did not achieve 38% or if performance deteriorated over time (e.g., fouling of blades), calculations would yield even higher costs per kilowatt hour.

What all of this suggests is that Synergics will be hard pressed to stick with any firm notion of the higher cost it will likely charge to utilities, which in turn will surely pass those costs back to consumers. The European experience demonstrates that the cost of wind energy is twice the cost of conventional power sources. According to "The Costs of Generating Electricity," by Phil Ruffles (Chairman of the Study Steering Group) from the Royal Academy of Engineering in London, March, 2004, wind energy will cost as much as a third more than other sources. The report factored in a number of cost issues surrounding each fuel. For example, for coal, the cost of mitigating CO2 emissions was added as a significant negative value. The factor driving the cost of wind was the intermittency problem, that is, the cost of providing "stand by" generation, while assuming a very generous capacity factor of 35 percent. The bottom line: coal fuel's current and future costs (on a pence per kilowatt basis) on average—3.33 and 3.28 respectively (page 31). For onshore windplants, the costs were 5.35 and 4.68 respectively, nearly 35 percent of which was for standby generation (page50).

A very recent study ("All In, Wind Power is Not Cheap" [*Attachment Q*) from Canaccord Capital Corporation, one of Canada's leading investment firms, found that "Wind power costs range from $67 to $105 a megawatt, including a return on capital, compared with all-in operating costs of $34 for coal, $47 for nuclear power and $53 for hydro." Moreover, the report states further that the "capital cost of installing a megawatt of wind power is about $1.7 million," with low utilization rates pushing the real cost to "almost $5 million, compared with $1.3 million and $2 million for each utilized megawatt for coal and gas-fired plants."

The captive market in Maryland that wind now enjoys because of the Renewable Standards will also surely drive the price of wind energy up vis-à-vis electricity prices from conventional power plants.

Altogether, publicly funded tax avoidance schemes reimburse wind energy developers as much as two-thirds of the capital cost of each $1.65 million wind turbine [presentation on

December 15, 2004, by Ed Feo to the Renewable Energy Resources Committee of the American Bar Association], with many states creating incentives to cover on average an additional ten percent of these costs. Windplant owners can use these tax shelters, or sell them, or enter into "equity partnerships" with other companies—all to reduce their corporate tax obligations by tens of millions each year, as the Marriott Corporation did a few years ago with a similar clean energy scheme, within a year reducing its corporate tax obligations from 36 to 6 percent— and a nearly $100 million reduction to the federal treasury (See "The Great Energy Scam. How a Plan to Cut Oil Imports Turned Into a Corporate Giveaway," Time Magazine, October 13, 2003).

The Florida Power and Light Group, the parent of FPL Energy, paid no income tax in 2002 and 2003, according to Citizens for Tax Justice (CTJ), despite having a profit of $2.2 billion during those years. The FPL Group made large investments in wind energy deployment during those years, and now claims to be the nation's leading wind energy producer.[Citizens for Tax Justice, "Bush Policies Drive Surge in Corporate Tax Freeloading: 82 Big U.S. Corporations Paid No Tax in One or More Bush Years," September 22, 2004]. It is now the parent company of Meyersdale Wind and the Mountaineer Wind Energy Center, both of which have provided virtually no local taxes to date.

These costs to the Treasury, which are borne by average taxpayers and ratepayers, don't appear to be worth the meager benefits accruing to less than a handful of full time employees and to undisclosed, likely very meager amounts of annual lease payment to a very few property owners -- much less to reduce the tax obligations of corporations.

Q. WOULD YOU PLEASE ADDRESS YOUR CONCERNS ABOUT THE DECOMMISSIONING PROCESS IN THIS CASE

A. Today, thousands of earlier, smaller, inactive turbines litter the landscape, abandoned after investors had secured their profits and tax subsidies. *Attachment M* is a copy of Paul Gipe's eight year old article about decommissioning wind turbines in California. Mr. Gipe is a nationally known advocate for responsible wind development. At that time, he wrote that the costs to remove the non-operating turbines still standing in California could exceed $100,000,000. It's important to note that many of these defunct turbines stand just 30 feet high; they are not the giants proposed or being built now.

Gipe reported that to remove just one 0.5-megawatt turbine in Bushland, Texas, the cost was $325,000 to restore the site to agricultural use. Restoration is important because, as Gipe points out, there are site reclamation responsibilities as well as turbine removal that should be addressed. By themselves, the concrete "pads" into which Synergics' turbines will be anchored will cost a lot of money to remove.

The Maryland Energy Administration, working with the PSC, has recently negotiated procedures on an *ad hoc* basis for decommissioning two windplants. While this is a good start, a number of problems remain. Agency staff should have investigated the matter in the way Gipe did, rather than relying upon the developers estimates of removal costs and salvage value.

The good news is that each of the two approved windplants in the state must establish an escrow account held by a third party. However, in the Clipper Windpower case, the bad news is that the escrow account will not be fully funded for 25 years. The negotiated estimate of the cost of decommissioning each turbine was $23,000 (the net cost—less salvage value)—only 1.5 percent of the construction costs. But without documentation of the salvage value, even this figure is questionable. Moreover, if these turbines remain inactive for one year, then the PSC requires them to be decommissioned. But the windplant owner may request an extension from the PSC. Finally, the negotiated agreements were silent about requiring public notice to property owners. As mentioned previously, these newer skyscraper-sized turbines provide little historic information about their useful life. If Synergics 2.50 MW turbines do indeed achieve a useful life of 30 years, as claimed, how can anyone estimate what the salvage value will be in 30 years? (See the Gipe article.)

Synergics has not disclosed any details of its lease/easement contracts with property owners. The PSC has supported other wind developers who have sought to abandon all their equipment to the property owners, compensating them with a bond worth a maximum of $2,000 and stating that the value of salvage will help the property owners recover the remaining portion of removal costs. But if the salvage is worth so much, why aren't the wind companies themselves cashing in? And what might happen if a property lessor, at the end of the contract term, wished to end the arrangement while the turbines were still in operation? Would any escrow account be then used to remove those turbines? Paul Gipe raises serious questions about the adequacy of the funding for turbine removal and site restoration heretofore sanctioned by the PSC.

The PSC should investigate this issue with much more rigor than it has. It should demand that any liabilities, such as abandoned equipment, be cleaned up by the Applicant or the responsible agent at the time of abandonment. The present situation is a game of "dodge ball," pretending that the company's liabilities will be mitigated but not really assigning any effective means to do so. The PSC should also note the ways in which the Shawano County wind ordinance handles this problem (see page 9):

> 3.2.13 Abandonment, Removal and Site Restoration Plan Required: The applicant shall submit a removal and site restoration plan and removal and site restoration plan cost estimate to the Shawano County PD and Z Committee for its review and approval. The restoration plan shall identify the specific properties it applies to and shall indicate removal of all materials above and below ground; road repair costs, if any; and all re-grading and re-vegetation necessary to return the subject property to the condition existing prior to establishment of the wind energy facility. The restoration shall reflect the site-specific character including topography, vegetation, drainage, and any unique environmental features and shall be completed within one year. The plan shall include a certified estimate of the total cost (by element) of implementing the removal and site restoration plan.
>
> 3.2.14 Abandonment Liability: Signed and notarized legal document stating the landowner will be held liable for removal of the wind turbine(s) should the owner or operators' LLC (or other corporate distinction) become liquidated or the posted bond not be sufficient to cover the costs associated with removal.

Q. WHAT CONCLUSIONS HAVE YOU DRAWN ABOUT THE ADEQUACY AND RELIABILITY OF THE CLAIMS THIS APPLICANT HAS MADE IN THE PROCESS OF SEEKING A CPCN FROM THE MDPSC?

A. Throughout this commentary, I raise concerns about promises made and not fulfilled. In its proposal, Synergics promises:

- a 30 year turbine life;
- only .67 acre clearing per turbine,
- turbine efficiency at 38% of rated capacity;
- significantly increased local revenue;
- no property devaluation or viewshed degradation,
- no decommissioning cost to be borne by landowners or the public;
- "acceptable" nuisance levels (noise, shadow flicker);
- little or no adverse impact to wildlife;
- improved air quality due to its operation;
- improved public health due to its operation;
- decreased dependence upon foreign oil.

I believe the Applicant has failed to make the case for every one of these claims. However, the issue at hand is not necessarily what I believe: the real reason for concern is what will happen if the requested permit is approved and none or few of the claims are later realized? Who will monitor and report any failure? And to whom would those reports be delivered? Will any penalties accrue if these claims are not met? Who will be responsible to remedy a problem?

Wind companies are well aware of the problems their technology creates: it is very likely Synergics, as other wind energy developers have done, may acknowledge many of the problems it says are not by-products of their installation by including various exculpatory "nuisance" easements in its "confidential" turbine leases. People who may experience problems because of the windplant, including adjacent owners whose property may be degraded and devalued, will have to seek a remedy in the courts—at their time and expense. The PSC should do everything possible to avoid this circumstance. This project is Synergics' first venture in windplant technology, and Garrett County should not suffer from a long learning curve.

In pursuit of a financial bonanza, the wind industry fiercely resists any federal or state regulation guiding windplant installation. To protect their investment potential, eliminate the perception of negative effects, and neutralize critics, wind developers have unleashed a sophisticated public relations campaign permeated with false and misleading claims, appealing to those hoping for the benefits of a safer, more healthful alternative to the mining and burning of fossil fuels. This campaign has helped build a political alliance attractive to many politicians, who give the impression their bills will result in improved public policy without resorting to unpopular conservation measures and expensive regulations to promote efficiency, reinforcing the comfort of the status quo-- especially for the coal industry as it buys "equity partnerships" in windpower. The same politicians bestow government-sponsored financial incentives wind investors seek. This cycle exemplifies much that is problematic about national and state policies, where corporate lobbyists influence lawmakers to gain financial reward at the expense of public well being. And enabling agencies, along with seemingly disinterested departments involved in natural resource protection, are headed by political appointees. This zeal for profit and the politicization of public policy too often override responsible citizenship and stewardship. All this plays out against the backdrop of neo-colonialism, where the people and politicians of affluence exploit the people and resources of the hinterlands to maintain the illusion of "progress."

Given substantial government-induced subsidies (and I believe probable increases for rate payers) that will benefit a relatively few investors who seek tax avoidance opportunities at the expense of average tax and rate payers; given the relatively small amounts of electricity (meaningless, really in the larger effort to reduce the effects of global warming) that will be produced; given the various nuisances likely to be generated in the vicinity of the facility; given the evident violation that will occur to Garrett County's Heritage Plan; and given the likely adverse impacts on wildlife, I can think of few initiatives more worthy of the sobriquet "irresponsible development."

Throughout, I have documented reasonable concerns and doubts about Synergics' project. Perhaps there are laws and regulatory measures which would severely penalize wind developers for making claims they did not deliver once their facility was built. But, if so, I don't know of them. It is incumbent on the Applicant to substantiate and validate the many claims he makes---and it is the duty of the PSC not to a issue a certificate of public "convenience and necessity" until it is *certain* (1) the developer can deliver on all of them and (2) it has determined an enforceable set of sanctions, prepared to shut the plant down and order its decommissioning if major problems ensue.

Q. AS AN ENVIRONMENTALIST, WHY DO YOU BELIEVE WINDPLANTS LIKE THE KIND SYNERGICS PROPOSES ARE PROBLEMATIC?

A. Our society has much the same dependence upon power from fossil fuel combustion as a three pack a day Marlboro smoker has with nicotine. Although each gets a "lift" from the experience, the mounting evidence for both demonstrates dire health and quality of life risks resulting from the behavior. Industrial windplants like Synergics are to the reduction of dependence on fossil fuels as the smoker who seeks to mitigate the dangers of smoking by switching to three daily packs of Marlboro Lites.

If the wind industry were fully deployed in the uplands of the Mid-Atlantic region, with thousands of windplants like the one Synergics is proposing, coalplants will still be puffing away despite all the gigantic wind turbines permeating the landscape and killing wildlife, destroying culturally significant viewsheds, devaluing nearby property, while creating major nuisances for proximate neighbors. And, because of the region's relentlessly increasing demand for electricity, likely resulting in the combustion of ever larger amounts of fossil fuels, the air quality will likely deteriorate, people would be getting sicker as a result--while paying more in rates and taxes. I submit this is not enlightened public policy

The only humane short-range solution to the problems of global warming and air quality must combine effective conservation efforts with much higher efficiency standards—heavy lifting indeed for the most wasteful culture in the history of the planet. The wind industry, as it targets huge powerplants along the uplands of our region, is a placebo solution to these problems, distracting from the necessary level of discourse --and political action-- for achieving genuinely functional responses.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

Attachments:

A. Wind Capacity Factor Charts

B. Map of US Wind Electricity Potential

C. Actual and Potential Regional Windplants

D. Garrett County Heritage Plan Excerpts

E. Shawano County, WI Wind Ordinance

F. Meyersdale, PA WindPlant Clearcut Photo

G. Lincoln Township Moratorium Committee Excerpt

H. Russell Bounds' Letter

I. Life Under a Windplant DVD—See May 17 Statement of Concerns to PSC

J. Robert Laravee's Letter

K. Shawano County, WI Measurement Protocol for Windplant Noise

L. MD Wind Potential Map

M. Paul Gipe Report

N. Photographs Documenting Construction of Cefn Croes Windplant in Wales

O. Announcement of First International Wind Conference

P. EON "Wind Report 2004"

Q. News Account from the Globe and Mail (July 18, 2005) of the Canaccord Capital Corporation. I am working on obtaining a copy of the entire report.

"Dr. Jon Boone's testimony to the Maryland Public Service Commission

Spring 2005

CONCERNS ABOUT THIS HEARING AND APPLICATION

I'm uneasy about the precedent-setting nature of these early wind applications. The intervenors in this case should help broaden the scope and rigor of review beyond the rather cursory analysis of previous cases. That the PSC chose not to notify nearby property owners individually, the people most affected by propinquity to a massive windplant, was a questionable omission for earlier cases and remains a major concern. Further, I believe the PSC decision to hold the evidentiary hearing for this application in Baltimore rather than in Garrett County is a disservice to the citizens of that county. At the very least, the public meeting there should provide ample time for comment and be held in a venue appropriate to accommodate the many people who will want to be heard. As the only resident of Garrett County involved directly in this hearing, I hope to bring a citizen's perspective, while seeking clear responses about this project's costs to and benefits for the public.

Either directly or with supporting documents, the Applicant has stated his windplant (1) will lessen dependence on foreign oil; improve air quality by mitigating the production of fossil fueled power plants; improve the health of Maryland residents; (2) provide electrical power for 13,000 to 33,000 homes; and (3) add significant revenues to Garrett County's economy. In addition, the Applicant has stated (4) his technology would not pose significant risk to wildlife, nor (5) alter the landscape in perceptible ways, nor decrease the value for surrounding properties, nor introduce disturbances that might jeopardize the right of neighbors to quietly enjoy their property. Conversely, he barely mentions the extraordinary subsidies that taxpayers provide, although these are clearly the motivating reason for the application. Finally, the developer contends that (6) decommissioning of the turbines is a non-issue.

Each of these claims, as well as any increased taxpayer or ratepayer obligations that may result due to the project, should be scrutinized and interrogated with great care to determine their validity.

PROBLEMS WITH RELIANCE ON FOSSIL FUELS AND WIND ENERGY

Power to supply our demand for electricity now comes primarily from the combustion of fossil fuels like coal, with poisonous consequences. Because windpower does not emit toxins into the air and its source of energy is recurrent, it offers the promise of a clean, renewable alternative to fossil fuels, along with a reduction in the significant environmental problems fossil fuels cause. Indeed, the understandable desire to reduce the toxins caused by reliance on fossil fuel combustion, as well as to eliminate such draconian extraction techniques for coal as strip mining and mountaintop removal, has enabled windpower advocates to make strong gains in recent years.

The quest for renewable energy has had a long contrapuntal history. A few hundred years ago, timber seemed inexhaustible, but our demand made short work of the supply. Coal, too, is renewable, but again, our demand will at some time overrun supply—and our meager lifespan won't extend the tens of millions of years necessary to replenish it. A few generations ago, hydroelectric dams were all the rage. Although these do produce a lot of electricity from a renewable source, they are so environmentally damaging that many are now being dismantled, at taxpayer expense.

The central problem with harnessing any form of energy is that enormous energies are wasted in the process of producing and channeling a relatively small amount (a phenomenon described by the Second Law of Thermodynamics). Hydroelectric dams, for example, transformed whole ecosystems, but the resulting supply of electricity was only a small percentage of the total energy within the ecosystem before the dams were built. This "loss" of energy was really the loss of valuable natural dynamics that previously functioned to maintain wetlands and mitigate erosion.

Windpower, too, has this inherent difficulty. There are significant losses—direct and indirect-- in the process of producing wind energy at industrial scales, which I will detail throughout this commentary. But because time seems to be running out on fossil fuels and the lure of non-polluting windpower is so seductive, otherwise sensible people are now promoting windpower initiatives at any cost, without investigating potential negative consequences— and with no apparent knowledge of even recent environmental history.

SUCH WINDPLANTS WILL NOT LESSEN DEPENDENCE ON FOREIGN OIL

The wind industry in the uplands of the eastern United States, for all its size and intrusiveness, will not put much of a dent in our overall reliance on fossil fuels. The claim about energy independence is one of the more misleading this Applicant makes. For example, US dependence on foreign oil is primarily a function of the desire for *refined* oil and gasoline. Allegheny Power, the major electricity provider in the region including Western Maryland, reports that oil accounted for less than 2% of the resources used to generate its power in 2003. Nationwide, this figure is less than 3%. Coal and gas-fired power plants do pollute the air with toxic hydro-carbons, although the sheer volume of automobile exhausts is also a major culprit. *More than 60% of the nation's energy consumption does not involve electricity.* Wind *only* produces electricity. Consequently, even if we constructed thousands of massive turbines to replace the two percent of electricity that oil now produces in the region, Western Maryland would still be more than 98 percent dependent on other, mostly "dirty" power sources.

SUCH WINDPLANTS WILL NOT REDUCE THE MINING/BURNING OF FOSSIL FUELS IN THE REGION

It would take thousands of these clean-energy, landscape-marring machines [wind turbines] to generate only a slice of the region's [Maryland's] power needs. Consider a recent Department of Energy Study. It shows that nationwide, moving to 10 percent renewable energy would still see coal burning increase substantially because of rapidly growing electrical demand.
---Tom Horton, staff environmental writer of the weekly column, On the Bay, The Baltimore Sun: "Wind farms a problem, too," February 27, 2004.

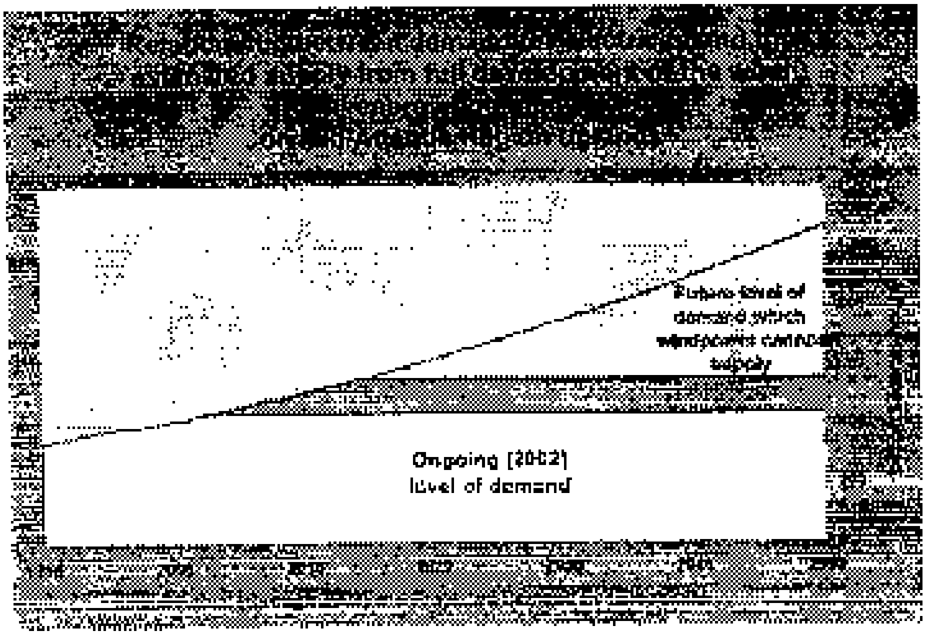
Wind technology in the uplands of this region stands little chance of displacing fossil fuel extraction efforts or reducing its consumption, given our increasing rate of electricity demand. Wind machinery has problems accessing and controlling its source of power. Because of the intermittent nature of wind velocity, sometimes it is not strong enough to generate power and other times it is too strong to be commercially tapped. The wind needs to blow eight to fourteen miles an hour before a turbine will produce electricity, and a turbine is programmed to shut down when the wind velocity exceeds 50 or 55 miles per hour to prevent harm to its gears. Despite these problems, the industry has attempted to increase its effectiveness by making taller machines and targeting them on high ridges with excellent wind potential. However, these turbines still require back-up from other, often "dirty" power sources for the time they do not operate or work at sub-optimal levels, creating potential cost and management issues for the electricity grid.

All six windplants in the Mid-Atlantic region have had an annual capacity factor of under 30 percent. What the capacity factor means is that, on average, each wind turbine with a given rated capacity sited on high elevation, wind-rich ridges will *actually* generate electricity over time as a function of this factor. For example, if the capacity factor is 30 percent, a rated 1.65 MW turbine should generate about .50 MW of electricity annually.

Since other windplants struggle to achieve a 30 percent capacity factor, it is unclear how Synergics has arrived at its claim of 38 percent (down from an earlier claim of nearly 60 percent-- the theoretical maximum!). The developer does not disclose how this capacity will be achieved, and has refused to provide any wind energy measurement data pursuant to my information request. The PSC should require these wind measurement data to be made public.

With a generous 30 percent capacity factor, *more than 2400 giant turbines are needed to equal the annual production of one 1600 MW coal plant* (i.e., Mt. Storm, West Virginia). Even if we placed huge wind machines at *all* the good wind sites possible in the uplands east of the Mississippi River (a region with only 5% of the wind energy potential of the continental US), this would still not reduce the mining or burning of coal, given that our demand for electricity will likely nearly double in 30 years. In fact, wind technology works least when the need is greatest— summer peak demand, when the wind is typically not very active. At the nearby Mountaineer wind facility, the capacity factor during summer months averages less than 15 percent--half of the average annual capacity factor.

Consider the following graph showing the relationship between demand for electricity and the potential of windpower to meet it in the uplands of the Mid-Atlantic region.



The ridges of this region, comprising Maryland, the District of Columbia, Delaware, Pennsylvania, New Jersey, Virginia, and much of West Virginia, have little more than one half of one percent of the nation's wind energy potential. Moving from left to right, the upward curve on the graph represents the demand for electricity which is expected to increase in the region at a conservative projection rate of two percent each year into the foreseeable future. Present supply comes from a variety of power sources, primarily fossil fuels, with negligible contributions from wind.

However, *if* (and this is a most improbable if) the wind industry could immediately exploit *all* the wind potential available in the region's uplands, saturating it with 30,000 huge turbines functioning at a capacity factor of 30 percent (see the table below), then it could produce enough electricity to supply about one-fourth of the *present* level of demand. In the graph, this hypothetical supply from wind is represented in blue atop the ongoing level of demand. But note, in about 15 years, our increased rate of demand will absorb any yield produced by windpower, necessitating additional energy sources to supply it. Unless wind turbines fill up the Chesapeake Bay and are constructed off the ocean's shore, the projected additional future power sources will not come from wind, for the industry will be capped out on land. As the graph rather dramatically shows, wind energy development of the region's uplands—at its realistic maximum— will not result in a net reduction of greenhouse gases or cut the present rate of the burning of coal and other fossil fuels. The very best case scenario for windpower in the Mid-Atlantic region is that future wind energy development will only slightly lessen the rapidly increasing rate in the growth of demand for electricity from "dirty" power sources.

The claim Synergics makes about its potential wind energy production may seem impressive. However, a million hamsters churning treadmills will also produce electricity. But what's the point? In this larger scheme, Synergics comparatively minuscule power production would immediately be engulfed by increasing demand. The boast that its plant would be an important first step in the direction of a comprehensively effective windpower system is therefore unsupportable.

STATE	Geothermal Potential [illegible]	Landfill Gas Potential [illegible]	Clean Biomass Potential [illegible]	Wind Potential (onshore) [illegible]	TOTAL OF RENEWABLE ENERGY SOURCES [illegible]	% TOTAL FROM WIND	NUMBER OF INDUSTRIAL WIND TURBINES TO GENERATE WIND POTENTIAL
DC	0	0	0	0	0	[illegible]	0
Delaware	0	[illegible]	[illegible]	4,920	5,430	[illegible]	1,219
Maryland	0	[illegible]	2,333	3,640	6,499	[illegible]	1,431
New Jersey	0	1,374	457	[illegible]	17,132	[illegible]	3,928
Pennsylvania	0	1,749	[illegible]	[illegible]	73,911	85%	17,[illegible]
Virginia	0	[illegible]	[illegible]	[illegible]	26,192	[illegible]	[illegible]
West Virginia	0	[illegible]	[illegible]	[illegible]	15,697	[illegible]	2,472
TOTAL	0	4,259	30,327	116,797	151,391	77%	29,629

[illegible]

THIS PROJECT WILL NOT IMPROVE AIR QUALITY AND PUBLIC HEALTH

Unfortunately, the demand for electricity will be so great over the next thirty years that additional coal plants are likely to be built. Florida Power and Light, the nation's third largest electric utility company, now owns over one-half of the wind energy facilities in the US. Moreover, AES Corporation, which operates a coal-burning powerplant at Cumberland, Maryland, has recently joined with US WindForce (which has several approved and planned projects in West Virginia and Maryland), lending its financial backing to wind energy developments in the region. US WindForce is the most ambitious developer of wind energy in the Alleghenies. Here is a weblink to the announced collaboration with AES, an international owner of mostly fossil fueled powerplants: http://www.aes.com/aes/index?page=news&reqid=609530&print=Y.

Such "equity investments" between wind and coal will likely grow in number, as the former industry reaps the cachet of association with a major electricity producer while the latter gathers in the use of wind's generous tax avoidance shelters and its reputation as a green energy source. The irony of these partnerships should not be lost on the PSC.

Unless we have a major change of political direction, fossil fuel combustion, and the toxins it emits into the air, will increase in the future, contributing to such dire statistics as the rate of asthma doubling every five years. The wind industry will not itself alter this circumstance. Only when the public insists upon implementing appropriate standards and newer equipment to increase efficiency, as well as conservation measures that reduce per capita consumption demand, will air quality improve. Indeed, because of some of these measures residual to the last Administration, which mandated newer, more efficient coal-burning technology, air quality in the region has actually improved in recent years.

Altogether, the wind industry in the uplands of the eastern US is not an answer to the concerns about global warming, energy independence, air pollution, or public health.

SYNERGICS' WINDPLANT WILL NOT POWER 13,00-33,000 HOMES

Here's why. Let's return to the concept of the capacity factor mentioned earlier, examining whether this proposed 40 megawatt windplant would generate enough electricity to power 13,000 homes, let alone 33,000. A megawatt (MW) is one million watts or one thousand kilowatts (KW). The average home consumes 12,000 KW hours annually (per EPA estimate)-- not the low 9000 average KW hours Synergics postulates. Assuming a realistic 12, 000 KW hours for household use as an annual average, one can rather easily obtain a reasonable annual projection for the number of homes this windplant can power. The following example assumes a 24 turbine windplant with 400-foot tall turbines, each rated with a potential of 1.65MW and a generous capacity factor of 30 percent.

1.65 MW x 30% efficiency = .50 MW (or 500 KW)
500 KW x 24 hours x 365 days = 4, 380,000 KW hours per year per turbine
4,380,000 KW x 24 turbines = 105,120,000 KW hours annual plant output
105,120,000 KW / 12,000 KW hours average household use per year = 8760 homes powered annually.

Consequently, a 40 MW windplant would power less than 9,000 homes annually. Even this may overstate the case, however. Because electricity from wind is inherently intermittent and volatile, it would really "serve" those homes where the occupants were willing to have electricity only when the wind was blowing in the right speed range --or for them to invest in an expensive battery storage system. Seen in this light, windpower would service no homes in any conventional sense of that term's use.

QUESTIONABLE LOCAL ECONOMIC BENEFITS

Promised "windfall" revenue is tantalizing. However, Garrett County relies heavily upon tourism attracted to the region's scenic natural beauty. The lure of additional revenue without any apparent cost often blinds authorities to the problems created by development which will diminish the natural beauty at the heart of the economy.

Garrett County has no ordinances for zoning a windplant in ways commensurate with the $40 million capital value of the proposed windplant. This developer's claims about what his windplant will pay in personal property taxes are in need of clarification: for there are assurances Garrett County would receive about $750,000 in the first year alone. The PSC staff should evaluate these claims, examining, among other things, how the equipment section of the county's business personal property tax applies. Nowhere is it made clear what the assessed value of each turbine will be for tax purposes. The developer suggests a 20 year life, which seems meaningless in light of the federal depreciation schedule allowed.

An examination of two recently constructed windplants in Pennsylvania and West Virginia reveals they have contributed virtually nothing to the local tax base. Synergics will not be taxed as a public utility. Indeed, it is not clear what taxes it would be obliged to pay. With knowledgeable tax accountants, a developer will undoubtedly look to protect its investors, not a local economy hundreds of miles away from its corporate offices. What penalties apply if Garrett County does not receive these promised revenues?

Since this project will lease private land, the county will receive little additional property tax. Wind leases are typically written to favor the developer, restricting the owner's use of the land for up to 35 years and devaluing it significantly (a major problem for those in need of emergency funds). Turbine leases also may allow abandoning all equipment to the property owner, providing little or no indemnification for any decommissioning, removal, or restoration costs. And they often include noise and other "nuisance" easements, holding the developer harmless from legal responsibility if his machines create such nuisances.

Income generated from turbine lease agreements varies widely. Synergics claims that lease income will range from $4,000-$6,000 annually per turbine, although it is not clear how this estimate was derived. An examination of a lease from another wind company reveals provision for an initial, one time payment (from $500 to $1,000) to reserve a turbine lease and pledges a minimum annual rental income of about $1500 per turbine against a small percentage of the power the turbines actually produce, generating at maximum about $2500 per turbine. The PSC should interrogate this claim carefully to protect wind lessors, especially in light of Synergics' reduction in the capacity factor of its machines. Moreover, if a wind lessor does not reside locally, the local economy will not benefit from any increased income tax.

Very few permanent jobs will likely be created— perhaps a couple of low wage maintenance employees. According to a report by the National Renewable Energy Lab on windplant jobs, the national average is one maintenance employee for every 12-15 turbines. A 20 turbine windplant in Meyersdale, Pennsylvania now employs only two maintenance employees. The claim here that four permanent jobs will be created appears generous. But even if it were true, this is a very small return relative to a $40 million capital project.

During construction, a few local security guards and some local earth moving crews may be hired for a few months, while the bulk of construction will probably be completed by primarily non-local labor, since NEG Micon turbines (if, as Synergics' application indicates, NEG Micon turbines are chosen) are manufactured in Europe with warranties likely serviced by the manufacturer and its employees. A recent study by the Iowa Department of Natural Resources on the "Top of Iowa" windplant showed that, of the 200 total construction jobs, only 20 were local — and all disappeared within six months.

Synergics has overstated the general local economic benefits by counting the full price of goods and services, rather than value added. Generally, a large part of the price paid to a local supplier has to be paid by that supplier to another agent, in this case likely to be a party outside the local area. This price is part of the local supplier's cost of acquiring the goods (for example, the purchase of fuel, wiring, cement) the local supplier is reselling to the windplant. The only portion of the price paid by the windplant that should be tallied is the difference between the local supplier's cost and the price he charges — that is, the value added portion — which in any case would be extremely small in Garrett County as most goods will be purchased elsewhere.

QUESTIONABLE CLAIMS ABOUT SAFETY TO WILDLIFE

Science is the disinterested search for the objective truth about the material world. — Richard Dawkins

Theories crumble, but good observations never fade. — Harlow Shapley

The less one knows about the universe, the easier it is to explain. — *Leon Brunschvicg*

Good public policy requires those who make claims about the safety of their product to substantiate those claims *before* introducing it into the environment, deferring to what Rachel Carson called the precautionary principle. Industry funded research is always suspect. Experts who work for an industry should submit their research and resulting conclusions for independent, peer-reviewed analysis. Science insists upon conclusions which account for all the evidence, not selective pieces which fit the convenience of a developer's agenda. *Post-construction* studies are extremely problematic.

This is surely the principal reason that the US Fish and Wildlife Service guidelines call for a three year preconstruction analysis before a permit such as that which Synergics seeks is granted. And the presumption seems to be that if these studies show significant risk, then the project would be denied. As is the case presently at Altamont Pass, California, where thousands of birds have been killed annually for many years prompting a pending lawsuit, who is going to shut down a $[illegible] million capital facility after it is up and running, even if later studies verify it kills significant wildlife?

Others at this hearing will likely bring forward critical commentary about the claims of wildlife safety that this developer has made. I will limit my remarks to the following.

If this project really were a grand first step in the mitigation of fossil fuel emissions, making the air cleaner and our society less "vulnerable from imported energy sources" (although it will do neither), the prospect it will likely kill thousands of birds and bats (and create hardship for other wildlife as well) might be justifiable, although the small population of some of these species makes them extremely vulnerable.

The Roth Rock firetower area is the only place where Mourning Warblers have been consistently found to nest in the state in recent years. Three years ago, I located four nests there, some through serendipity, others by watching the adults carry food. One of those nest locations was destroyed a few years ago because Synergics cleared three acres of forest habitat to erect a meteorological device. Last season, I heard only two singing Mourning Warblers in the area, but did not seek out their nesting sites. Although I'm aware this is a bird that frequents cut-over, disturbed habitat, I'm also aware it does not tolerate intrusion; it is a most cautious bird characterized by its "skulking" behavior. I have little doubt that a windplant at the scale proposed here will eliminate the Mourning Warbler as a nesting species at this locale. Perhaps, as Paul Kerlinger, Synergics' avian expert suggests, it won't affect the species' regional or global population levels. But it very likely will purge the Mourning Warbler as a resident nester in the state. And if this happens, how does Synergics propose to compensate the state for this resource loss?

Dr. Kerlinger's avian risk study mocks the scientific method. Scientists are not just experts; they work in an analytic process characterized by rigorously evaluated *if* this, *then* that experimental "conditionals." Analysis of this kind is supposed to have predictive power because it comprehensively considers the many variables individually - and then works to understand how they integrate to create "regularities"—patterns with a certain outcome. These predictable outcomes—and the processes used to achieve them—are then scrutinized by other scientists for validation in a process known as independent peer review. A particular experiment, however honestly and intelligently conducted, can yield the "wrong" answer for a variety of reasons. This is why experiments must be checked by other scientists, using other instruments, other conditions, even other ideas.

On the basis of only two walks in the woods at a time (July) well after spring and before fall migration when most nesting birds are extremely quiet because they are feeding young out of the nest, Kerlinger makes predictive assessments about the quantity and quality of bird-life in the area. His technical area of expertise resides in birds of prey, not passerines like *Oporornis* warblers. Moreover, his recitation both of the literature and personal contacts used as part of his evaluation protocol is highly selective. In a way favorable to his client, he mischaracterizes conversations he had with representatives of the Maryland Ornithological Society and with Chandler S. Robbins, the area's most knowledgeable ornithologist who has been studying birds there for over 50 years. He invokes the "broad front theory" to justify his statements that birds won't fly low enough to collide with his employer's large turbines, in full knowledge there are significant exceptions to the application of this theory. In conditions of fog and low clouds (which abound in the spring and fall around the Garrett County mountains), night migrating neotropical songbirds in large numbers are sometimes forced to fly low enough to encounter 400 foot tall structures atop a 3200 foot ridge. Rather than modifying the broad front theory to accord with all observations, however, Kerlinger continues to invoke it as some sort of sacred text, somehow uncontaminated by reality. This is the antithesis of the scientific method. His tactics here seem similar to those Cinderella's step-sisters employed to create the illusion their outsized feet really did fit that damned slipper.

The radar study to which Kerlinger refers in his testimony as evidence supporting the broad front theory's explanatory power is not the only such study extant. Yet he does not mention these other studies. Recent radar reconnaissance at proposed industrial windplant locations atop the mountains of Vermont and West Virginia demonstrate that hundreds of thousands of migratory birds and bats fly low enough to collide with huge turbines, placing them at risk—especially in times of fog and low clouds. This is the case with buildings, cell towers, even fire towers which are along a migratory route. The taller the turbines, the larger the threat. These studies also give evidence that ridges here in the Allegheny Highlands may in fact channel migrating birds and bats, a phenomenon which Dr. Robbins has previously testified he has witnessed. In 2003, a developer-sponsored mortality study conducted over a several week period at a West Virginia windplant revealed that over 2,000 birds and bats had been killed during fall migration in that span. Independent experts have doubled that mortality figure to more than 4,000, concluding that Kerlinger's accounting methodology was deficient.

In previous windplant testimony, Kerlinger initially said (inaccurately) the Backbone ridge had relatively few migrating birds passing over, and then used an apples to orangutans comparison, citing statistics (only two or three birds killed per turbine) derived from western turbines averaging about 150 feet tall and located in fields not known for significant avian migration—stating these should be comparable to 400 foot turbines located on prominent forested ridges in areas well known as a major avian flyway. This kind of comparison is no basis for credible prediction, which is the purpose of scientific analysis.

Given the evidence of bodies on the ground in California and West Virginia, wind industry pundits like Kerlinger have now begun to admit that windplant mortality may be higher than they had expected. But not high enough for him to deter the building of windplants in risky areas, since, although the wildlife mortality at these sites may be significant, and may indeed eliminate one species from nesting in the state, it may not be "biologically significant," threatening any species with extinction, as if the scientific community had agreed to a clear definition of the meaning of "biologically significant." These protean rationales are clearly intended to suit the needs of a desperate client rather than provide a scientific explanation of complex wildlife dynamics.

I believe strongly that the many windplants targeted for Garrett County and the surrounding area (*Attachment A*) represents a staggering challenge—a semi-annual gauntlet for migratory wildlife, which in their cumulative aspect may one day be responsible for slaughtering millions of birds and bats.

To my knowledge, Kerlinger has never submitted his avian wind risk assessments for independent peer reviewed evaluation. The PSC, however, should be very suspicious about such sponsored "research." The PSC should work to develop a process for independently assessing conflicting claims made by experts involving very specialized knowledge. This is not something that should be adjudicated in an adversarial forum. "Truth" does not necessarily lie in the middle between two points of view.

Adequate preconstruction study does not mean that, because such study is made, therefore windplants should be built. Rather, any studies should be made to determine whether or not they should be built at all. Consider the FDA model. I will continue to demand more preconstruction studies not only as predictors of risk; but also as a means of assessing whether the risk is defensible. This is where a peer review panel of independent experts should come in--since the resultant cost-benefit analysis would require a fairly high level of sophistication and expertise over many areas of knowledge.

THE TRUTH ABOUT PREVIOUS WILDLIFE STUDIES AND MY DESIRE TO SUPPRESS THEM

Synergics' representatives continue to maintain that I and others are refusing to release important field studies that might demonstrate how safe wind technology is for migratory wildlife. This is a lie. Here is the truth.

Since I was one of those responsible for getting those studies done in the first place, the charge is more than ironic. The company involved, Clipper Windpower, insisted on a non-disclosure condition which it alone imposed on those studies. Clipper had agreed to do this study only at the request of the PSC hearing examiner in order to induce the various intervenors to settle. As an intervenor in the Clipper hearing, I was aghast at the idea of such "secrecy." Nonetheless, Clipper insisted that it would not agree to fund those studies unless *all* intervenors signed agreements that the *studies not be released until after the wind turbines were operating.* I reluctantly agreed to do so only after I became convinced that, if we did not, the PSC would likely approve Clipper's application anyhow—and no studies would be done at all. The need for data seemed paramount at the time, even if it were revealed after the fact.

The Applicant has known for many months that *all* the intervenors would be pleased to release those studies in the following way: Clipper must admit in writing that it insisted on the non-disclosure nature of the studies; the reports must be released *for independent peer review* in their entirety, including all data, without restriction; and they must not be used to excuse the need for additional research to map the complex mosaic involved in wildlife migration over the Allegheny ridgetops. I published this in all the local papers months ago. To date, I have not had any response from Clipper — and certainly not from Synergics.

I'm confident these reports will demonstrate, as similar recent research already has, that massive windplants constructed atop mountains in areas well known for wildlife migration pose an unacceptable risk to birds and bats. At the same time, this important issue should not distract from other threats posed by this industry –devaluation of property, destruction of heritage views, and noise/light disturbances to nearby residents.

VIEWSHED DEGRADATION

Note the photo below of the existing Meyersdale windplant sited atop a prominent ridge.

375 Foot Turbines Over Meyersdale, PA

As Synergics own simulated photographs show, this project will transform the viewscape—and it will do so for many miles. The still photographic representations do not do the visual experience full justice, however. One must see a windplant to observe that the turbine blades are often in motion at differing angles and speeds- and hear pulsing noise, like jet engines roaring on a runway, over distances more than a mile away. These turbines will simply take the 3200 foot ridge away from the viewing experience. Contrary to this developer's assertion that his machines will disappear into the mountains at distances beyond four miles, they will be a very visible presence for many miles more, as is the case at Meyersdale.

PROBLEMS WITH INDUSTRIAL DEVELOPMENT ON BACKBONE MOUNTAIN

I'm a strong advocate of wind farms on the high seas. But there are appropriate places for everything. We wouldn't put one of these in Yosemite, and I think environmentalists are falling into a trap if they think the only wilderness areas worth preserving are in the West. The most important are the ones close to our cities, where the public has access to them. And Nantucket Sound is a wilderness, which people need to experience. I always get nervous when people talk about privatizing the commons. In this case, the benefits of the power extracted from Nantucket Sound are far outweighed by the other values our communities derive from it.
—Robert Kennedy Jr., E Magazine (November/December 2003).

In April, 2003, Garrett County adopted a Heritage Plan which, among many other features, recognizes Backbone Mountain as a key natural heritage resource. The Plan assures that the most significant features of the county's past and rural way of life—heritage resources will be preserved and bequeathed in stewardship to future generations. This is not to say that development cannot take place along the Backbone ridge, for some already has. But the clear intent of the Plan would prohibit industrial development that greatly altered the mountain's appearance. [*Attachment B*: I've excerpted the Heritage Plan and attached it to this testimony. The entire document is available from the Garrett County Office of Planning and Zoning and may be read at the county library.]

The mountains of Maryland are one of the state's compelling natural resources, with vistas inspiring reminders of the importance of wilderness and the special place natural beauty has in our culture. As the state's most prominent, longest mountain, Backbone represents this idea perfectly, and this is the reason for its special status within the county Heritage Plan. However, this project, as proposed, would be a jarring, discordant visual assault, with more towers scrapping the sky in this rural county than there are in Baltimore City (there are only two buildings in the city which exceed the height of these turbines). The scale of this project would visually take the mountaintop away. This is not personal aesthetic judgment, but rather one focusing upon heritage considerations and the public's right to determine modifications to that heritage. Synergics' turbines are not bucolic Dutch windmills and its development infrastructure is not a "farm."

In July, 2004, the Maryland Heritage Areas Authority (MHAA), a unit within the Department of Housing and Community Development, approved the Heritage Plan, formally recognizing Garrett County as a Recognized Heritage Area (RHA). The next stage of this process involves crafting a detailed management plan that will describe how the county will implement and support the RHA. When this step is concluded and approved, the county will be designated a Certified Heritage Area (CHA) and will be eligible for state technical and financial assistance to support the CHA, such as grants for operating assistance, capital and non-capital project support, and marketing, as well as low interest loans and tax credits.

The Heritage Plan, while rooted in historic preservation, is nonetheless a practical recognition of the importance of heritage tourism. "Garrett County receives over 500,000 visitors annually from outdoor related activities and other related tourism activities." (Page 4.15) People are attracted to unspoiled views of nature and want to participate in it. Industrial strength windplants threaten this idea.

Elizabeth Cole, an administrator for the Project Review and Compliance Section of the DHCD, has already notified Synergics (her letter accompanied the application) about the need to identify and evaluate historic properties that "may be affected by the project and to develop measures to avoid, reduce or mitigate any adverse effects on significant historic properties. Doing this requires a range of activity. Under Section 106 of the National Historic Preservation Act of 1966, this is a formal requirement for all such applications requiring federal or state permits. Garrett County's Heritage Plan adds yet another dimension to this process.

In its 2003 decision granting a CPNC for Clipper Windpower, the PSC made a number of incorrect assumptions about that project's impact on the Garrett County landscape, agreeing with the developer that his turbines "will blend in with the landscape in the background beyond 4 miles [and that] The visual impact will not be significant because the project will be intermittently shielded by terrain and vegetation which will reduce visibility from highways and roads." Moreover, the PSC also inaccurately concluded that "The project will have minimal visual impact on existing residences in the vicinity of the project site because the area has been extensively logged and farmed and the existing landscape has been modified by electrical power lines, communication towers, and roads." And "Each turbine will be framed in the front and back by existing vegetation." All these claims are unwarranted for that project and for the Synergics project as well, in light of the visibility of the smaller Meyersdale, Pennsylvania windplant.

SYNERGICS PROPOSAL AND THE GARRETT COUNTY HERITAGE PLAN

The PSC and the Power Plant team within DNR should understand the implications of this project for Garrett County's Heritage Plan—not just for Garrett County but also for the residents of the entire state and even the tri-state region. Backbone Mountain's majesty should be protected as a reminder of the importance of nature in our lives. There are many design standards and guidelines staff can use for this process. In order to give others involved with this hearing an understanding of the craft involved, I'll list some of them in the next paragraph. But all should be mindful of the difficulties for any design prophylactic to soften and mitigate the effects of such a Goliath facility. The inherent incompatibility of mammoth industrial wind factories targeted for areas that pride themselves on their natural beauty makes for a hard, perhaps impossible, fit. Industrial scaled turbines are probably beyond any reasonable scheme's abilities to integrate that scale into a visual harmony with the environment, let alone disguise their intrusion into a historic view.

At a minimum, siting guidelines for wind turbines require mapping areas of high wind potential together with sensitive natural areas (including national/state/regional parks and scenic areas; gardens and designed landscapes; recreational and wild lands; and lands that promote biodiversity and scientific interest). Buffer zones should be established around areas of high sensitivity. Regional capacity studies should be done that include the cumulative effects on natural heritage sites, visual impact, wildlife/habitat, and local recreational and economic opportunities. See: Scottish Natural Heritage: Guidance for Onshore Wind Farms (www.snh.org.us/pdfs/polstat/ar-ps01.pdf) and Scottish Natural Heritage: Cumulative Effect of Windfarms (www.snh.org.us/pdfs/polstat/cgw.pdf).

Since industrial windplants sited along the uplands of the East won't really achieve the claims made for them, perhaps the PSC should encourage developers to consider smaller scaled, locally distributed auxiliary wind energy systems. These offer the prospects of local conservation as well as give design standards a chance to work. Here, individuals and small businesses would be encouraged to build windpower systems at an appropriate scale through tax credits and other subsidies, rather than making them available mainly to industrial wind developers. Small turbines (towers less than 120 feet) could provide power directly to users and any excess power could enter the grid. See: Siting a Wind Turbine on Your Property (www.state.vt.us/psb/application_forms/PSB_wind.pdf).

There is also the reality of rich wind potential in the deep oceans, and I believe, if the wind industry really wants to engage the issue of fossil fuel consumption in a meaningful way, it must get serious about tapping this vast resource, after first doing the necessary studies to ensure the safety of wind technology for marine life. Here is where the taxpayer supported subsidies for wind could perhaps be justified, for the promise of the industry might actually then be aligned with its ability to really deliver on it—without encountering the difficulties inherent with onshore development.

PROPERTY DEVALUATION

While looming windplants are a relatively recent phenomenon in the East, there is increasing evidence that the closer one resides to them, the lower one's property value falls. The premiums paid for the serenity of natural views can no longer be justified in an area surrounded by huge turbines. The Pleasant Valley viewshed is one of the most beautiful natural areas in the state, filled with Amish farms and framed by misty mountains. Those who feel that a single wind structure is beautiful should visit Meyersdale to see how the 2750 foot mountain there seems to disappear with 375 ft. wind machines on top (one can see these 15 miles away on a clear day). Note, too, the four acres of clear-cut around each turbine (*Attachment C*).

One of the most validated real estate precepts is the idea that significant natural views have premium value, and intrusions which restrict that view erode value. Realtors doing business near windplants in the western United States and in Europe understand that property will sell for between ten and thirty percent less than previous market value, depending upon how close it is to the windplant. The few "studies" which appear to support the claim that windplants don't devalue property are extremely flawed in fact and methodology, often surveying people and evaluating property miles away from a wind site, then "averaging" these results with properties adjacent to windplants.

THE REPP STUDY

The Renewable Energy Policy Project (May, 2003) study that Synergics offers on behalf of the claim that its project will not diminish property values contains serious methodological flaws:

1. The study covers just ten projects, only one of which comes close to the size and scope of Synergics' project—and this site (Madison County, NY—the Fenner Site), with 20 1.5 MW turbines situated on farm fields—not atop prominent ridgelines-- interestingly showed significant decreases in property values.

2. The time frame of the study was so short that even the study's authors were compelled to state the data was insufficient to offer compelling conclusions.

3. The study did not verify whether individual properties had a direct view of the windplants, making the use of the term "viewshed" something of a misnomer in this context, since the viewshed properties were actually all properties within a five mile radius of the turbines regardless of whether they had a direct line of sight. To mitigate this problem, the researchers conducted phone interviews with tax assessors and other local authorities to get estimates on the number of properties in the defined viewshed that *might* have had views of the turbines. However, under scrutiny, many of these estimates proved inaccurate.

4. The analysis used in this study did not incorporate distance from a wind facility as a variable or weighting factor, so that a viewshed property sale five miles away from a windplant counted the same as one a quarter mile away. It is at least plausible that if windplants do have an effect on property values, it would be strongest close to the turbines and decline with distance. Simple geometry suggests that the majority of properties in the area of a five mile circle are likely to be fairly distant from the wind development 64% of the area of this circle is three miles or more from the center -- and only 4% lies within the first mile. Though properties are not necessarily distributed evenly about the landscape, and property values conceivably can be affected by other things in the vicinity, the REPP study confuses substantially the proportion of properties that either have only a distant view of wind turbines

or no view at all.

5. The study relied on average rates of sale prices before and after the windplant construction and between viewshed properties and properties in a comparison group. Therefore, if one calculates that sale prices among viewshed properties increased $50/month faster than sale prices in the comparison group, then it makes a difference whether the statistical uncertainty in the point estimate is plus or minus $25/month or $500/month. The former leads to a conclusion that the wind development unlikely had a negative effect on property values while the latter intimates that the data are inconclusive – there could be a large negative impact, a large positive impact or no impact at all. These "smoothed" average sale prices against a very small time variable creates a regression analysis which is, for prediction purposes, almost beside the point, suggestive of nothing.

The REPP "study," although its basic methodological approach holds considerable promise, is severely flawed. To say, as Synergics does, that the study demonstrates its proposed windplant will have no effect on property values, that it may in fact enhance them, is disingenuous. George Sterzinger, the executive director of the REPP, admitted as much in response to critics who stressed the study contained no proof that windplants were the reason for changes in property values. "We have no idea," he said, noting that the REPP did not have time or money to answer that question. (Cape Cod Times, June 20, 2003). Sterzinger further agreed that the study's findings have to be applied carefully to different situations.

There are very few windplants in the world, let alone in the United States, with turbines over 400 feet tall placed on such a prominent ridgeline. Consequently, there will be no "comparable" facility "yardstick" by which appraisers can measure the impact in Garrett County for predictive purposes. And without knowing about the various nuisances this kind of windplant will produce, the problems for credible prediction increase even more.

EVIDENCE THAT WINDPLANTS WILL DEVALUE PROPERTY

In 2001-2002, the Moratorium Committee of Kewaunee County, Lincoln Township, Wisconsin compared property sales prices to assessed values before and after the construction of two wind energy facilities, each having relatively small .65 MW turbines. An assessor reported that property sales (vs. 2001 assessed values) declined by 26% within one mile and by 18% more than one mile of the wind project. The Moratorium Committee also sent anonymous survey forms to 330 property owners, of whom 223 responded. These responses were then grouped based upon proximity to the windplants.

The survey results found that 74% of respondents would not build or buy within ¼ mile, 61% within ½ mile and 59% within 2 miles of the windplants. In fact, a large percentage stated that they would not buy a home within 5 miles of the turbines. The windplant's offer to purchase neighboring homes for demolition--to create an 'additional buffer for the windmills'--came immediately following the release of a noise study showing the Lincoln wind turbines increased the ambient noise level by 5 dB(A) to 20 dB(A), depending on wind conditions, etc. [See *Attachment I* for the Lincoln Township Moratorium Committee' Report]

A 1996 Danish report, *Social Assessment of Wind Power-Visual Effect and Noise from Windmills-Quantifying and Valuation*, contained a survey of 342 people living close to windplants. The accompanying survey found 13% of people in the area considered wind facilities a nuisance and would be willing to pay 982 DKK per year to have them leave. A survey of house sale prices showed a 16,200 DKK lower price near a single wind turbine and a 94,000 DKK lower price near windplants versus similar houses located in other areas.

In October, 2003, the Beacon Hill Institute, as part of a study of the proposed Cape Wind project in which hundreds of 430 foot turbines are to be located five miles off shore from Cape Cod in Nantucket Sound, contacted 45 real estate professionals operating in towns around the Sound, asking them about the anticipated effects of the wind power project on property values. Forty-nine percent of these realtors expected property values within the region to fall if the Cape Wind power plant was erected. [Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, pp. 16-17]

The BHI study also surveyed 501 home owners in the six towns that would be most affected by the Cape Wind project . Sixty-eight percent of these said that the turbines would worsen the view over Nantucket Sound 'slightly' or 'a lot'.[BHI study, page 14] On average, they believed that Cape Wind would reduce property values by 4.0%. Those
with waterfront property believed that it would lose 10.9% of its value. The study
concluded that, based on the loss of property value expected by home owners, the total
loss in property values resulting from the construction of Cape Wind would be $1.35
billion, a sum substantially larger than the approximately $800 million cost of the project itself.[BHI study, page 4]

As the study noted, any reduction in property values would, in turn, lead to a fall in
property tax collections in the affected towns; the drop in these tax collections would be
$8 million annually. If the tax rates were raised to maintain revenue, this would shift
some of the property tax burden off waterfront residents (whose property values would
fall the most) and on to the (less affluent) island residents.[BHI study, pages 4, 5]

In the home owner survey, in response to the statement: "It is important to protect an uninterrupted view of Nantucket Sound," 76% strongly agreed, 18% somewhat agreed, 3% were neutral, 2% somewhat disagreed, and 1% strongly disagreed.[BHI study, page 28] It's worth noting that of the home owners surveyed, 94% did *not* have homes with a view of the Sound; [BHI study, page 32] 76% were not members of a conservation or environmental organization.[BHI study, page 34]. Their main reasons for living in the area were the 'beauty of the region,' 'the beaches,' and 'the ocean views.'[BHI study, page 31].

Russell Bounds, one of Garrett County's leading realtors in large property transactions, has already lost sales in the area of proposed windplants (*Attachment D*). He has stated that huge industrial windplants "would be devastating not only to the real estate values in the Pleasant Valley viewshed, especially to neighboring properties, but would also negatively affect the entire county economy, since so much of that economy is tied up with tourism drawn by the county's natural views." (Personal communication, February 27, 2005.)

Attachment E, a DVD I made this past January documents life near large wind installations for residents in Meyersdale, Pennsylvania, as well as for residents along the outskirts of Berlin, a small town a few miles north of Meyersdale. The DVD features interviews with three people--Todd Hutzell (738 Main Street, Rockwood, Pa 15557), Rodger Hutzell (327 Ridge Road, Meyersdale, PA 15552), and Karen Ervin (561 Ridge Road), who all live nearly a mile from the 20-375 foot turbines Meyersdale Wind facility; with Helen Gallagher (343 Meyers Ave. Meyersdale, Pa 15552), who lives nearly three miles away; with Susan Wilson (2250 Juniper Lane, Rockwood, PA 15557); and with Russell Bounds, the aforementioned Garrett County realtor. It also shows views of the Meyersdale facility from various vantages, as well as views of the 340 foot tall Somerset Wind facility located in farm fields outside Berlin, with images of two properties there that were sold in 2002 for considerably less than market value.

According to witnesses and deed records, Somerset Wind LLC (incorporated in Delaware with offices in Texas-- an Enron spawn), in order to settle lawsuits brought by owners who felt that Somerset's wind turbines were disturbing the quiet enjoyment of their property, bought these properties near Berlin for fair market value—one in May, 2002 from Keith Sarver, 308 Beachley Hill Road, for $101,049, reselling it in August to Robert and Tomalee Will, (who had leased their land to the wind company in the first place) for $20,000—*20 percent of the previous sale price!* The other property was owned by David Sass, 322 Beachley Hill Road. In May, 2002, Somerset Wind purchased the Sass property for $104,447, selling it in August to Jeffrey Ream, for $65,000—*62 percent less than the purchase price!* The new owners, moreover, signed a "memorandum of non-disturbance easement agreement," which absolves the wind company from liability for what the owners might regard as wind turbine-caused nuisances such as "noise, lights, air movement, odor, dust, vibration, traffic, obstruction of view, [and] light or air currents."

Both the Meyersdale windplant site and the project area proposed by Synergics involve a forested prominent ridgetop; both sites have similar ridge shape, orientation and elevation differences to east and west sides; both sites have Class 3-5 wind; both sites have residences located within a mile of the ridgetop. In addition, the Meyersdale windplant installed 20 1.5 MW wind turbines manufactured by NEG Micon, which involve 72-m rotor diameters and have the nacelle mounted on an 80-m hub height; whereas Synergics plans to install 24 1.65 MW wind turbines with 80 m hub height and 82 m rotor diameter, and these may be built by the same manufacturer.

The burden of proof that problems at the proposed Roth Rock facility would not be similar to the Meyersdale windplant rests with the Applicant.

WINDPLANT NOISE

Tall wind turbines in concert with each other, especially those sited on prominent ridgetops, create profound, relentless noise reverberations extending out for more than a mile, sounding like "a boot tumbling in a dryer" or the revving of jet engines on a runway. A letter from Meyersdale resident Bob Larivee, who lives 3,000 feet from the windplant, documents how he measured the noise over a 48 hour period (*Attachment F*). The results "showed an average reading of about 75 decibels during that period." "According to the EPA, noise levels above 45dB(A) disturb sleep and most people cannot sleep above noise levels of 70 dB(A)."

The noise reproduced in *Life Under a Windplant* has not been altered in any way; Larivee's measurements give some context to the DVD's recorded noise. Noise from European windplants is a notorious and well-documented nuisance there. The wind industry is very aware of this problem but often tries to "hide" it by taking visitors by day directly under the turbines where there is typically little noise or by conducting tours from May-September when wind speeds are typically lower.

Turbine noise is so irritating and disconcerting that it often causes people to seek medical attention, as Roger Hutzell had to do. Wind leases typically contain "noise easements" to protect the company from liability. Somerset Wind insisted upon such conditions for those who leased their properties for wind turbines, e.g., such as those leases which Don and Jamye Paul and Richard and Barbara Holland signed, whose properties help comprise the windplant near Berlin.

A leading acoustical researcher of the noise problem, G.P. van den Berg of the University of Groningen in the Netherlands, believes loud aerodynamic sounds are generated when the moving propeller blade passes the turbine tower mast, creating sound pressure fluctuations. Such fluctuations may not be great from an individual turbine, but when several turbines operate "nearly synchronously, the pulses…may occur in phase," significantly magnifying the sound. Van den Berg also notes a "distinct audible difference between the night and daytime wind turbine sound at some distance [more than one mile] from the turbines"—a finding consistent with the experiences of Meyersdale residents. (Both quotes were taken from G.P. van den Berg, Effects of the Wind Profile at Night on Wind Turbine Sound; *Journal of Sound and Vibration* (November 2004) 277:955-970.)

The PSC and the DNR Power Plant team should insist upon acoustical field research to assess this noise phenomenon at the Meyersdale windplant, requiring independent measurements and interviewing nearby residents. The PSC and the DNR Power Plant experts should recognize the need to verify Synergics' claim that its windplant would average 45 dB. This "average" would not mean much if it were applied, say, to residents living next door to Merriweather Post Pavilion during a rock concert. And it will not mean much to the residents of Garrett County, either--who are used to the enjoyment of a quiet landscape.

OTHER NUISANCES ASSOCIATED WITH WINDPLANTS LIKE SYNERGICS'

The Applicant has admitted that *interference with television reception* may occur, stating that it was a problem relatively easy to fix—but did not say how or at whose expense. The following weblink contains a March, 2004 BBC report, "The Impact of Large Buildings and Structures (Including Wind Farms) on Terrestrial Television Reception" see: https://www.bbc.co.uk/reception/factsheets/docs/buildings.pdf. "Wind turbines affect reception up to a maximum distance of 5km" is one of the key sentences in the report.

Lightning and power surges. Wind turbines themselves may cause irregularities in the power supply as wind speed changes. Within the power grid, supply and demand must always be balanced; there is no storage of electricity on this scale. When the wind dies, there is less power (brown-out) until a plant using a more reliable resource powers up to increase production. When the wind gusts, there may be power surges. Residents living near the installation in Meyersdale, which came on-line in December 2003, have had to replace stove elements and small appliances due to power surges which started at that time. Residents of Lincoln Township, Wisconsin, near a wind installation noticed an increase in power surges associated with lightning strikes in their area after the turbines went on-line in June 1999. Two computers protected by surge protectors and a TV set, all in different houses, were simultaneously "fried" one evening when lightning struck a nearby wind turbine tower.

Shadow Flicker and Strobe Lighting. When turning with the sun behind them, turbine blades cast moving shadows across the landscape and into houses in ways that may affect surrounding properties at a considerable distance; these are commonly described as a strobe effect within houses that can be difficult to block out. "Some people lose their balance or become nauseated from seeing the movement. As with car or sea sickness, this is because the three organs of position perception (the inner ear, eyes, and stretch receptors in muscles and joints) are not agreeing with each other: the eyes say there is movement, while the ears and stretch receptors do not. People with a personal or family history of migraine, or migraine-associated phenomena such as car sickness or vertigo, are more susceptible to these effects. The strobe effect can also provoke seizures in people with epilepsy." (Nina Pierpont, PhD, MD in a personal conversation. Dr. Pierpont was formerly a clinical professor of pediatrics at Columbia, University and is now in private practice in Malone, New York).

Shoddy site construction practices can also cause serious erosion problems, especially if built along steep slopes.

NIMBYISM

One of the most persistent hypocrisies from corporate wind and its supporters is the accusation that locals who resist the industry are selfishly holding back progress—the NIMBY factor. However, many politicians who vote to enable industrial wind do so fully aware that windplants will be built in someone else's back yard, realizing they would not survive the political backlash if one were constructed in their own district. Wind investors-- and the politicians who enable them—live hundreds of miles away from the results of their handiwork. While there are many areas of good wind potential available, the industry focuses on rural, often economically depressed areas which don't have much money or political influence. In Maryland, for example, the Chesapeake Bay has the best overall wind potential (*Attachment G*).

Yet this particular wind developer, surely aware of the political repercussions, avoids areas like St. Michaels—his own backyard-- preferring instead to target Appalachia. He has publicly stated that the choice people will have about an improved environment is between his project in the hinterlands of Maryland and dirty coalplants. He does not demonstrate how this is a one-and-not-the-other situation, of course, while also neglecting to mention how much money he expects his company will earn or, conversely, how much it might lose if his application is denied. The sanctimonious concern for environmental improvement, which will not obtain with this windplant, obscures the evident desire for profit.

As I have shown, there are many legitimate reasons for locals to be concerned about the effects of a massive windplant in their neighborhood.

TAXPAYER/RATEPAYER SUBSIDIES FOR THE WIND INDUSTRY

In *Life Under a Windplant*, Karen Ervin of Meyersdale continually asks, "Who Benefits?" from the massive windplant around her town. Not her and not her town.

On a per kilowatt hour basis, wind is among the most heavily subsidized sources of industrialized power in the nation. In response to a long term and very sophisticated lobbying effort, Congress has re-authorized substantial subsidies to wind development, including an accelerated double declining capital depreciation schedule and extraordinary investment and production tax avoidance shelters. Taxpayers must underwrite losses to the public treasury to support these subsidies, while the state's electricity consumers are likely to pay more in their utility bills, since Maryland and sixteen other states have passed renewable portfolio standards requiring each state to purchase a percentage of its electricity from renewable power sources. In Maryland it's 7.5 percent. The Maryland Public Interest Research Group (MaryPIRG) estimates that the wind industry will generate nearly seventy percent of this targeted goal. In effect, this legislation obligates utility companies doing business in the state to purchase much of that electricity from the wind and hydro-electric industries -- both of which cause environmental destruction.

Such government support will provide a stable, predictable, fairly long term investment scheme—all perfectly legal—to minimize risk. What companies like Synergics require to make the strategy work is a lot of land. If that commodity is brought on line, any other risks to the company would doubtless be handled through insurance. Insurance is available to wind energy companies to protect them even if their turbines supply insufficient power to meet contractual obligations.

One should not mind a company making money in this way, provided it delivers on what it promises. But since the promises Synergics makes are for meaningfully cleaner air, less pollution, less reliance on foreign oil, the company simply cannot deliver on them. Its pretentious environmentalism and sanctimonious concern for the public health too often diverts attention from the *business* of wind energy.

How much money is involved? Let's examine three of the financial mechanisms wind developers such as Synergics can use to artificially enhance their bottom line and shelter income by avoiding usual corporate tax obligations—(1) the federal five year double declining accelerated capital depreciation schedule; (2) the federal production tax credits, good for ten years, at a current rate of 1.8 cents per kW hour produced; and (3) the state's Renewable Portfolio Standards.

1. Assuming that the assessed capital cost of Synergics' 24 turbine plant will be $40 million, the company can depreciate its capital value as follows: $8 million in the first year (20%); $12.8 million in the second year (32%); $7.68 million in the third year (19.2%); $4.608 million each in the fourth and fifth years (11.52 percent); and $2.304 million in the sixth year (5.76 percent). This front-loaded depreciation schedule has enormous tax sheltering advantages, especially to wealthy corporations in search of one. And if Synergics sells its facility to another company after the accelerated depreciation allowance had been used, the new owner would also be able to put these generous depreciation benefits to work as well. The incentive here to "trade back and forth" is enormous. Who guards consumers against this kind of caprice?

2. Federal production tax credits remain front and center for wind developers and their investors, today giving the industry tax credits worth 1.8 cents for each kilowatt hour it produces. If Synergics' 40 MW windplant should produce about one hundred million KW hours annually (each 1.65 MW turbine would yield about four million KW hours a year assuming a 30% capacity factor, it would generate about $18 million in tax credits over the ten year period allowed by the production tax legislation. Since this windplant would power about 9000 homes a year, the total subsidy, underwritten by taxpayers, would be about $2,000 for each household powered! Of course, if Synergics' windplant, if built, actually realizes a 38 percent capacity factor, these numbers would be modified accordingly.

3. Maryland's RPS law virtually guarantees wind companies doing business in the state a non-competitive customer, and will create an artificial demand for thousands of massive wind turbines in the region. Of the various "renewable sources" of power, the only practical industrial source of renewable energy in the foreseeable future is wind, principally because hydroelectric energy is not going to expand in the state. Landfill gas is relatively limited in quantity and availability. The cost of electricity produced by wind is regulated by "market forces" outside the regulatory authority of the PSC - within fairly generous bounds set by the RPS standards. One of the issues I intend to press in this hearing is the cost of wind-generated electricity to utilities because of this lack of competition.

No one knows the true long term costs per KWh of electricity from today's wind turbines. All claims about these costs are based on untested assumptions, particularly because there has not been enough long term experience with today's large wind machines to know:

- How long they will last (i.e., their useful lifetime)?
- How much electricity they will produce (i.e., capacity factor)?
- How much their performance will deteriorate over time?
- What their maintenance, repair and replacement costs will be as facilities age?

Yet, all of these factors must be known to make a valid claim about the actual costs of electricity from wind turbines. In fact, none of the turbines now being installed (especially 1.65 MW turbines) have been in operation long enough to provide actual data.

Synergics is assuming that its turbines will last 20 years and that its capacity factor is accurate for the targeted site, which would yield a particular "overnight" kilowatt hour capital cost. If, however, its turbines last only 10 years (or were abandoned after 10 years because all the tax benefits had been captured, performance had deteriorated, or maintenance costs became prohibitive), the overnight capital cost would be twice as much. This simple example deals only with the useful life of a wind turbine. It ignores all the other factors that would actually have to be taken into account, such as cost of capital;

maintenance, repair and replacement costs; cost of other equipment and facilities such as substation, transmission, control and data acquisition, and more. Also, if the capacity factor did not achieve 38% or if performance deteriorated over time (e.g., fouling of blades), calculations would yield even higher costs per kilowatt hour.

What all of this suggests is that Synergics will be hard pressed to stick with any firm notion of the higher cost it will likely charge to utilities, which in turn will surely pass those costs back to consumers. The European experience demonstrates that the cost of wind energy is significantly more than the cost of conventional power sources. The captive market in Maryland that wind now enjoys because of the Renewable Standards will also surely drive the price of wind energy up vis-à-vis electricity prices from conventional power plants.

Altogether, publicly funded tax avoidance schemes reimburse wind energy developers as much as two thirds of the capital cost of each $1.65 million wind turbine (presentation on December 15, 2004, by Ed Feo to the Renewable Energy Resources Committee of the American Bar Association), with many states creating incentives to cover on average an additional ten percent of these costs. Windplant owners can use these tax shelters, or sell them, or enter into "equity partnerships" with other companies—all to reduce their corporate tax obligations by tens of millions each year, as the Marriott Corporation did a few years ago with a similar clean energy scheme, within a year reducing its corporate tax obligations from 36 to 6 percent and a nearly $100 million reduction to the federal treasury (See "The Great Energy Scam: How a Plan to Cut Oil Imports Turned Into a Corporate Giveaway," Time Magazine, October 13, 2003).

The Florida Power and Light Group, the parent of FPL Energy, paid no income tax in 2002 and 2003, according to Citizens for Tax Justice (CTJ), despite having a profit of $2.2 billion during those years. The FPL Group made large investments in wind energy deployment during those years, and now claims to be the nation's leading wind energy producer.(Citizens for Tax Justice, "Bush Policies Drive Surge in Corporate Tax Freeloading: 82 Big U.S. Corporations Paid No Tax in One or More Bush Years," September 22, 2004). It is now the parent company of Meyersdale Wind and the Mountaineer Wind Energy Center, both of which have provided virtually no local taxes to date.

These costs to the Treasury, which are borne by average taxpayers and ratepayers, don't appear to be worth the meager benefits accruing to less than a handful of full time employees and to undisclosed, likely very meager amounts of annual lease payment to a very few property owners -- much less to reduce the tax obligations of corporations.

DECOMMISSIONING

Today, thousands of earlier, smaller, inactive turbines litter the landscape, abandoned after investors had secured their profits and tax subsidies. *Attachment H* is a copy of Paul Gipe's eight year old article about decommissioning wind turbines in California. Mr. Gipe is a nationally known advocate for responsible wind development. At that time, he wrote that the costs to remove the non-operating turbines still standing in California could exceed $100,000,000. It's important to note that many of these defunct turbines stand just 30 feet high; they are not the giants proposed or being built now.

Gipe reported that to remove just one 0.5-megawatt turbine in Bushland, Texas, the cost was $325,000 to restore the site to agricultural use. Restoration is important because, as Gipe points out, there are site reclamation responsibilities as well as turbine removal that should be addressed. By themselves, the concrete "pads" into which Synergics' turbines will be anchored will cost a lot of money to remove.

The Maryland Energy Administration, working with the PSC, has recently negotiated procedures on an *ad hoc* basis for decommissioning two windplants. While this is a good start, a number of problems remain. Agency staff should have investigated the matter in the way Gipe did, rather than relying upon the developers estimates of removal costs and salvage value.

The good news is that each of the two approved windplants in the state must establish an escrow account held by a third party. However, in the Clipper Windpower case, the bad news is that the escrow account will not be fully funded for 25 years. The negotiated estimate of the cost of decommissioning each turbine was $23,000 (the net cost—less salvage value)—only 1.5 percent of the construction costs. But without documentation of the salvage value, even this figure is questionable. Moreover, if those turbines remain inactive for one year, then the PSC requires them to be decommissioned. But the windplant owner may request an extension from the PSC. Finally, the negotiated agreements were silent about requiring public notice to property owners. As mentioned previously, these newer skyscraper-sized turbines provide little historic information about their useful life. If Synergics 1.65 MW turbines do indeed achieve a useful life of 30 years, as claimed, how can anyone estimate what the salvage value will be in 30 years?(See the Gipe article.)

Synergics has not disclosed any details of its lease/easement contracts with property owners. The PSC has supported other wind developers who have sought to abandon all their equipment to the property owners, compensating them with a bond worth a maximum of $2,000 and stating that the value of salvage will help the property owners recover the remaining portion of removal costs. But if the salvage is worth so much, why aren't the wind companies themselves cashing in? And what might happen if a property lessor, at the end of the contract term, wished to end the arrangement while the turbines were still in operation? Would any escrow account be then used to remove those turbines? Paul Gipe raises serious questions about the adequacy of the funding for turbine removal and site restoration heretofore sanctioned by the PSC.

The PSC should investigate this issue with much more rigor than it has. It should demand that any liabilities, such as abandoned equipment, be cleaned up by the Applicant or the responsible agent at the time of abandonment. The present situation is a game of "dodge ball," pretending that the company's liabilities will be mitigated but not really assigning any effective means to do so.

CONCLUSION

Throughout this commentary, I raise concerns about promises made and not fulfilled. In its proposal, Synergics promises:

- a 30 year turbine life;
- only .67 acre clearing per turbine;
- turbine efficiency at 38% of rated capacity;
- significantly increased local revenue;
- no property devaluation or viewshed degradation;
- no decommissioning cost to be borne by landowners or the public;
- "acceptable" nuisance levels (noise, shadow flicker);
- little or no adverse impact to wildlife;
- improved air quality due to its operation;
- improved public health due to its operation;
- decreased dependence upon foreign oil.

I believe the Applicant has failed to make the case for every one of these claims. However, the issue at hand is not necessarily what I believe; the real reason for concern is what will happen if the requested permit is approved and none or few of the claims are later realized? Who will monitor and report any failure? And to whom would those reports be delivered? Will any penalties accrue if these claims are not met? Who will be responsible to remedy a problem?

Wind companies are well aware of the problems their technology creates; it is very likely Synergics, as other wind energy developers have done, may acknowledge many of the problems it says are not by-products of their installation by including various exculpatory "nuisance" easements in its "confidential" turbine leases. People who may experience problems because of the windplant, including adjacent owners whose property may be degraded and devalued, will have to seek a remedy in the courts—at their time and expense. The PSC should do everything possible to avoid this circumstance. This project evidently is Synergics' first venture in windplant technology, and Garrett County should not suffer from a long learning curve.

Throughout, I have documented reasonable concerns and doubts about Synergics' project. It is incumbent on the Applicant to substantiate and validate the many claims he makes—and it is the duty of the PSC not to a issue a certificate of public "convenience and necessity" until it is *certain* the developer can deliver on all of them.

EPILOGUE

Our society has much the same dependence upon power from fossil fuel combustion as a three pack a day Marlboro smoker has with nicotine. Although each gets a "lift" from the experience, the mounting evidence for both demonstrates dire health and quality of life risks resulting from the behavior. Industrial windplants like Synergics are to the reduction of dependence on fossil fuels as the smoker who seeks to mitigate the dangers of smoking by switching to three daily packs of Marlboro Lites.

If the wind industry were fully deployed in the uplands of the Mid-Atlantic region, with thousands of windplants like the one Synergics is proposing, coalplants will still be puffing away despite all the gigantic wind turbines permeating the landscape and killing wildlife, destroying culturally significant viewsheds, devaluing nearby property, while creating major nuisances for proximate neighbors. And, because of the region's relentlessly increasing demand for electricity, likely resulting in the combustion of ever larger amounts of fossil fuels, the air quality will likely deteriorate, people would be getting sicker as a result--while paying more in rates and taxes. I submit this is not enlightened public policy.

The only humane short-range solution to the problems of global warming and air quality must combine effective conservation efforts with much higher efficiency standards-- heavy lifting indeed for the most wasteful culture in the history of the planet. The wind industry, as it targets huge powerplants along the uplands of our region, is a placebo solution to these problems, distracting from the necessary level of discourse—and political action-- for achieving genuinely functional responses.

Attachments:

A. Actual and Potential Regional Windplants

B. Garrett County Heritage Plan

C. Meyersdale, PA Turbine Construction

D. Russell Bounds' Letter

E. Life Under a Windplant DVD

F. Robert Larivee's Letter

G. Wind Potential in Maryland

H. Paul Gipe Report, Spring 1997

I. Lincoln Township Moratorium Committee Excerpt

MY BACKGROUND

As a life-long environmentalist, I know the dangers of heavy reliance upon fossil fuel combustion. A few years ago, I hoped windpower, since it does not directly emit greenhouse gases into the air, might fulfill its promise to reduce the region's coal mining and significantly improve air quality. But after an earlier PSC windplant application experience, where I focused primarily on wildlife concerns, I did more research, from which I gained much more context about the industry and its potential to displace fossil fuels in the production of electricity.

Nearly 30 years ago, I helped found the North American Bluebird Society to undo the damage resulting from well-meaning but ill-considered decisions made 100 years previously. During my lifetime, I have witnessed countless examples of this kind of damage. Seventy years ago, hydroelectric dams exemplified renewable, "clean" energy initiatives; today, they are known to be so environmentally destructive that many are being dismantled—at taxpayer expense. The indiscriminate use of DDT cost us dearly, although it did help in the fight against malaria; the encouraging effort to restore the Bald Eagle and Peregrine Falcon after the chemical's broad usage was banned has cost millions of public dollars. And now here we are with the swash and buckle of the windpower industry, with its often pretentious environmentalism.

My interest in birds and nature began in childhood, and I have nourished that interest with considerable reading and observation over many years. I know the avifauna of the targeted area as well as anyone, spending much time there in recent years studying the nesting behavior of, to give but one example, the state-endangered Mourning Warbler. Although my interest in birds is that of a passionate amateur, I nonetheless have written about the nesting cycle of the Golden-crowned Kinglet (finding the first kinglet nest in Maryland) as well as a number of other articles on the history and effectiveness of field guides. I also lecture on the subject of Garrett County birds, and often take groups of people around the countryside for intimate looks at the way birds make their living in various county habitats. I knew and corresponded with Roger Tory Peterson, the famed naturalist, and continue to be informed and inspired by perhaps this country's most renowned ornithologist, Chandler S. Robbins, who has studied migratory birds in the mountains of Maryland for nearly 60 years.

My work on this subject is a public service. My sole interest is enlightened public policy. Neither I nor any members of my family own property in the proposed viewshed of this project—and the facility would not be visible at our place of residence. Although I belong to Friends of Backbone Mountain, a Garrett County group of about 200 people dedicated to the protection of Backbone Mountain as a natural heritage resource, I accept no funding from any source on this wind issue. While I consult with members of Friends of Backbone Mountain, I am not bound by any directives from the organization. By profession, I am a painter, often using the forms of nature to inspire my work. In recent years, I've written extensively on the Dutch artist, Johannes Vermeer, although my PhD is in American history. This is the second windpower application I have reviewed.

From: "ARTHUR GIACALONE" <ajglaw@verizon.net>
To: "Anne" <wow@westelcom.com>
Sent: Wednesday, December 07, 2005 2:25 PM
Subject: RE: Proper citation of a paper you presented to the town of Clinton

Anne, I'm not certain what you're looking for. The document is known as The REPP Report, "The Effect of Wind Development on Local Property Values", and was published in May 2003. I don't have a clearer copy of the cover

Here's what I said about it in my 11/9/05 letter to the Clinton Town Board:

When evaluating the potential impact of wind turbines and related facilities on surrounding property values, the Town Board should, at a minimum, do the following:

- Look critically at the reports relied upon by wind energy proponents who claim that wind energy facilities do not have adverse impacts on property values. For example, the so-called "REPP report", a favorite of the wind industry, is deeply flawed. It claims to compare the sale price of homes within five miles of wind turbines, the purported "view shed", with the sale prices of homes in a comparable region, but homes are treated as being within the "view shed" whether or not they actually have a "view" of a turbine. While the REPP report recognizes the desirability of refining the view shed in order to look at the relationship between property values and the precise distance from development, it failed to take that step because, in its words, the project "lacked the resources to determine (through site visits, interviews, or other means) whether or not individual properties in the vicinity of the ten selected wind farms have a direct view of the wind turbines."

Communities that meet all five of the above criteria are selected for consideration as comparable communities. In addition to analysis of Census data, interviews with County Assessors, other local and state officials, and in some cases with knowledgeable real estate agents are taken into account in the selection of comparables.

E. Analysis

1. Literature Review

In selecting the type of analysis to use in determining whether there is any statistical evidence that wind farms negatively affect property values, we first conducted literature research to identify any studies previously conducted for this purpose. We found only four studies relating wind and property value effects, three of which are only qualitative.

A 1996 quantitative study, Social Assessment of Wind Power (Institute of Local Government Studies, Denmark), applied regression analysis to determine the effect of individual wind turbines, small wind turbine clusters, and larger wind parks on residential property values. The regression used the hedonic method, discussed in more detail below, in which site specific data on a number of quantitative and qualitative variables is used to predict housing values. The study concluded that homes close to a wind turbine or turbines ranged in value from DKK 16,200 to 94,000 [approximately $2,900 to $16,800] less than homes further away. The study had a number of weaknesses, including a lack of definition of the distance from turbines, lack of specification of the size and number of turbines, and regression on a very small data sample. In contrast, a 2002 qualitative study, Public Attitudes Towards Wind Power (Danish Wind Industry Association), quoted the 1996 Sydthy Study as concluding that residents closer than 500 meters to the nearest wind turbine tend to be more positive about wind turbines than residents further away.

A 2002 qualitative study, Social Economics and Tourism (Sinclair Knight Merz), said that for highly sought after properties along Salmon Beach, Australia closer than 250 meters from wind turbines, the general consensus among local real estate agents is that "property prices near the generators have stayed the same or increased after installation." However, the study concluded that while properties with wind turbines on them may increase in value, other properties may be adversely affected if within sight or audible distance of the wind turbines. Finally, the 2002 qualitative study, Economic Impacts of Wind Power in Kittitas County (ECO Northwest), concluded from interviews with assessors around the United States that there is no evidence of a negative impact on property values from wind farms. The weakness of the study is that it relies on subjective comments to arrive at its conclusions.

We also reviewed several studies that attempt to quantify the visual and property value impacts of electric transmission towers and lines. There is a large body of information on this subject, as transmission lines have been the subject of scrutiny and regulation for many years.

A 1992 study, The Effects of Overhead Transmission Lines on Property Values (C.A. Kroll and T. Priestley), reviews the methodology and conclusions of a number of studies on overhead transmission lines and property values over the 25 year period of 1967 through 1992. This study was very helpful in identifying the types of analyses and their strengths and weaknesses, which could be adapted for use in this REPP report. The study concluded that appraisal offices have the longest history of studying and evaluating line impacts, but lack in depth statistical analysis to verify obtained results. Data collected from face-to-face conversation and through surveys attempts to ascertain the attitudes and opinions of property owners to transmission equipment, but personal opinions were found to produce widely varying results. Statistical analysis of appraiser findings provided a better interpretation of appraiser information, but produced varying results due to different methodologies.

- Interviews with Industry Experts. A power industry analyst with extensive experience in quantitative analysis of visual impacts of transmission lines stated in an interview that a rule of thumb used for the zone of visual influence of installations such as transmission lines and large wind turbines is a distance of approximately five miles.

There are other possible definitions of the view shed. At present, new proposals are sometimes required to conduct a Zone of Visual Influence (ZVI) analysis to determine the extent of visibility of a development. The zone comprises a visual envelope within which it is possible to view the development, notwithstanding the presence of any intervening obstacles such as forests, buildings, and other objects. Digital terrain computer programs are used to calculate and plot the areas from which the wind farm can be seen on a reference grid that indicates how many turbines can be seen from a given point. One weakness of the standard ZVI analysis is that all turbines are given equal weight of visual impact. That is, a turbine 20 miles from the viewer is assigned the same visual impact as a turbine one mile away.

Possible definitions for view sheds include the set of real properties that have a view of one or more wind turbines from inside the residence, that have a view of one or more turbines from any point on the property, or that are simply within some defined distance from the wind turbines, whether there is a view from each property to the turbines or not. In the last case, it is assumed that property owners in the area will still be potentially affected by views of the wind farms, as they will see them while traveling and conducting business in their vicinity.

Because this project lacked the resources to determine (through site visits, interviews, or other means) whether or not individual properties in the vicinity of the ten selected wind farms have a direct view of the wind turbines, the view shed is defined as all properties within a given radius of the outermost wind turbines in a wind farm. The value of this radius will clearly affect the results of the analysis. If the radius is too large, including many properties not potentially affected will overshadow the potential effect of the presence of wind turbines on property values. If the radius is too small, not all potentially affected properties will be accounted for in the analysis, and the number of data points gathered may be too small to yield valid statistical results.

D. Comparable Criteria

With the view shed of the wind farm defined, a set of neighboring communities outside of the view shed is selected to evaluate trends in residential house sales prices without the potential effects of wind farms on property values. These townships and incorporated cities are required to be clearly outside of the view shed area and not containing any large wind turbines. This selection is the "comparable" region. To define the comparable REPP consulted with local County Assessors and analyzed 1990 and 2000 U.S. Census data for the townships and incorporated cities under consideration.

Criteria used in selection of comparable communities include economic, demographic, and geographic attributes and trends. The goal in selecting comparable communities is to have communities that are as similar as possible with respect to variables that might affect residential house values, with the exception of the presence or absence of wind farms. When possible, comparable communities are selected in the same county as the wind farm location. If this is not possible due to placement of wind farms or availability of suitable data, comparable communities are selected from counties immediately adjacent to the county containing the wind farm.

"Wind turbines don't make good neighbors"

Some Problems of Wind Power in the Berkshires

Researched and written by Eleanor Tillinghast, Green Berkshires, Inc , May 14, 2004

"Wind turbines don't make good neighbors."[1] So says John Zimmerman of Enxco, Inc.,[2] the company preparing to construct the 20-turbine Hoosac wind power plant in the towns of Florida and Monroe, in the northern part of Berkshire County, Massachusetts.

As has been demonstrated in other parts of the United States, and abroad, wind power plants can have significant negative impacts on visual aesthetics, tourism, property values, public roads, public safety, and quality of life for people living both close and at a distance from the developments The financial benefits accrue to the individuals who lease or sell land for the plants, and in some cases to the towns that permit the plants, but the problems permeate the surrounding communities The issue of whether or not we here in Berkshire County want wind power plants on our ridgelines is truly of regional concern.

Other than offshore siting,[3] the most suitable place for commercial-scale wind power plants in Massachusetts is here in the Berkshire and Taconic mountains of Berkshire County. That's because onshore coastal areas that have sufficient wind generally have dense populations which would be put at risk by proximity to massive wind turbines.[4] Otherwise, the strongest winds tend to be along the highest mountains, and those are out here.[5] Within New England, Massachusetts has a greater percentage of land suitable for wind power plants than any other state (CT 6%, ME 7%, MA 16%, NH 3%, RI 8%, VT 3%,) according to U.S. Department of Energy calculations.[6]

To achieve the renewable energy goals mandated by Massachusetts's 1997 electric utility restructuring act[7] will necessitate about 200 wind turbines installed along our ridgelines within the next five years -- and that number is predicated on the assumption that the 420-megawatt ["MW"] Cape Wind project planned for Nantucket Sound[8] will be operational by 2009.

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1 Robin Smith, "Wind Towers Spark Debate," *Caledonian-Record*, 7/1/03, http://www.CaledonianRecord.com/pages/local_news/story/c2296e810

2 Hill Engineers, Architects, Planners, Inc., *Special Permit Application for enXco Incorporated: Hoosac Wind Project, Florida / Monroe, Mass.*, 10/6/03, p. 1; http://www.enxco.com/east.html

3 http://www.SaveOurSound.org

4 Comments of Steven Weisman, Green Power Program Director, Renewable Energy Trust, Massachusetts Technology Collaborative, Community Wind Collaborative public meeting, North Adams, MA, 9/19/03.

5 http://TrueWind.TeamCamelot.com/ne/

6 http://www.epa.gov/region1/eco/energy/renewable_energy.html

7 Chapter 164 of the Acts of 1997, http://www.state.ma.us/legis/laws/seslaw97/sl970164.htm

8 Commonwealth of Massachusetts, Executive Office of Environmental Affairs, "Certificate of the Secretary of Environmental Affairs on the Environmental Notification Form," EOEA #12643, 4/22/02, p. 1; http://www.nationalwind.org/events/offshore/020925/presentations/Wickersham.pdf

As of that date, 4% of our state's energy sales must come from new construction of renewable energy sources.[9] The Massachusetts Technology Collaborative ["MTC"], deputized by the legislature to oversee this endeavor[10] has projected that meeting all the new capacity with wind power will require 908 MWs of new generation.[11] However, at a public meeting, the head of MTC's Renewable Energy Trust said that, in fact, he expects 80% of the new capacity required by 2009 will be from wind power,[12] or 726.4 MW. Subtracting Cape Wind's 420 MW means that 306.4 MW must be built additionally. If each wind turbine is 1.5 MW, the onshore standard today (and the size of the Hoosac turbines), that will mean 204 turbines. Using Hoosac as a prototype, with approximately 10 turbines per ridgeline, that will mean 20 mountains covered with turbines.

You may want to believe this can't happen, well, it is happening all across countrysides here and abroad. Seven proposals are under consideration in Vermont.[13] 17 projects have been proposed in a 50-mile area at the junction of Virginia, Pennsylvania, and Maryland.[14] 87 wind power plants have been erected in the United Kingdom, with 1,101 turbines, for a total of 712.4 MW of power,[15] the output of one large natural-gas plant.

If you wonder why we here in the Berkshires are suddenly seeing a spate of public meetings on the wonders of wind power, it's because an alliance of political, business, and environmental interests is focused on winning our county's support for this massive alteration of our landscape in the name of larger goals like reducing global warming, pollution, dependence on fossil fuels, and energy consumption that, while worthy, will not be ameliorated one whit by the construction of these turbines on our mountains.

The need for Berkshire County residents to understand the impetus behind this new focus on wind power is all the more urgent since Secretary of Environmental Affairs Ellen Roy Herzfelder is preparing to open public lands for wind power development.[16] Furthermore, she has already demonstrated with her certificates on the Hoosac, Brodie, and Princeton wind power projects that she will not demand substantive pre-construction environmental

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[9] Enxco, Inc., *Hoosac Wind Power News*, Volume 1, Number 2, February 2003, p. 1, http://www.HoosacWind.com/newsletter2.pdf; Massachusetts Incentives for Renewable Energy, Renewable Portfolio Standard: http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=MA05R&state=MA&CurrentPageID=1

[10] http://www.mtpc.org/RenewableEnergy/faq.htm

[11] http://www.mtpc.org/RenewableEnergy/green_power/rps_scenarios.pdf

[12] Comments of Rob Pratt, Director, Renewable Energy Trust, Massachusetts Technology Collaborative, Community Wind Collaborative public meeting, North Adams, MA, 9/19/03.

[13] Robin Palmer, "Wrestling with the wind," *Barre Montpelier Times Argus*, 12/12/03, http://www.timesargus.com/Archive/Articles/Article/75908

[14] Map produced by D. Dan Boone, March 2003.

[15] http://www.bwea.org

[16] Commonwealth of Massachusetts, Executive Office of Environmental Affairs, "Certificate of the Secretary of Environmental Affairs on the Environmental Notification Form," Princeton Wind Farm Infrastructure Improvements, EOEA #13229, 4/23/04, p. 7. http://www.state.ma.us/envir/mepa/pdffiles/certificates/13229pdfversion.pdf

reviews.[17] Her boss and the governor's top aide, Chief of Commonwealth Development Douglas Foy, has made removing barriers to development of renewable energy facilities one of his priorities.[18] State Representative Dan Bosley and State Senator Andy Nuciforo have signaled their strong support for wind power.[19] Some of the most powerful corporations in the world, including General Electric,[20] are lining up to benefit from the massive subsidies, incentives, and tax breaks being offered at the state and federal levels.[21] The former director of the Massachusetts Environmental Policy Act ["MEPA"] office is a consultant to Enxco.[22] And Enxco's finance director is on the advisory Green Power Working Group of the MTC,[23] which is financing so much of this development thanks to monthly surcharges on our electric bills.[24] Environmental groups frustrated by years of disappointment in their efforts to reduce the impacts of energy consumption, see the advent of wind power plants as a tangible sign that we are finally willing to take responsibility for our toll on the environment, and they are pushing hard for wind power development.[25] The consequence of all these factors is that events are rushing faster than the education of many people who wish to protect our environment but haven't gotten much information from all sides of the issue.

In this paper, I want to focus on just a few wind power problems of special concern to

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[17] Commonwealth of Massachusetts, Executive Office of Environmental Affairs, "Certificate of the Secretary of Environmental Affairs on the Environmental Notification Form," Hoosac Wind Project, EOEA #13143, 12/26/03, http://www.state.ma.us/envir/mepa/downloads/13143enfpdfversion.pdf, Commonwealth of Massachusetts, Executive Office of Environmental Affairs, "Certificate of the Secretary of Environmental Affairs on the Notice of Project Change," Berkshire Wind Power Project, EOEA #12532; Commonwealth of Massachusetts, Executive Office of Environmental Affairs, "Certificate of the Secretary of Environmental Affairs on the Environmental Notification Form," Princeton Wind Farm Infrastructure Improvements, EOEA #13229, http://www.state.ma.us/envir/mepa/pdffiles/certificates/13229pdfversion.pdf

[18] Press Release, "Romney Unveils Climate Protection Plan for Massachusetts," Commonwealth of Massachusetts, Executive Department, 5/6/04, http://www.mass.gov/portal/govPR.jsp?gov_pr=gov_pr_040506_climate_action_plan.xml; Press Release, "Massachusetts Electric Offers Customers New Green Energy Program," National Grid, 9/16/03, http://www.nationalgridus.com/aboutus/newsreleases/2003_09_16a.asp; "Key Committee Approves Renewable Energy Bill – CLF Expresses Strong Support," 4/22/03, http://www.clf.org/hot/20030422.htm; David Mehegan, "The evolution of Doug Foy," *Boston Globe*, 3/25/01, http://www.clf.org/hot/evolution_of_doug_foy.htm

[19] Susan Bush, "Legislature approves petition to boost enXco wind project," *Berkshire Eagle*, 12/14/03, http://www.BerkshireEagle.com

[20] "General Electric, Warren Buffett, Farmers Invest in Wind Power," *Bloomberg News*, 2/27/04, http://quote.bloomberg.com/apps/news?pid=nifea&&sid=akd3Ltss8Xvbk; "Welsh wind power project moves ahead," *SolarAccess.com*, 4/29/04, http://www.solaraccess.com/news/story?storyid=6627

[21] Dave Wilson, "Shell buys the wind in Wyoming," *The Engineer*, 7/12/01, http://www.e4engineering.com/story.aspx?uid=cc529e49-41bc-4987-9b5d-e6c075b27664; Don Hendershot, "Is wind the future for WNC?" *Smoky Mountain News*, 7/9/03, http://www.smokymountainnews.com/issues/07_03/07_09_03/out_wind_future.html, "SIIF Energies Takes Over American Enxco," *European Report*, 6/5/02.

[22] Email from Jay Wickersham, Noble & Wickersham LLP, to Arthur Pugsley, MEPA, Subject: Air emissions avoidance estimates for Hoosac Wind project, Friday, December 19, 2003 2:41 PM.

[23] Massachusetts Technology Collaborative, *Harnessing the Power of Innovation: Annual Report Fiscal Year 2003*, p. 18, http://www.mtpc.org/NewsandReports/annual_2003.pdf

[24] http://www.mtpc.org/RenewableEnergy/faq.htm

[25] http://www.ceronline.org; http://www.clf.org

Berkshire County In order to avoid misrepresenting information, I've paraphrased or lifted language directly from research sources, almost all of which were found through internet searches. Rather than clutter the page with quote marks, I've footnoted every statement, with hyperlinks to the sources whenever possible.

1. Visual Aesthetics

A year from now, the third highest point in all of Massachusetts will be turbine #16 of the Hoosac wind power plant, with a blade tip height of 3,175' above sea level. Only Greylock (3,491') and Saddle Ball (3,238') of the Taconic Mountains will be taller.

It will be one of nine wind turbines covering the tallest of the Berkshire Hills,[26] Crum Hill.

Overall, at their full extension, seven Hoosac turbines will be among the 10 highest points in the state. Sixteen will be among the top 20. Eleven will be above 3,000'. Only three mountains in all of Massachusetts are taller than 3,000' (Fitch at 3,110' is the third mountain, also in the Taconics, and north of Greylock and Saddle Ball.)

Here are the ground elevations of the turbine locations, as shown in the plans accompanying the Environmental Notification Form for Hoosac, filed with MEPA by Enxco.[27] Full heights with the addition of the 340' turbines are also shown:

Bakke Mountain			**Crum Hill**		
Turbines	Elevations	w/340' turbines	Turbines	Elevations	w/340' turbines
1	2,568	2,908	**12**	2,748	**3,088**
2	2,609	2,949	**13**	2,829	**3,169**
3	2,666	**3,006**	**14**	2,772	**3,112**
4	2,758	**3,098**	**15**	2,809	**3,149**
5	2,751	**3,091**	**16**	2,835	**3,175**
6	2,696	**3,036**	**17**	2,805	**3,145**
7	2,662	**3,002**	**18**	2,574	2,914
8	2,644	2,984	**19**	2,539	2,879
9	2,610	2,950	**20**	2,559	2,899
10	2,574	2,914			
11	2,530	2,870			

To give you a sense of the extent to which these turbines will be visible to their immediate surroundings, consider this list of the tallest peaks in each of the neighboring state forests, based on the *DeLorme Massachusetts Atlas & Gazetteer*:

- Monroe State Forest - Spruce Mountain - 2,730'

[26] Raymo, Chet, and Maureen E. Raymo. *Written in Stone: A Geological History of the Northeastern United States*. Hensonville NY: Black Dome Press Corp., 1989, 2001, p. 63.
[27] Enxco, Inc., *Environmental Notification Form*, EOEA #13145.

- Savoy Mountain State Forest - Spruce Hill - 2,566'; Borden Mountain - 2,515'
- Mohawk Trail State Forest - Hawks Mountain - 1,880'

Nearby Whitcomb Summit, the highest point on Route 2, is 2,240'.[28]

Once the wind power plant is built on Brodie Mountain,[29] and if Mark D. Smith with Michael A. Deep and Williams College go forward with plants in North Adams[30] and along the New York border,[31] respectively, visitors to the top of Mount Greylock Veterans War Memorial Tower will be partially encircled by miles of 340' turbines and perpetually flashing lights to the southwest, northwest, and northeast. And now the town of Lenox is considering installing one or two turbines along its major escarpment,[32] affecting views of people in parts of Richmond, Lenox, and Pittsfield.

From how far will all these turbines be visible? Enxco has tried to show that the Hoosac wind turbines will be relatively unobtrusive. However, in an interview with a reporter about an Enxco proposal in Vermont, Mr. Zimmerman was more candid about the towers' visibility. "Any place we are looking to be in, you can see from a long way away. There's no real hiding them."[33]

On a webpage of photos of the 1.5 MW[34] wind turbines in Montfort, Wisconsin, the photographer wrote: "Impressive or overbearing? When I was there, the latter predominated…As I drove into the area, these gangly Wisconsin towers dominated the horizon from more than six miles away."[35] A reporter noted simply that the Montfort Wind Farm "is visible for miles on the south side of U.S. Highway 18."[36] A contributor to an email thread on www.Backpacker.com described the effect more loquaciously: "There's a single row of such really tall and HUGE towers sitting along Highway 18 around the vicinity of Cobb, WI…maybe 45 minutes west of Madison. You see them from far away, lights and all. They are enormous, dwarfing silos and anything else near them. They stretch for two miles; I've clocked it."[37]

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[28] http://www.mohawktrail.com/html/body_florida.html
[29] Press Release, "MTC Announces $32 Million for Five New Clean Energy Projects," Massachusetts Technology Collaborative, 11/13/03, http://www.mtpc.org/NewsandReports/press/pr_11_13_03_MGPP.htm
[30] Karen Gardner, "Planning Board delays approval for test tower," *North Adams Transcript*, 2/10/04, http://www.TheTranscript.com
[31] Jon Wiener, "Williams group studying N.Y. site for wind turbines," *Berkshire Eagle*, 10/1/02, corrected 10/2/02, http://www.BerkshireEagle.com
[32] "Lenox to host public meeting on wind power in Berkshires," *Berkshire Eagle*, 4/18/04, http://www.BerkshireEagle.com
[33] Robin Smith, "Wind Towers Spark Debate," *Caledonian-Record*, 7/1/03, http://www.CaledonianRecord.com/pages/local_news/story/c2296c810
[34] http://www.awea.org/projects/wisconsin.html
[35] Montfort, Wisconsin Wind Turbines, http://www.WorksAndWords.com/wind01.htm
[36] Don Behm, "Wind farm dispute creates turbulence," *Milwaukee Journal Sentinel*, 11/22/01, http://www.jsonline.com/news/ozwash/nov01/wind23112201a.asp
[37] lizs 01:34:59 PM 08/08/02, http://www.thebackpacker.com/trailtalk/thread/15592,-1.php

According to a brochure about the 1.5 MW[38] wind turbines in Fenner, New York: "The windmills of Fenner can be seen from the north shore of Oneida Lake, from vantage points in Onondaga County and from portions of the towns of Cazenovia, Lenox, Smithfield, Sullivan, Nelson and Madison. Their gigantic blades can be seen from as far away as Lowville in Lewis County, about 25 miles southeast of Watertown."[39]

The facilities of Montfort WI and Fenner NY are on relatively flat open land. The permitting handbook of the National Wind Coordinating Committee ["NWCC"], an industry collaborative, notes: "Where wind turbines are arrayed along ridgelines to capture wind flows over the ridges, the units are visible over greater distances."[40]

The Appalachian Trail Conference ["ATC"] has been opposing a wind power project in Maine that would entail an extensive line of wind turbines in direct view of one of the Trail's most scenic sections in the western part of that state. This is the ATC's description of the visual impact:

> The towers—as high as a 40-story building—would be visible for about four days of hiking on the Trail between Saddleback and the Bigelow Preserve. They would appear to crawl across the ranges by day as the blades whirled and to be like little lightning strokes at night, as their strobe beacons alerted airplanes to their presence, destroying any illusion of remoteness.[41]

In the Berkshires, parts of the Appalachian Trail, Taconic Crest Trail, and the Mohawk Trail will be exposed to the sight of the Hoosac and Brodie wind power plants – as well as the two proposed by Messrs. Deep and Smith and Williams College, if those are built. In addition, there are numerous other trails, high points, and scenic overlooks throughout the Berkshires from which the 34-story turbines and lights will be visible.

Enxco has tried to argue that the Federal Aviation Administration ["FAA"] might permit it to reduce the number of lights on the turbines. That seems unlikely. The FAA requires lighting on all structures taller than 200 feet.[42] Two airports are nearby, in North Adams and Pittsfield, both of which about to be expanded, and an airport in Albany is not much farther away. These turbines will be among the highest points in the region. As Enxco acknowledged in its 10/6/03 special permit application to the towns of Florida and Monroe, the assumption should be that there will be two white simultaneously flashing L-

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[38] http://www.awea.org/projects/newyork.html

[39] Carl Stone. "Winds of Change." *Fenner Windmills Brochure*, http://MadisonCounty.org/PressRelease/Windmills.htm

[40] National Wind Coordinating Committee, Siting Subcommittee. *Permitting of Wind Energy Facilities: A Handbook, Revised 2002*. August 2002, p. 28. http://www.NationalWind.org/pubs/permit/permitting2002.pdf

[41] Appalachian Trail Conference. "ATC Opposes Maine Wind Farm Project." http://www.AppalachianTrail.org/protect/issues/redington.html

[42] Berkshire Regional Planning Commission. *Permitting Wind Energy Facilities*, Berkshire Planning Tools. November 2003. p. 1.

865 lights during the day and two red simultaneously flashing L-864 lights during the night on each of the 20 turbines.[43]

This reality is reinforced by the comments made at a wind power siting workshop of the NWCC. A spokesperson for a Madison, New York wind power plant noted that the strobe system in place there is, unfortunately, very noticeable and commented that the FAA is fairly inflexible on its requirements.[44]

Enxco often points to the apparent local acceptance of the facility in Searsburg, Vermont,[45] the only commercial-scale wind power plant in New England, as an example of what to expect once Hoosac is constructed. However, the Searsburg turbines are shorter than 200', and so are not lit. [46]

Near wind power plants with turbines taller than 200', the effects, particularly at night, are a cause of persistent distress to neighbors.

Around wind turbines in Kewaunee County, Wisconsin, "some people complain that turbines…ruin the night sky with their flashing red lights," according to one newspaper article.[47] Arlin Monfils, a town official there, described "flashing red lights (FAA) interfering with nearby homes."[48]

In a recent letter to the *Berkshire Eagle*, Lou Orchek, a town official near the Waymart wind power plant in Pennsylvania, complained about "the multitude of red blinking aircraft warning lights that now trace across the ridge top at night."[49]

As far as I know, the only place in Massachusetts with 34-story buildings is Boston. Imagine structures of that height along our ridgelines. Think about the visual impact of even a few towers on our landscape, and on tourists driving around the Berkshires, and seeking out our trails and summits for a wilderness experience.

2. Tourism

Tourism is a $250 million industry in Berkshire County, with some 2,250,000 visitors annually supporting about 11,000 jobs in cultural organizations and ancillary businesses,

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[43] Hill Engineers, Architects, Planners, Inc. *Special Permit Application for enXco Incorporated: Hoosac Wind Project, Florida / Monroe, Mass.*, 10/6/03, p. 9.

[44] National Wind Coordinating Committee, "New England Wind Power Siting Workshop," Boston, MA, 10/24/01, p. 10, http://www.NationalWind.org/events/regional/newengland/summary.pdf

[45] Steve Blake, "Public discussion begins on Lowell wind project," *The Chronicle*, 9/24/03, http://www.LowellWind.com/images/photos/lowell/Chronicle_092403.pdf

[46] Robin Palmer, "Blowin' in the wind," *Barre Montpelier Times Argus*, 11/30/02, http://TimesArgus.nybor.com/Leisure/SunMag/Story/56949.html

[47] Associated Press, "Wind turbines draw complaints from some nearby neighbors," *Beloit Daily News*, 9/27/99, http://www.BeloitDailyNews.com/999/3wis27.htm

[48] Letter from Arlin Monfils, Chairperson, Town of Lincoln, Kewaunee County, Wisconsin, 2/1/00.

[49] Lou Orchek, "Wind farms have many drawbacks," *Berkshire Eagle*, 3/11/04, http://www.BerkshireEagle.com

and paying $13 million in state taxes and $6.6 million in local taxes.[30] It is our primary economic generator,[31] and it shapes every aspect of our region.

In his comments at the 3/30/04 Regional Issues Committee meeting of the Berkshire Regional Planning Commission ["BRPC"], Bill Wilson of the Berkshire Visitors Bureau was clear about his opinion on whether or not wind turbines would attract visitors. I'm paraphrasing his comments here, based on my notes. He said his organization has done extensive studies of the Berkshire tourist, and has 20 years of experience. While there will always be someone willing to drive 150 miles to see a ball of twine, windmills will not put 'heads in beds.' The Berkshire type of tourist will not come here to see turbines.

The Bureau's extensive research shows that visitors to this area are looking for a premium cultural experience in a pastoral setting, such as is found nowhere else in America. The reason people come here is not to see industrial installations but for the scenic, rural, pastoral environment. Their sense of country is going back to a simpler time, a gentler time

At one point, a BRPC staffer suggested that if tourists are already here, maybe they'll do a day trip to the town of Florida to see the Hoosac turbines. Mr. Wilson interjected "that's not supported by the research we've done."

He emphasized that anything degrading the pastoral experience risks the $250 million tourism industry. He was clear that we cannot risk jeopardizing that essential component. Highly visible vistas shouldn't be damaged. Wind turbines will not be a major tourist attraction, period, he declared. There is no way, he said, that he will be convinced that wind turbines will be a tourist draw.[32]

Mr. Wilson's assessment is supported by tourism directors and studies done in places around the world with comparable scenic qualities and tourism-based economies

In May of 2002, Scotland's National Tourism Board announced that it would conduct a survey of visitors to determine their attitudes toward wind farms in scenic areas. In response, the head of communications for the British Wind Energy Association -- which promotes the use of wind energy -- said: "We welcome this research, and we are looking forward to its findings. I should be very surprised if the research showed that windfarms are detrimental to tourism."[33]

In November of 2002, the study was released. 80% of the visitors surveyed said they went to Scotland for the beautiful scenery 95% said they valued the chance to see unspoiled nature. 58% agreed that wind-power sites spoiled the look of the countryside

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[30] Editorial. "The industry of the future." *Berkshire Eagle*, 4/19/04. http://www.BerkshireEagle.com
[31] Karen Gardner. "Shift in tourism benefits county." *North Adams Transcript*, 4/10/03. www.TheTranscript.com
[32] Berkshire Regional Planning Commission. Regional Issues Committee public meeting, 3/30/04.
[33] Murdo MacLeod, "Research examines the wind of change." *The Scotsman*, 5/12/02. http://news.scotsman.com/topics.cfm?tid=605&id=514782002

28% said they would avoid parts of the countryside with wind developments.[54] Tourism is Scotland's second largest income generator after agriculture.[55]

Cameron McNeish, president of Scotland's Ramblers Association, said more recently, "It seems that Scottish tourism and the Scottish landscape are being sacrificed to create more electricity for the big power users in the south of England. People come here because of the landscape quality of Scotland, because it's the last remaining wilderness on the edge of Europe and that would be very much threatened if all these proposals go ahead."[56]

In Australia, commenting about the Bay of Islands, an area that attracts more than 2.6 million overnight visitors and 130,000 international visitors annually, Adam Ruggero, Shipwreck Tourism Coast manager, noted that *Conde Nast Traveler* magazine had rated the coast's Great Ocean Road number one of its top 20 journeys of a lifetime. "The visitors come to see the pristine coastline and a windfarm would detract from that," he declared. "We support green energy without it detracting from the natural environment but we feel this would," he added.[57]

Roger Grant, chairman of Great Ocean Road Marketing, was similarly emphatic: "Wind farm promoters say they are a tourist attraction in themselves, which is nonsense…International tourists want to see our natural beauty, not wind turbine pylons."[58] He elaborated: "Certainly we know research tells us the reason people come to this part of the world is because of our natural attractions. When you start reducing our capacity to present natural attractions though the introduction of wind farms or industrial infrastructure...it's going to have a significant effect on the local economy. It should be rejected by the community, it should be rejected by the Government as inappropriate."[59]

Randall Bell, chairman of Australia's National Trust, has also been scathing about effects of the wind energy industry. He said wind turbines would deter tourists who come to Australia to experience 'reef, rock and road' - the Great Ocean Road. "It's going to absolutely crucify the greatest asset in the country. We are very emphatic in saying this is a no-go zone for this type of industrial activity."[60]

In Northern Ireland, plans for an offshore wind power plant along the north coast received a cool reception from the manager of the regional tourism organization, who

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[54] Jeremy Watson, "Tourists blow ill wind on renewable energy," *The Scotsman*, 11/17/02. http://news.scotsman.com/topics.cfm?tid=605&id=1278652002

[55] Paul Miles, "Giant wind farm will keep tourists away, warn Scots operators," *Daily Telegraph*, 10/12/02, http://www.telegraph.co.uk/travel/main.jhtml?xml=/travel/2002/10/12/etnewswind12.xml

[56] Vidal, John, "An ill wind?" *The Guardian*, 5/7/04, http://www.guardian.co.uk/renewable/Story/0,2763,1211314,00.html

[57] Jaclyn Densley, "Windfarms slammed by tourist head," *Warrnambool Standard*, 2/4/03. http://www.hotkey.net.au/~rayw1/pages/npa-standard.html#04-02-03

[58] Geoff Strong, "Wind farm plan creates anger," *The Age*, 4/22/03, http://www.theage.com.au/articles/2003/04/21/1050777312046.html

[59] Krista Hamblin, "Ocean road tourism under threat: Grant," *Warrnambool Standard*, 4/21/03. http://www.hotkey.net.au/~rayw1/pages/npa-standard.html#21-04-03d

[60] Krista Hamblin, "Windfarm deterrent," *Warrnambool Standard*, 4/10/03, http://www.hotkey.net.au/~rayw1/pages/npa-standard.html#10-04-03

said research has shown the outstanding natural beauty of the area is the prime draw for visitors. "Any development, not just this proposal for a wind farm, which poses a threat on the environment would give us some concern," said Don Wilmot, who manages the Causeway Coast and Glens Regional Tourism Organisation. He explained: "Tourism is a major earner for the region and generates some £100 million of revenue. Anything that would impact on us would give us serious cause for concern."[61]

Protesting plans for a wind power plant in Cumbria, England, John Hatt Firbank wrote a letter to the *Westmorland Gazette* last fall, drawing on his ten years as Travel Editor for *Harpers & Queen*, and visits to 92 countries. Here is an excerpt:

> Having been in the travel business, I can also warn of long-term damage to tourism, which is hugely important to Britain, and most especially to Cumbria. Tourism is the largest business in the world, and it is often the most crucial source of revenue for many rural areas.
>
> Nevertheless, as a travel writer I have learned that visitors will travel a long distance only for landscapes that are unique. The Cumbrian landscape is still unique (I can always recognise its subtle and individual beauty in any photograph, even if not captioned); but this uniqueness, and the indefinable magic that draws visitors, would be catastrophically diminished by the turbines.
>
> I must also emphasise a more general point. Not one square-mile of new countryside is being created. Instead, it is being steadily diminished by urban incursions and clutter, including satellite masts, new roads, and windfarms ..Once a bit of countryside is gone, it is gone forever.[62]

His stance was seconded by businesses warning the Lake District National Park Authority that the proposed wind power plant would have a "terrible impact" on tourism and the local economy.[63] As a result, the Authority agreed to lodge an objection to the scheme.[64] Eric Robson, chairman of the Cumbria Tourist Board has also been outspoken about his opposition to wind power plants.[65]

Germany produces more megawatts of energy from wind power than any other country in the world, and is often cited as an aspirational example. More than 100 university

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[61] "Tourism fears over wind farm plan," *BBC News*, 2/14/02. http://news.bbc.co.uk/1/hi/northern_ireland/1819985.stm

[62] John Hatt Firbank, "Wind Farm: Keep Cumbria beautiful," *Westmorland Gazette*, 10/17/03. http://www.thisisthelakedistrict.co.uk/search/display.var.424044.0.wind_farm_keep_cumbria_beautiful.php

[63] "'Glaring error' in windfarm document," *Westmorland Gazette*, 12/10/03. http://www.thisisthelakedistrict.co.uk/search/display.var.440421.0.glaring_error_in_windfarm_document.php

[64] Justin Hawkins, "Park Authority raises objection to wind farm," *Westmorland Gazette*, 1/9/04. http://www.thisisthelakedistrict.co.uk/search/display.var.447629.0.park_authority_raises_objection_to_wind_farm.php

[65] Jennie Dennett, "Windpower battle shifts to new front," *Westmorland Gazette*, 10/29/03. http://www.thisisthelakedistrict.co.uk/search/display.var.427243.0.windpower_battle_shifts_to_new_front.php

professors and scientists have signed the Darmstadt Manifesto against wind power plants in that country:

> Our country is on the point of losing a precious asset…The industrial transformation of cultural landscapes which have evolved over centuries and even of whole regions is being allowed. Ecologically and economically useless wind generators, some of which stand as high as 120 metres and can be seen from many kilometres away, are not only destroying the characteristic landscape of our most valuable countryside and holiday areas, but are also having an equally radical alienating effect on the historical appearance of our towns and villages which until recently had churches, palaces and castles as their outstanding features.[66]

Last year, the Beacon Hill Institute at Suffolk University in Boston conducted an in-depth survey of 497 tourists to Cape Cod on the possible impacts of wind turbines in Nantucket Sound. Cape Cod and the Islands attract 6,000,000 visitors annually who directly account for 21% of the region's employment, and indirectly for 40%, and generate approximately $84 million in state and local tax receipts.[67] The survey showed that very small changes in tourist behavior would have large economic impacts. 62% of the 497 tourists questioned said turbines would worsen the view slightly or a lot.[68] 3.2% said they would spend an average of 2.9 fewer days on the Cape, another 1.8% said they would not visit at all, 11% said they would pay less for lodging. The net effect was $75.15 less spending on average per respondent per year. Grossed up to represent all tourists, this would represent a reduction in spending of between $57 million and $123 million annually, according to the study.[69]

3. Property Values

A British judge found that wind power plants can destroy the value of nearby homes. In 2001, District Judge Michael Buckley ruled that the noise, visual intrusion, and flickering of light through turbines blades 550 meters away reduced the value of a neighboring home by 20%. According to the *Times of London*, he said, "The effect is significant and it has a significant effect on the property. It is an incursion into the countryside. It ruins the peace."[70]

His words are reflected in the sentiments of real estate agents in England and other

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[66] Press Release, "Darmstadt Manifesto," 9/1/98, http://www.windfarm.fsnet.co.uk/downloads/darmstadte.pdf

[67] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 10 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[68] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p 34 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[69] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, pp. 3-4 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[70] Lewis Smith, "Wind farms ruin peace, says judge," *The Times*, 1/10/04, http://www.timesonline.co.uk/

countries where wind power plants have been proposed and constructed.

Kyle Blue, a real estate agent working near a planned wind power plant in Tebay, England, told a newspaper reporter, "To me, it is absolute common sense that if you put up huge industrial structures in an exceptionally beautiful area, property prices are going to suffer."

He then recounted that his agency had been "trying to sell a beautifully restored farmhouse for £340,000. We told one prospective buyer about the wind farm and he said: 'It doesn't bother me. My family and I are very green and supportive of this kind of energy.' Then he went away and visited wind farms all over the country. Three weeks later he came back to us and said he couldn't come to terms with the development after all. We had to take the property off the market and it remains unsold."[71]

In a vacation area near the Toora wind power plant in South Gippsland, Australia, a real estate agent told a news reporter that the 12 turbines were 'definitely' having an impact on values. "If they are near the property, buyers are staying away," Wesfarmers Landmark Leongatha agent Glen Wright said. "If I had to put a figure on it, I would say (a reduction of) 25 to 30 per cent on the going value."

Another real estate sales manager had major difficulties selling a property near the Toora plant. "I would have shown 50 or 60 people through that property and I would say half of those wouldn't even look at the place once they realize it's in the vicinity of wind turbines," Bruce Falk said. "And half of the other 50 per cent were concerned about resale so they offered 20 per cent less than the price the owners would accept."[72]

In another part of southwest Australia, John Denham, who had leased his farm for eight turbines, found that their presence hindered his efforts to find a buyer when ill health forced him to sell the land.[73]

In Denmark, Erwin Thorius, president of the National Association of Neighbours to Wind Turbines, said recently that people living near windmills found it impossible to sell their homes.[74] A study in Denmark about 10 years ago found that housing prices decreased near wind power plants, ranging from about US $2,900 at that time for a one-turbine

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[71] Ross Clark, "An ill wind blowing?" *The Telegraph*, 2/14/04, http://www.telegraph.co.uk/property/main.jhtml?xml=/property/2004/02/14/pfarm14.xml; Justin Hawkins, "Precedent fuels windfarm flight," *Westmorland Gazette*, 1/14/04, http://www.thisisthelakedistrict.co.uk/search/display.var.448830.0.precedent_fuels_windfarm_flight.php

[72] Paul Sellars, "Turbines cast shadow over land values," *Weekly Times*, 4/6/03, http://www.hotkey.net.au/~mywl/

[73] Adam Morton, "An ill wind blows down on the farm," *Warrnambool Standard*, 12/17/01, http://www.hotkey.net.au/~mywl/

[74] Renee Mickelburgh, Tony Paterson, and Kim Willsher, "Huge protests by voters force the continent's governments to rethink so-called green energy," *The Telegraph*, 4/4/04, http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2004/04/04/wwind04.xml&secureRefresh=true&_requestid=1493

facility to US $16,800 for a 12-turbine site [75]

In a 1998 report about effects on property values, British estate agent FPD Savills concluded: "Generally, the higher the value of the property the greater the blight will be... As you go up the value scale, buyers become more discerning and the value of a farmhouse may be affected by as much as 30 per cent if it is in close proximity to the wind turbine."[76]

Here in the U.S., at a public meeting on Enxco's proposal for a wind power plant in Lowell, Vermont, a realtor trying to sell a farm near the site told Mr. Zimmerman that his claim that land values won't decrease is 'ludicrous.' Don Maclure said that when he tells people interested in buying the farm about the proposed project he never hears from them again.[77]

Other realtors are similarly skeptical. "They say there will be no effect on property values. That is absolutely incorrect," said real estate agent Roger Weaver of Kittitas County, Washington.[78] "There is no way wind farms won't affect property values in the Kittitas Valley. In a tremendously scenic area like the valley, the view is a major consideration in what people want."

Mr. Weaver explained that people from Puget Sound are purchasing country lands for homes while still working in Puget Sound. "They want a beautiful place to live and retire," he said. "Wind farms will have a real negative effect on the property values because the scenic views are a big deal, a real big deal to these people."[79]

As part of a study of the proposed Cape Wind project, 45 real estate professionals operating in towns around Nantucket Sound were contacted and asked about anticipated effects of the wind power project on property values.

49% of realtors expect property values within the region to fall if the Cape Wind power plant is erected.[80]

501 home owners in the six towns that would be most affected by the Cape Wind project were also surveyed. 68% said that the turbines would worsen the view over Nantucket

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[75] Tennessee Valley Authority, "20-MW Wind Farm and Associated Energy Storage Facility Environment Assessment, Appendix F: The Impact of Views on Property Values," April 2002, p. F-2, http://www.tva.gov/environment/reports/windfarm/index.htm

[76] Alexander Garred, "Ugly side of clean power," *The Guardian*, 3/2/03, http://observer.guardian.co.uk/cash/story/0,6903,905539,00.html

[77] Steve Blake, "Public discussion begins on Lowell wind project," *The Chronicle*, 9/24/03, http://www.LowellWind.com/images/photos/lowell/Chronicle_092403.pdf

[78] Mike Johnston, "Will turbines hurt land value?" *Daily Record*, 1/21/04, http://www.kvnews.com/articles/2004/01/21/news/news01.txt

[79] Mike Johnston, "Study of land value draws reactions," *Daily Record*, 7/1/03, http://www.kvnews.com/articles/2003/07/01/news/news02.txt

[80] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, pp. 16-17 of 53. http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

Sound 'slightly' or 'a lot'.[81]

On average, they believed that Cape Wind would reduce property values by 4.0%. Those with waterfront property believed that it would lose 10.9% of its value. The study concluded that, based on the loss of property value expected by home owners, the total loss in property values resulting from the construction of Cape Wind would be $1.35 billion, a sum substantially larger than the approximately $800 million cost of the project itself.[82]

As the study noted, any reduction in property values would, in turn, lead to a fall in property tax collections in the affected towns; the drop in these tax collections would be $8 million annually. If the tax rates were raised to maintain revenue, this would shift some of the property tax burden off waterfront residents (whose property values would fall the most) and on to the (less affluent) island residents.[83]

In the home owner survey, in response to the statement: It is important to protect an uninterrupted view of Nantucket Sound, 76% strongly agreed, 18% somewhat agreed, 3% were neutral, 2% somewhat disagreed, and 1% strongly disagreed.[84]

It's worth noting that of the home owners surveyed, 94% did not have homes with a view of the Sound.[85] 76% were not members of a conservation or environmental organization.[86] Regardless, their main reasons for living in the area were the 'beauty of the region,' 'the beaches,' and 'the ocean views.'[87]

Here in the Berkshires, according to a recent article about housing prices, realtor Paul Harsch said he'd noticed a trend of out-of-towners coming into the northern part of the

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[81] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 14 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[82] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 4 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[83] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, pp. 4-5 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[84] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 28 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[85] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 32 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[86] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 34 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

[87] Jonathan Haughton, Douglas Giuffre, and John Barrett, *Blowing in the Wind: Offshore Wind and the Cape Cod Economy*, Beacon Hill Institute at Suffolk University, October 2003, p. 31 of 53, http://www.BeaconHill.org/BHIStudies/BHIWindFarmStudy102803.pdf

county, which he guessed was a result of the Massachusetts Museum of Contemporary Art in North Adams, and a growth in the arts.[88]

What will be the effect on second-home demand in towns around Hoosac and Brodie when 340' turbines with flashing lights are installed? What about primary residences? In particular, I wonder about the impacts on residents of Tilda Hill Road in the town of Florida, who might want to sell their houses after they've experienced the noise and light strobing of nearby turbines

4. Public Roads

At the 12/3/03 meeting of BRPC's Clearinghouse Review Committee, Enxco engineer Jason Krzanowski said that the longest vehicles transporting turbine components to the Hoosac wind power plant site will be 135', with a 120' turning radius, and a maximum turning grade of 1%. The heaviest vehicle weight will be 197,000 pounds.[89]

Engineers at the Massachusetts Highway Department have told me that the longest vehicle for which state roads are designed is 67', with a 45' turning radius. That length is half of the tractor-trailer employed for moving wind turbine blades. Apparently, the Department doesn't have any specifications for 135' vehicles.

In response to my request for the truck-turning template of the 135' vehicle to be used at Hoosac, Mr. Krzanowski said that such templates are not published.[90] However, I found one in documentation for another project.[91] It has diagrams showing specifications for a 135' or 139' tractor-trailer (the type is fuzzy) carrying a single 116' wind turbine blade. This is the same blade length noted in Enxco's 10/6/03 special permit application for Hoosac. The tractor-trailer's loaded height is 14', the number of axles is five, and the span between the two central axles is 98'. There is no driver at the rear, and the turning radius is 120' 7"

There are also specifications for the truck that will transport other large tower parts. The overall truck length is 112' with 11 axles, the loaded height is 15' 4", the width is 11' 6", and the gross weight is 197,000 pounds. The turning radius is 111' 3". The axles are grouped thusly, from front to back: one with a load of 12,000 pounds; three spaced 4.5' apart (axle to axle) for a maximum of 45,000 pounds; two at the same interval for a total of 40,000 pounds; three with the same intervals and a maximum of 60,000 pounds; and the rear two, same intervals, totaling 40,000 pounds

[88] Donna Roberts. "Realtors say home sales still booming," *North Adams Transcript*, 2/3/04. http://www.TheTranscript.com
[89] Berkshire Regional Planning Commission. Clearinghouse Review Committee public meeting, 12/3/03.
[90] Email from Jason Krzanowski, Hill Engineers, to Eleanor Tillinghast. Subject: Hoosac Wind Project RFI, 4/15/2004 12:52 PM
[91] Princeton Municipal Light Department, *Expanded Environmental Notification Form: Princeton Wind Farm Infrastructure Improvements, Princeton, MA*. EOEA #13229, 3/1/04. Appendix A, Engineering Plan Sheets.

According to Enxco's *Hoosac Wind Power News*, delivery of components for each turbine requires approximately eight tractor-trailers.[92] That means 160 trips. I don't remember the number of vehicle trips expected with the 112', heavier, tractor-trailer, but the template I have shows the nacelle on it. This means 20 nacelles, and perhaps the 60 turbine tower parts (three to each turbine), for a possible total of 80 trips using that sized vehicle. The 135' tractor-trailer will be used to bring 60 blades, one blade to a trip. The 300-ton crane with a 301' 8" boom and 28.5' width will, I assume, be assembled on-site.

How will the narrow rural roads around Hoosac accommodate vehicles of these dimensions? Mr. Krzanowski said the hairpin turn on Route 2 from North Adams will exclude the 135' tractor-trailer, which needs a virtually flat (1%) turning surface. If I understood him correctly, there is at least one bridge from the east on Route 2 that can't support a 197,000-pound tractor-trailer.[93]

It's difficult to imagine vehicles like these being able to maneuver on country roads without significant clearing of roadside trees and stone walls near any turns, regrading of road elevations, especially at curves, and damage to road beds. Are there any underpasses that must be negotiated? Of course, roads will have to be closed to allow passage of these vehicles. And since all the loads won't arrive on one day, roads will have to be closed for parts of many days, inconveniencing residents, and potentially jeopardizing public safety.

5. Public Safety

There are four public safety issues that I want to touch on briefly: ice throw; turbine damage; driver distraction; and television, telecommunication, and radar interference. I'm not going to devote a lot of space here to each of these because on ice throw and signal interference there has been so much research that each could fill a paper, turbine damage is best illustrated with photos, which I will post on www.GreenBerkshires.org as soon as possible, and I haven't done a lot of research about the visual impact on passing drivers. Nonetheless, I want to give you some information for consideration.

A. Ice Throw

> Icing represents the most important threat to the integrity of wind turbines in cold weather. Based on the duration of inoperative wind measuring equipment at one surveyed mountain in western Massachusetts, it was determined that icing weather can occur as much as 15% of the time between the months of December and March (Kirchhoff, 1999)

[92] Enxco, Inc., *Hoosac Wind Power News*, Volume 1, Number 2, February 2003, p. 9. http://www.HoosacWind.com/newsletter2.pdf

[93] Berkshire Regional Planning Commission, Clearinghouse Review Committee public meeting, 12/3/03

That's from a paper on cold weather issues by the University of Massachusetts Renewable Energy Research Laboratory ["RERL"].[94] RERL has been deeply involved in promoting wind power in the Berkshires.

There are two kinds of ice most likely to coat wind turbines: glaze and rime. Glaze ice happens during ice storms, when water hits a frozen surface. It is hard and quite transparent. Rime ice occurs in freezing conditions when a surface is exposed to clouds or fog.[95]

Today's huge wind turbines on mountainous sites in northern climates, like Hoosac, can easily reach into lower clouds in the cold season, causing rime icing.[96]

During cold weather at altitudes above 2,300', rime ice can be expected approximately 10% of the time. Above 3,000', the figure doubles to 20%.[97] As noted earlier, 11 Hoosac turbines will reach above 3,000'.

According to Henry Seifert, an expert on the technical requirements of wind turbine blades operating in cold climates:

> If a wind turbine operates in icing conditions ...two types of risks may occur if the rotor blades collect ice. The fragments from the rotor are thrown off from the operating turbine due to aerodynamic and centrifugal forces or they fall down from the turbine when it is shut down or idling without power production."[98]

A lot of research has been done on the problems of icing and the dangers of ice throw.[99] Despite all that work, "A commercial ...anti-icing or de-icing system has not yet been proved reliable over many years. Just the opposite is the case,"[100] according to Mr. Seifert. The Searsburg wind power plant proves his point: black blades were installed to

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[94] Lacroix, Antoine, and Dr. James F. Manwell, *Wind Energy: Cold Weather Issues*, University of Massachusetts at Amherst, Renewable Energy Research Laboratory, June 2000, p. 6. http://www.ecs.umass.edu/mie/labs/rerl/research/Cold_Weather_White_Paper.pdf

[95] Lacroix, Antoine, and Dr. James F. Manwell, *Wind Energy: Cold Weather Issues*, University of Massachusetts at Amherst, Renewable Energy Research Laboratory, June 2000, pp. 6-7. http://www.ecs.umass.edu/mie/labs/rerl/research/Cold_Weather_White_Paper.pdf

[96] Seifert, Henry, Annette Westerhellweg, and Jurgen Kroning, *Risk analysis of ice throw from wind turbines*, BOREAS VI, April 2003, pp. 1, 2, http://www.msue.msu.edu/cdnr/icethrowseifertb.pdf

[97] Lacroix, Antoine, and Dr. James F. Manwell, *Wind Energy: Cold Weather Issues*, University of Massachusetts at Amherst, Renewable Energy Research Laboratory, June 2000, p. 9, http://www.ecs.umass.edu/mie/labs/rerl/research/Cold_Weather_White_Paper.pdf

[98] Seifert, Henry, Annette Westerhellweg, and Jurgen Kroning, *Risk analysis of ice throw from wind turbines*, BOREAS VI, April 2003, pp. 1, 2, http://www.msue.msu.edu/cdnr/icethrowseifertb.pdf

[99] Wind Energy in Cold Climates, http://www.vtt.fi/virtual/arcticwind/publications.htm; Seifert, Henry, *Technical Requirements for Rotor Blades Operating in Cold Climate*, 2003, http://www.dewi.de/dewi/themen/bibli/pdf/seifert_boreas6.pdf; Lacroix, Antoine, and Dr. James F. Manwell, *Wind Energy: Cold Weather Issues*, University of Massachusetts at Amherst, Renewable Energy Research Laboratory, June 2000, http://www.ecs.umass.edu/mie/labs/rerl/research/Cold_Weather_White_Paper.pdf

[100] Seifert, Henry, *Technical Requirements for Rotor Blades Operating in Cold Climate*, 2003, p. 1, http://www.dewi.de/dewi/themen/bibli/pdf/seifert_boreas6.pdf

prevent ice accumulation, yet as a photo in the RERL paper shows, ice still accretes on the blades.[101]

Enxco's Mr. Zimmerman has certainly acknowledged the risks.

As noted at the beginning of this paper, Mr. Zimmerman told a reporter: "Wind turbines don't make good neighbors." He added: "That's why ski areas are poor places to put big wind turbines. There must be a safety radius of 750 to 1,000 feet around the wind turbine, because they may fling ice off in winter."[102]

Three years earlier, he averred that a much larger safety radius was necessary, and his conclusion then was based on experience with Searsburg's turbines, which are considerably smaller than is now the norm. Here is a reprint of an email he wrote to an American Wind Energy Association listserv in 2000:

> I've watched over the wind turbines GMP has had installed in Vermont over the last 10 years and have several thoughts that be useful to this discussion.
>
> Here in Vermont, and elsewhere in the northeastern US, the winds blow strongest at the mountain tops, where it is also the most icy. A common first question to wind developers in this region is 'why don't you put the wind turbines at the ski areas (where there already is human development)'? The answer is because of the danger to public safety due to ice throws. Ski areas are not a good place for wind turbines.
>
> Back in the mid 1980s one of the windy areas that was being considered for wind development was near to ski trails. Boeing and/or Hamilton Standard did some work to determine how far we must stay away from the ski trails to be safe from ice being thrown from their turbines (the MOD 5b was the boeing machine at the time). Without going back to dig up those papers, and if I remember correctly, the distance was between .25 and .5 miles away, downwind. It's a function of blade tip speed, so applicable to present day turbines too.
>
> While the Boeing study was academic, the danger from ice being release from rotor blades overhead is real -- and a hard hat is not going to provide you with much comfort. I have stood near the turbines GMP had on Mt. Equinox in the early 1990s and more recently the Zond 500 KW turbines in Searsburg Vt during and after icing events. When there is heavy rime ice build up on the blades and the machines are running you instinctually want to stay away. They roar loudly and sound scarey. Probably you would feel safe within the .5 mile danger zone however.

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[101] Lacroix, Antoine, and Dr. James F. Manwell, *Wind Energy: Cold Weather Issues*, University of Massachusetts at Amherst, Renewable Energy Research Laboratory, June 2000, p. 12, http://www.ecs.umass.edu/mie/labs/rerl/research/Cold_Weather_White_Paper.pdf
[102] Robin Smith, "Wind Towers Spark Debate," *Caledonian-Record*, 7/1/03, http://www.CaledonianRecord.com/pages/local_news/story/c2296e810

> One time we found a piece near the base of the turbines that was pretty impressive. Three adults jumping on it couldn't break. It looked to be 5 or 6 inches thick, 3 feet wide and about 5 feet long. Probably weighed several hundred pounds. We couldn't lift it. There were a couple of other pieces nearby but we wondered where the rest of the pieces went.
>
> In the winter, icing is a real danger and GMP therefore restricts public access to the site(s). Maintenance workers have developed a protocol for working on turbines during icing conditions, though I am not familiar with the details. I'll 'dig into it' if you want.[103]

That's the entire email. I don't know if Mr. Zimmerman's memory served him correctly as to the exact distance for safety, but the maximum blade tip speed of the Searsburg turbines is 136.65915 mph, and that of the Hoosac turbines will be 180.64142 mph.

I've read that Brian Fairbank no longer offers skiing at Brodie Mountain, but does promote other winter activities. Also, at one point, he was considering condominiums there.[104] I don't know the distance between his property and the turbines proposed along the ridgeline, but I do know that the telecommunication towers and abandoned fire tower up there are near the upper ski lift drop-off. Since the wind blows more or less from the west, the ski area may be downwind of the wind turbines

As for the Hoosac wind turbines, they will be near a popular snowmobile route. With approximately four miles of new roads constructed for the project,[105] and no fencing around the property, there is a potential for injury, especially to teenagers who might not respond cautiously to danger and trespass warning signs.

In any case, Mr. Zimmerman's email explains the public safety hazard from icing of any turbines that might be near hiking trails, snowmobile routes, or other public uses.

B. Turbine Damage

Falling or flung parts of broken turbines would be another public safety concern. I hadn't thought to do any research on this possibility, but found a passage in an article which made me think more investigation needs to be done

Wind power proponents discount the problems of broken turbines, but I have seen photos to the contrary,[106] and will have to go back through my records to retrieve them. I'll post them on www.GreenBerkshires.org.

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[103] Email from John Zimmerman, VERA, to listserver-egroups-awea-windnet@egroups.com. Thu, 20 Jan 2000 10:51:43 -0500.

[104] John Hitchcock, "Blustery season blew away ski area profits." *The Advocate*. 4/7/04. http://www.berkshires.com/advocate/story13976.html

[105] Enxco, Inc., *Environmental Notification Form*. EOEA #13143. p. 11.

[106] http://www.misplacedwindpower.org/archives/windred.jpg

The article about the 1.5 MW General Electric turbines at the Waymart wind power plant in Pennsylvania is worth noting because those turbines are the same as will be installed at Hoosac:

According to Klaus Obel, Waymart Operations Manager, the wind turbines there are shut down when the temperature hovers around zero degrees Fahrenheit and lower. He said the 115' fiberglass blades can become brittle so the turbines are not operated at such temperatures.[107]

C. Driver Distraction

Construction of the Fenner NY wind power plant generated significant traffic. At the time, Fenner town supervisor Russell Cary said, "It's nothing to see 25 to 30 cars alongside the road watching the construction."[108]

In England, a decision by local officials to vote down a wind power plan was backed up by a government inspector who found that wind turbines would have a potentially "adverse effect" on highway safety.[109]

Undoubtedly, local and state highway employees will develop traffic control plans for cars stopping along Route 2 to watch construction of the Hoosac towers. But, after the turbines start operating, what will be the safety measures for drivers along Route 2, the major east-west artery from Williamstown to Boston, who suddenly encounter the visual impact of 34-story structures looming near the highway? From the vantage of Whitcomb Summit, the highest point on Route 2, the tallest Hoosac turbine blade tip will, at full extension, be more than 900 feet higher. As anyone driving south along Vermont's Route 8 knows, when you come up over the rise just north of the Searsburg towers, the visual effect is stunning. Luckily, there is a pull-out next to the road. The Hoosac towers are almost half again as tall as those at Searsburg, and Route 2 is a much busier route. No one I spoke with at the state highway department knew if a study has been done of the safety and mitigation issues.

D. Television, Telecommunication, and Radar Interference

1.) Television reception interference

During the permitting phase of wind power plants, developers routinely say television reception is not affected by wind turbines. Just as routinely, nearby residents complain of

[107] Peter Becker. "TV Tower To Fix Wind Farm Woe." *Wayne Independent*. 1/26/04. http://www.WayneIndependent.com/

[108] Mike Bilodeau. "Fenner windmills attract a crowd." *Oneida Dispatch*, 10/4/01. http://www.OneidaDispatch.com/site/news.cfm?newsid=2448508&BRD=1709&PAG=461&dept_id=68808&rfi=8

[109] "Inquiry rules out wind farm." *BBC News*. 7/22/03. http://news.bbc.co.uk/1/hi/england/tyne/3087471.stm

the problem once the turbines are built. (The exceptions, I should add, are the landowners leasing lands for the turbines.)

Last year, the developer and operator of the Top of Iowa Wind Farm, announced that it would offer free cable TV service to 145 residents in and around the project near Mason City, Iowa, because of signal interference created by the towers and whirling generator blades.[110] An article described the problem:

> Mike Kelly, director of operations at the Top of Iowa Wind Farm, said the 89-tower project was in full operation at the end of November 2001. The wind farm is in the midst of farm country spread over a 5,200-acre area. The towers are atop a gradually sloping hill 100 feet high.
>
> "As operations geared up, we started getting complaints," Kelly said. "We never have gotten complaints like this before from other projects, and it was new. It was a combination of factors unique to the Top of Iowa project."
>
> He said broadcast television signals come from TV transmission towers staggered at 25 to 60 miles away. The distance and the hill downgrades the signals, he said, and many people were not getting a perfect signal to begin with.
>
> Out of about 350 homes within and around the project area, 175 complaints came to Zilkha, Kelly said. People with complaints indicated further downgrading of signals they received that involved a ghosting or shadow effect on screens.
>
> He said the signals bounce off towers and whirling blades and create a second signal that comes to television sets moments behind the initial signal. This creates ghosts and reduced signal strength.
>
> "It had nothing to do with electromagnetic fields," Kelly said. "It was a physical interference issue or a momentary interruption of the signal."
>
> Most new televisions filter out the ghosting effect, but older sets don't, he said.
>
> Many rural or isolated areas where wind farms are located, he said, have residents who get television by cable or satellite signal, which are not affected by the towers.[111]

During a ceremony at which the Secretary of Pennsylvania's Department of Environmental Protection handed a permit to the British developer of the Waymart wind

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[110] Mike Johnston, "Got TV?" *Daily Record*, 4/5/03. http://www.kvnews.com/articles/2003/04/05/news/news02.txt

[111] Mike Johnston, "Got TV?" *Daily Record*, 4/5/03. http://www.kvnews.com/articles/2003/04/05/news/news02.txt

power plant, the company's representative affirmed that there is evidence turbines can interfere with radio and television reception.[112]

Residents near Waymart do complain about television reception. Ray Vogt said that since the plant began operating, he can actually see the interference move as the blades go around. Several other people said their TVs have also been affected.[113] Some have been using a UHF antenna and others have cable service.[114]

Satellite service could also be affected. Here are two excerpts from an environmental impact statement for a wind power project in Kittitas Valley WA:

> Other potential forms of television interference generated during turbine operations are signal reflection (ghosting) and signal blocking caused by the relative locations of the turbine structures and the receiving antenna with respect to the incoming television signal. Television signals that operate at higher frequencies, such as satellite receivers, are not affected by corona-generated television interference. However, because they are line-of-sight systems, physical interference from the turbine towers or blades is a possibility.
>
> Based on a turbine blade radius of approximately 130 feet, the study concluded that 12 proposed turbines could potentially obstruct five existing microwave paths in the project area.[115]

2.) Radar and telecommunications interference

In the Berkshires, as noted earlier, there are airports in Pittsfield and North Adams, and an airport in nearby Albany, New York. There is also the Westover Air Reserve Base in Chicopee MA. I have not done much research on the topic of radar interference, but an article in the British *Guardian* encapsulates the problem:

> Put simply, one piece of fast-moving metal looks pretty much like another to a radar operator, whether it's the rotating blades of a wind turbine or the approach of an…aircraft."[116]

Consequently, in Britain and Norway, the military has objected to some plans for wind power plants along coastal sites, saying those can disturb telecommunications and produce false radar echoes.

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[112] Peter Becker, "Wind Farm Approved," *Wayne Independent*, 1/29/02. http://www.WayneIndependent.com/

[113] Peter Becker, "Impact of windmills addressed at public forum," *Wayne Independent*, 11/20/03, http://www.WayneIndependent.com/ ; Thomas M. Di-Stasio, "Windmills blamed for bad TV reception," *Wayne Independent*, 10/03/03. http://www.WayneIndependent.com/

[114] Peter Becker, "TV Tower To Fix Wind Farm Woe," *Wayne Independent*, 1/26/04. http://www.WayneIndependent.com/

[115] *Kittitas Valley Wind Power Project Draft EIS*, Section 3.10 Transportation, December 2003, p. 3.13-15.

[116] David Adam, "Why do wind turbines confuse military radar?" *The Guardian*, 3/4/04. http://www.guardian.co.uk/life/thisweek/story/0,12977,1161090,00.html

The British Ministry of Defense has opposed numerous preliminary applications for wind power plant construction: 48% in 2003, up from 34% in 2002. "There are genuine concerns over how wind turbines can interfere with our radar systems," said a Ministry spokesman.[117]

In 2002, the owner of the Glasgow airport in Scotland objected to a wind power plant proposed 15 miles away, saying the turbines would create a "snowstorm" of false blips on its radar, making it almost impossible to pick out aircraft coming in to land. The turbines would pose a "serious threat to the safe operation of the airport's airspace."[118]

In 2002, an effort to construct a wind power plant near the U.S. Air Force's Nevada Test and Training Range was canceled due to concerns of Nellis Air Force Base officials that the wind turbine blades would interfere with radar.[119]

A study done in 2003 for the British Department of Trade and Industry on *Wind Farms Impact on Radar Aviation Interests* provides more explanation. Here are a few excerpts (each paragraph from different parts of the report):

> However, it is safe to say that the materials used in the manufacture of a wind turbine will affect the wind turbine's RCS value. In particular, metals and other electrically conducted materials, such as carbon fibre, are reflective to radar and, therefore, will contribute to increasing the RCS signature.
>
> The turbine rotor is very important in considering the effect of wind turbines on radar. As it is spinning a proportion of the blades (depending on yaw angle and RPM) will be traveling fast enough to be unsuppressed by most radar stationary clutter filters. Hence, unless these returns are below the radar threshold then the turbine will appear as a target on the radar PPI display.
>
> Current procedures have put a lot of emphasis on the range of the wind farm from the radar. This has led to an impression that the further from the radar the farm is placed the smaller the interference. The situation is not that simple. A greater range is only better because it will increase the chances of intervening terrain and the earth's curvature obscuring the radar LoS to the turbines. Due to the magnitude of scattering from a wind turbine, if the wind farm is within the operating range of the radar and the LoS exists then the radar will receive clutter signals from the turbines.
>
> Wind farms can create a detectable radar return even when not in direct LoS of

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[117] David Adam, "Why do wind turbines confuse military radar?" *The Guardian*, 3/4/04. http://www.guardian.co.uk/life/thisweek/story/0,12977,1161090,00.html

[118] Frank Hurley, "Windfarm plan hits turbulence," *Scotsman*, 5/26/02. http://news.scotsman.com/topics.cfm?tid=605&id=571152002

[119] Dave Wilson, "US wind power: Illinois: 1, Nevada: 0," *e4engineering.com*, 7/22/02, http://www.e4engineering.com/story.aspx?uid=b22cc991-ff31-47a1-9ca6-aa8a3df01f6b

the radar. This is due to diffraction over the intervening ground between the radar and wind farm. The level of detectability of the wind farm is dependent on frequency of radar and the distance from the wind farm to the point of diffraction and the distance below the LoS horizon where the wind farm is located.

The diffraction effects mentioned above and the design of wind turbines, mean that wind turbines individually create 'radar shadows'. Any shadow that does exist behind wind turbine decreases in intensity with distance (e.g.) for a 3GHz radar, the shadow extends hundreds of metres behind a typical wind turbine.

All radar contain filtering systems that are designed to extract out information that is of use for the particular radar purpose and to reject all other information (perceived as clutter). As already discussed above, operating wind turbines exhibit many of the characteristics associated with aircraft i.e. relatively large RCS with a strong Doppler shift. As current generation radar systems are not designed for the removal, by filtering, of clutter from wind turbines, we have a situation where wind turbines can cause clutter and false tracks on radar displays.[120]

6. Quality of Life

In addition to television interference, there are other issues directly affecting the quality of life for people living near wind power plants. Two, in particular, are noise and strobing light.

A. Noise

"Wind farms 'make people sick who live up to a mile away.'"

That's the title of an article that appeared in the British *Daily Telegraph* earlier this year Here is an excerpt:

> Onshore wind farms are a health hazard to people living near them because of the low-frequency noise that they emit, according to new medical studies. Doctors say that the turbines - some of which are taller than Big Ben - can cause headaches and depression among residents living up to a mile away.
>
> One survey found that all but one of 14 people living near the Bears Down wind farm at Padstow, Cornwall, where 16 turbines were put up two years ago, had experienced increased numbers of headaches, and 10 said that they had problems sleeping and suffered from anxiety.
>
> Dr Amanda Harry, a local GP who did the research, said: "People demonstrated a range of symptoms from headaches, migraines, nausea, dizziness, palpitations and

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[120] Poupart, Gavin J., *Wind Farms Impact on Radar Aviation Interest – Final Report*, Prepared for the Department of Trade and Industry, September 2003, pp. 6-8, http://www.bwea.com/aviation/QinetiQ-Radar-Study-part1.pdf

tinnitus to sleep disturbance, stress, anxiety and depression. These symptoms had a knock-on effect in their daily lives, causing poor concentration, irritability and an inability to cope."

Dr Harry said that low-frequency noise - which was used as an instrument of torture by the Germans during the Second World War because it induced headaches and anxiety attacks - could disturb rest and sleep at even very low levels

"It travels further than audible noise, is ground-borne and is felt through vibrations," she said. "Some people are having to leave their homes to get away from the nuisance. Yet, despite their obvious suffering, little is being done to relieve the situation and they feel that their plight is ignored."

Similar problems have been found by Dr Bridget Osborne, a doctor in Moel Maelogan, a village in North Wales, where three turbines were erected in 2002. She has presented a paper to the Royal College of General Practitioners detailing a 'marked' increase in depression among local people.

"There is a public perception that wind power is 'green' and has no detrimental effect on the environment," said Dr Osborne. "However, these turbines make low-frequency noises that can be as damaging as high-frequency noises. When wind farm developers do surveys to assess the suitability of a site they measure the audible range of noise but never the infrasound measurement - the low-frequency noise that causes vibrations that you can feel through your feet and chest. This frequency resonates with the human body - their effect being dependent on body shape. There are those on whom there is virtually no effect, but others for whom it is incredibly disturbing."[21]

The *Wall Street Journal Europe* reported on one woman's experience in Germany:

Diana Hutchinson used to like the sound of the wind blowing past her small-country house, near the German village of Kamscheid. Now she prays for calm weather because when the wind blows her once-tranquil life is shattered. Mrs. Hutchinson lives 250 meters from a state-of-the-art windmill.

Known as an Enercon E40 wind turbine, the windmill stands 85 meters high and has a wingspan of 40 meters. It was installed two years ago and the incessant noise of the spinning blades has made the Hutchinsons' life unbearable. "The noise of the revolving blades echoes throughout the house, and all thought of sleep, or even of having a quiet conversation, is lost," says Mrs. Hutchinson. "When the wind blows the people nearby stay indoors and shut their windows,

[21] Catherine Milner. "Wind farms 'make people sick who live up to a mile away,'" *Daily Telegraph*. 1/25/04.
http://www.telegraph.co.uk/news/main.jhtml?xml=%2Fnews%2F2004%2F01%2F25%2Fnwind25.xml

> even on a hot summer day. Life would be more pleasant if we lived right next to a motorway."[122]

Shortly after wind turbines were installed in Kewaunee County, Wisconsin, in 1999, a local newspaper ran a story headlined, "Wind turbines draw complaints from some nearby neighbors." According to the story: "Artist Ken Loeber said he liked the concept until he started hearing turbine noise at his log home. 'It's more like we are living in an industrial park,' said Loeber, 51, who moved into a rural area of Kewaunee County, seeking peace and quiet, in the early 1970s. 'It's so noisy that some nights we can't open our windows.'"

The article then went on to quote Lincoln town chairman Arlin Monfils of Kewaunee County. "There's problems. There's more noise than people expected. And the problem is that it's almost constant."[123]

Mr. Monfils subsequently wrote a letter describing "wind turbine NOISE which interferes with neighbors' sleep and their mental health." For towns considering wind power plants, he warned: "Once the turbines are up and operating the wind turbine noise will be there. It will not be constant and it may not be above the decibel level that they establish as a maximum, but it will be irritating, at any time of day or night and will vary in its intensity with the wind direction and speed."[124]

A year later, Kewaunee neighbors were still distressed. One woman was quoted in a newspaper: "They are very noisy," Darlene Martin said, likening the sound to a farmer's silo unloader that runs constantly. "It is worse at night when a person is trying to sleep. It is just a steady kind of humming and sometimes you hear the wind, 'Swoosh, swoosh.'"[125]

In 2002, neighbors there were still complaining. As reported by the *Chicago Tribune* "Across the fields of corn and soybeans, where [Nancy] Larson and her husband, Mike Washachek, have a clear view of all 14 wind turbines, the initial enthusiasm over embracing clean, renewable energy has been overwhelmed by the unexpected. A strobe effect flashes their home at sundown as the sun hits the turning rotors. There also is television signal interference. And noise. 'I wake up some nights and think I left the dryer on with a tennis shoe in it,' Larson said. 'We were used to the beautiful quiet nights, and now that's gone.'"[126]

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[122] Brian O'Connell, "The Answer Is Not Blowing in the Wind," *Wall Street Journal Europe*, http://www.junkscience.com/mar01/wsje_OCONNELL.htm

[123] Associated Press, "Wind turbines draw complaints from some nearby neighbors," *Beloit Daily News*, 9/27/99, http://www.BeloitDailyNews.com/999/3wis27.htm

[124] Letter from Arlin Monfils, Chairperson, Town of Lincoln, Kewaunee County, Wisconsin, 2/1/00

[125] Associated Press, "Wind generators keep popping up," *Beloit Daily News*, 12/11/00, http://www.BeloitDailyNews.com/1200/6wis11.htm

[126] Tim Jones, "Rush to wind farms has noisy price," *Chicago Tribune*, 7/24/02, http://www.GlebeMountainGroup.org/Newslist.htm

Shortly after the Waymart wind power plant in Pennsylvania was constructed last fall, residents began complaining of noise there. One man who lives about 1,500 feet from one turbine said the rotors are so loud they keep him awake at night. "It sounds like an airport... my peace is gone forever," he lamented.[127] Those are 1.5 MW[128] General Electric turbines,[129] just like the ones planned for Hoosac.

In a January 2004 letter to the *Berkshire Eagle*, Lou Orebek, the PA town official mentioned earlier, wrote of the Waymart wind power plant: "The windmills have been described as 'running refrigerator' quiet. During the day the noise they generate is not above the level of background noise. It is in the quiet hours during the night when members of my family have found a distinct problem. Although studies are pending, it is the opinion of members of my family that the windmills generate a low frequency 'grind' from the turbine inside and this noise travels more than 7,000 feet. The noise is further amplified by multiple windmills."[130]

In May 2004, frustrations of residents near the Waymart facility came to a head. They appealed to the county commissioners for help in their dealings with the wind power plant owner, FPL Energy. "After seven months, the only thing I got was aggravation. You write a letter to them you get no response," said David Pevec. "Now my property will be hard to sell. I love it there. I hate the noise. You go to bed at night and it's there." The company spokesperson said she couldn't release the noise standard data sought by the residents from General Electric, the turbine manufacturer. The county commissioners had no remedies for the neighbors, except a suggestion to call the state department of environmental protection.[131]

In Australia, the farmer who leased his property for eight turbines, some as close as 600 meters to his house, said they sounded 'like a braking semi-trailer' on windy days. "If you are the landholder receiving lease payments, you can put up with it but we can understand why neighbors who get no direct benefit from the windfarm would find the noise objectionable," he wrote.[132]

Of another Australian wind power plant: A couple told a reporter that the noise from the Toora wind turbines is sometimes so loud they cannot sleep. They live less than 800 meters away from the 12-turbine wind farm and are planning to move to a new property they have bought elsewhere in the district. The turbines are not always noisy, they said,

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[127] Peter Becker, "Impact of windmills addressed at public forum," *Wayne Independent*, 11/20/03, http://www.WayneIndependent.com/

[128] Peter Becker, "Heavy winds won't disturb turbines," *Wayne Independent*, 9/19/03, http://www.WayneIndependent.com/

[129] Lori Gabriele, "Winds Blow Different Ways On Turbine Issues," *Wayne Independent*, 5/5/04, http://www.WayneIndependent.com/

[130] Lou Orebek, "Wind farms have many drawbacks," *Berkshire Eagle*, 1/11/04, http://www.BerkshireEagle.com

[131] Lori Gabriele, "Winds Blow Different Ways On Turbine Issues," *Wayne Independent*, 5/5/04, http://www.WayneIndependent.com/

[132] Adam Morton, "An ill wind blows down on the farm," *Warrnambool Standard*, 12/17/01, http://www.hotkey.net.au/~mvw1/

but "we can't walk out on our porch without hearing it 90 per cent of the time."[133]

And they are not the only complainants.

That article went on to describe the experience of another resident there: A nearby landowner, who asked not to be named, said he had initially supported the wind farm, but his view changed dramatically after the turbines were erected in 2002. "Since those turbines have been put up, I lose sleep and when I go outside I get migraine headaches," he said.[134]

People elsewhere in Australia were particularly outraged when a wind energy company said its turbines would be too noisy for a spa proposed near the 120-turbine facility it was preparing to build. This assertion was made in an appeal by the company of a planning permit granted to the spa developer. It claimed the spa would be incompatible with the wind turbines by reason of potential noise and nuisance during construction and normal operations of the wind power plant over at least 25 years.

During the earlier hearing for its own project, the company had insisted that noise from its wind power plant would not be an issue and that its turbines complied with 'exacting standards'. A consultant for the company had also said modern turbines were not noisy.[135]

In Holland, a community distressed by the noise generated by a wind power plant just over the border in Germany hired an acoustician, Frits van den Berg, to measure the aural effects of the wind turbines, particularly at night, during which the residents experienced the most disturbance. He was intrigued that other communities in the Netherlands were also complaining about annoying turbine sound at distances where they were not even expected to be able to hear the sound. Consequently, he did two studies that explain the phenomena experienced by so many people living around wind power plants.

First, he described the complaint, and then explained two aspects of the problem, which I will summarize here.

In his words, there is a distinct audible difference between daytime and nighttime wind sound at some distance from the turbines. On a summer's day in a moderate or even strong wind the turbines may only be heard within a few hundred meters. However, on quiet nights, they can be heard at distances of up to several kilometers when they rotate at high speed. On these nights, certainly at distances between 500 and 1000 meters from the wind power plant, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broadband 'noisy' sound. A

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[133] Paul Sellars, "Wind farm whips up a noise problem," *Weekly Times*, 4/6/03, http://www.hotkey.net.au/~raywl/

[134] Paul Sellars, "Wind farm whips up a noise problem," *Weekly Times*, 4/6/03, http://www.hotkey.net.au/~raywl/

[135] Paul Sellars, "Noise factor now an issue," *Weekly Times*, 11/6/02, http://www.hotkey.net.au/~raywl

resident living at 1.5 kilometers from the wind power plant described the sound as 'an endless train.' In daytime, these pulses are not clearly audible, and the sound is less intrusive or even inaudible (especially in strong wind because of the consequent high ambient sound level.)

Within the wind power plant itself, the turbines are audible for most of the (day and night) time, but the thumping is not evident, although a 'swishing' sound -- a regular variation in sound level caused by the pressure variation when a blade passes a turbine mast – is readily discernible. Sometimes a rumbling sound can be heard, but it is difficult to assign it, by ear, to a specific turbine or to assess its direction. Mr. van den Berg's studies show that the sound levels near the wind plant at night are much higher than expected from measurements performed during the day. Due to radiation cooling at the ground level at night, wind slows down near the ground but the same degree of cooling is not happening at the height of a turbine hub. With little wind at the ground surface, and therefore little wind-induced background sound, the sound from the blades at hub height is more audible. He established that the sound level can be up to 15 dB higher than the maximum expected sound level at 400 meters from the plant, and 18 dB higher than expected at 1,500 meters. He stressed that these maximums can occur not only at high wind speeds but also at low wind speeds along the ground surface.

In addition, the sound from the turbines has what he termed an "impulsive" character. When the blades rotate past the turbine mast, pressure is created between the blade and the turbine, which creates a swishing sound. When several turbines operate nearly synchronously, the pulses may occur in phase. Two pulses double the effect (+3dB), three triple it (+5dB.) Several low magnitude pulses thus cause an unexpected sound when they synchronize, which resembles in the words of that resident, 'an endless train.' The faster the rotational speed of the blades, the more frequent the repetitive thump. These sounds are not heard near the turbines, but at some distance. In fact, he said, the impulsiveness cannot be heard within the wind power plant.[136]

It's clear that audible and low-frequency noise from wind power plants, regardless of turbine size, is a real problem for people living in their vicinity. University of Massachusetts's RERL has acknowledged as much: "A major consideration and possible barrier to the installation of wind turbines in Massachusetts is noise. Recently, one wind turbine has been dismantled because of the perceived noise."[137]

B. Strobing Light and Shadows

> "When the sun is setting it shines through the blades, causing severe flashing in our house."

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[136] van den Berg, Frits G.P., "Wind turbines at night: acoustical practice and sound research," Science Shop for Physics, University of Groningen, the Netherlands, 2003, pp. 1-2, http://www.nowap.co.uk/docs/EURONOISE2003ID160.PDF; van den Berg, G.P., "Effects of the wind profile at night on wind turbine sound," *Journal of Sound and Vibration*, 9/22/03, pp. 1-2, http://landskapsskydd.nu/windnoise.pdf

[137] http://www.ecs.umass.edu/mie/labs/rerl/research/noise.html

"In the morning through the south bay window the blades can be watched on the walls."

"On sunny mornings the strobe lighting comes in the windows even with the blinds down."

"On sunny days we get shadows from blades."

"Very hard to watch TV or do any work in the kitchen, as the shadows are distracting."

"We get a 'strobe effect' throughout our house and over our entire property (40 acres)."

"In the spring and fall there is a strobe effect inside the house and in our yard."

"In fall I get a shadow."

"Shadows are cast over the ground and affect my balance."

"Shadows from the blades sweep over our house and yard and ruin our quality of life."

Those are some of the comments made in response to a 2001 community survey of the residents living near the wind turbines in Kewaunee County WI.[138]

According to an Associated Press article about the problems there:

> From the back deck of Tyler Yunk's home, blades from three towers spin just over the treetops. Yunk, 18, said the whirling blades sometimes combine with the setting sun to produce a strobe-light effect on the house. "It is like a flashlight and then a shadow and then a flashlight," he said. "There are times you got to get up and go outside and get out of the house. Your eyes can't take it."[139]

Wisconsin Public Service responded to complaints from home owners with curtains, shades, awnings and, in some cases, replacing broadcast television antennas with satellite TV. The utility also offered to buy out and relocate a half-dozen homes.[140]

Mr. Monfils cautioned other towns facing wind power plant proposals that rotating

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[138] Kabes, David E., and Crystal Smith, "Comments for the Lincoln Township Wind Turbine Survey," *Lincoln Township Wind Turbine Survey*, Agricultural Resource Center, University of Wisconsin-River Falls, 5/15/01

[139] Associated Press, "Wind generators keep popping up," *Beloit Daily News*, 12/11/00, http://www.BeloitDailyNews.com/1200/6wis11.htm

[140] Tim Jones, "Rush to wind farms has noisy price," *Chicago Tribune*, 7/24/02, http://www.GlebeMountainGroup.org/Newslist.htm

shadows in nearby homes were "problems that we had warned the utilities about but were assured that they would not occur."[141]

Regarding a wind power plant proposed in Addison County, Wisconsin, the developer, FPL Energy, obliquely acknowledged the potential problem in a permit application: "Some WTGs can cause reflective glare produced by the reflecting of sunlight or other external source of light from the blades, generator casing, or tower. No relevant government standards have been identified establishing hazardous exposure levels for glare."[142]

For a project proposed in Kittitas County WA, the company promised: "Potential shadow-flicker impacts from the three proposed wind power projects would be limited to the immediate vicinity (approximately 2,000 feet) of the wind turbines within each respective project area."[143]

For a plant in Iowa, Northern Iowa Windpower took the extra step of offering 'neighbor agreements' to people living within 1,200 feet of a turbine. According to a case study, the agreements allow the wind power plant to cast a shadow caused by the towers and blades across the respective land. The agreements also permit the plant to emit audible noise in excess of 50 dBA across the land. Sound levels at the outer walls of existing, occupied homes are kept at or below 50 dBA.[144]

Conclusion

Last month the British newspaper *The Telegraph* ran a story titled, "Huge protests by voters force the continent's governments to rethink so-called green energy." It began:

> They introduced the world to "environmentally friendly" energy, but now some of Europe's "greenest" countries are under pressure to backtrack on wind farms in the face of public anger over their impact on the countryside.
>
> Voters are outraged by the unsightly turbines, the loud, low-frequency humming noise that they create and the stroboscopic effects of blades rotating in sunshine.
>
> Opponents are dismayed at the proliferation of the turbines in some of the most beautiful areas of the continent. Conservationists complain that hundreds of birds are killed each month by the rotating blades.

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[141] Letter from Arlin Moulfils, Chairperson, Town of Lincoln, Kewaunee County, Wisconsin, 2/1/00.
[142] FPL Energy, "Application for a Conditional Use Permit for The Addison Wind Farm," 10/11/00, p. 11-10, see in Memo from Catherine M. Lawton to Town of Addison Plan Commission, 12/15/00, p. 36.
[143] Kittitas Valley Wind Power Project Draft EIS, Section 3.10 Transportation, December 2003, p. 3.14.12. http://www.efsec.wa.gov/kittitaswind/deis/3.10%20Transportation.pdf
[144] *Top of Iowa Wind Farm Case Study*, p. 6. http://www.state.ia.us/dnr/energy/main/programs/wind/documents/topofIAWindFarmCaseStudy.pdf

> "The dream of environmentally friendly energy has turned into highly subsidised destruction of the countryside," Germany's influential magazine *Der Spiegel* pronounced last week.[145]

The rest of the article recounts backlashes in Germany, France, Denmark, Holland, and Britain.

In a poll last fall, readers of British magazine *Country Life* voted wind power plants the number one eyesore of that country.[146] The sentiment was so strong that the magazine has launched a petition against the plants.[147] More than 60 national and local groups, led by some of the country's most prominent conservationists, have been fighting against proposed wind power facilities there.[148]

In Scotland, opponents to wind power have founded a new political party, called Scottish Wind Watch, to support at least one candidate to the European elections under the slogan "Save our Hills."[149]

Here in the United States, newspapers are beginning to print articles and editorials questioning the value of wind power. At least one newspaper, the *Caledonian-Record* in Vermont's Northeast Kingdom, has switched from favoring to opposing wind power.[150] Last year, 29 environmental groups, including the Massachusetts Audubon Society, sent a letter to the federal Fish & Wildlife Service asking for more research into turbine impacts on wildlife.[151] This year, the Massachusetts Fisheries & Wildlife Board has asked its federal counterpart for more pre-construction study.[152] In Vermont, multiple groups have galvanized against projects there,[153] the Public Service Board recently delayed permitting

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[145] Renee Mickelburgh, Tony Paterson, and Kim Willsher, "Huge protests by voters force the continent's governments to rethink so-called green energy" *The Telegraph*, 4/4/04, http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2004/04/04/wwind04.xml&secureRefresh=true&_requestid=1493

[146] Mary Miers, "The 10 Most Hated Eyesores Voted by Country Life Readers," *Country Life*, 11/13/03, http://www.countrylife.co.uk/countrysideconcerns/news/eyesore_results.php

[147] Country Life Wind-Farm Campaign, "Petition Against Windfarms," *Country Life*, http://www.countrylife.co.uk/turbinedebate_form.php

[148] Vidal, John, "An ill wind?" *The Guardian*, 5/7/04, http://www.guardian.co.uk/renewable/Story/0,2763,1211314,00.html

[149] Frank Urquhart, "Wind-power opponents form political party," *The Scotsman*, 5/1/04, http://news.scotsman.com/topics.cfm?tid=605&id=494132004&20040509134713

[150] Editorial, "Wind Power In The Northeast Kingdom," *Caledonian-Record*, 12/17/01, http://www.CaledonianRecord.com/pages/editorials/story/8ddcc20d3; Editorial, "Keep Wind Towers Out Of The Kingdom," *Caledonian-Record*, 8/9/03, http://www.CaledonianRecord.com/pages/editorials/story/cef8a53c2

[151] Letter from Meyer & Glitzenstein to Gale Norton, Secretary, Department of the Interior, et al., 6/24/03, http://www.FriendsOfTheAlleghenyFront.org/62403LettertoFWS.pdf

[152] Associated Press, "Berkshire wind farm contested," *Cape Cod Times*, 3/2/04, http://www.CapeCodOnline.com/special/windfarm/berkshirewind2.htm

[153] http://www.GlebeMountainGroup.org; http://www.KingdomCommonsGroup.org

one plan, asking for more study before proceeding,[154] and the governor just said he will not support any new proposals until a study by the legislature is completed.[155] Projects are being opposed in Maine, too.[156] This is not NIMBYism. I, for example, live about two hours away from the Hoosac site. Many people have many serious concerns about the many costs of wind power plants. Berkshire County as a whole seems to have accepted their value without much information from any perspective other than that of proponents. I hope this memo will cause people to investigate in more depth the probable impacts of wind power plants on the rural character, quality of life, and economic base of our region.

[154] Darren M. Allen, "Study on birds, bees may scuttle N.E. Kingdom wind project." *Barre Montpelier Times Argus*. 4/14/04. http://TimesArgus.com/Archive/Articles/Article/82107; Paul Lefebvre, "Birds delay PSB decision," *Barton Chronicle*, 3/24/04, http://www.BartonChronicle.com

[155] Darren M. Allen. "Douglas wants to wait for mandated wind study," *Barre Montpelier Times Argus*. 5/12/04, http://www.TimesArgus.com/04/Story/83562.html

[156] Appalachian Trail Conference. "ATC Opposes Maine Wind Farm Project." http://www.AppalachianTrail.org/protect/issues/redington.html

Date Thu, 4 Dec 2003 18:32:08 -0600

Excerpts from the Final Report of the Township of Lincoln Wind Turbine Moratorium Committee

After the wind turbines went online in Kewaunee County, Wisconsin, the Lincoln Township Board of Supervisors approved a moratorium on new turbine construction. The purpose of the moratorium was to delay new construction of wind turbines for eighteen months, giving the township the opportunity to assess the impacts of the 22 turbines installed by Wisconsin Public Service Corporation (WPSC) and Madison Gas and Electric (MG&E), which went online in June, 1999.

The following document summarizes some of the problems the Moratorium Committee faced in trying to address problems the township hadn't faced prior to turbine construction and some of the resulting changes the committee proposed as a result of its study. Verification of this information can be obtained from Lincoln Township officials.

Agenda
The Moratorium Committee met 39 times between January 17, 2000, and January 20, 2002, to 1) study the impact of wind factories on land, 2) study the impact on residents and 3) review conditional use permits used to build two existing wind factories inLincoln Township.

Survey
The committee conducted a survey on the perceived impacts of the wind turbines that was sent out to all property owners residing in the township. Each household received one vote. The results were presented on July 2, 2001, to the town board, two years after the wind factory construction.

Question: Are any of the following wind turbine issues currently causing problems in your household?

a. Shadows from the blades

residents w/i 800 ft. - 1/4 mi.	residents w/i 1/4 mi. - 1/2 mi.
33% yes	41% yes

Here are additional write-in comments from the survey:
* "We get a 'strobe effect' throughout our house and over our entire property (40 acres)."
* "Shadows are cast over the ground and affect my balance."
* "We installed vertical blinds but still have some problems."
* "They catch my eye and I look at them instead of the road. They are dangerous."
* "Strobe light, headaches, sick to the stomach, can't shit (sic) everything up enough to stop the strobe coming into the house."

An additional comment from Lincoln Township Supervisor John Yunk:

* "The strobing effect is so terrible that turbines should not be any closer than 1 mile from schools, roads and residences . . . They should never be set on East-West."

Dr. Jay Pettegrew, researcher, neurologist and professor for the University of Pittsburgh, testified before the Bureau County Zoning Board of Appeals that strobe effect could cause drivers to have seizures, which could result in fatal traffic accidents. At the very least, drivers could become disoriented and confused, he said. He testified that the turbine spacing (sited on top of hills instead of in a single field in orderly rows) would increase the likelihood of seizures.

It is important to know that according to Lincoln Township Chairperson Arlin Monfils, the wind developers publicly stated that strobe and shadow effect would not occur once the turbines were operating. In reality, strobe and shadow effects were problem enough that residents vehemently complained and the power company anted up for awnings, window treatment blinds and small trees to block the light at certain times of the day. Strobe and shadow effects take place for about 40 minutes during sunrise or sunset if the angle of the sun and the light intensity create the right conditions. Mr. Jeff Peacock, Bureau County highway engineer, has recommended denying permits for 8 turbines due to safety concerns, including strobe effect

Diane Heling, whose property is adjacent to the WPSC turbines, said the utility purchased blinds for her home, but especially in the spring and fall when there are no leaves on the trees, the strobing is at its worst in her home. "It's like a constant camera-flashing in the house. I can't stand to be in the room," Mrs. Heling said. Her neighbor, Linda Yunk, whose property is adjacent to the WPSC turbines, describes the strobe effect as unsettling. "It's like somebody turning something on and off, on and off, on and off . . . It's not a small thing when it happens in your house and when it affects your quality of life to that extent," Mrs. Yunk said.

b. **TV reception**

residents w/i 800 ft. - 1/4 mi.	residents w/i 1/4 mi. - 1/2 mi.
33% yes	37%yes

Additional write-in comments from survey:
* "Ever since they went up our reception is bad."
* "At times you can see shadowing on the TV that imitates the blades' moves, also poor reception."
* "Minimum of 50' antenna tower proposed but no guarantee that would be high enough. Such a tower is unacceptable."
* "At times we get black and white TV. Two channels come in hazy!!"

c. **Blinking lights from on top of the towers**

residents w/i 800 ft. - 1/4 mi.	residents w/i 1/4 mi. - 1/2 mi.

9%yes 15% yes

Additional write-in comments from survey:

* "Blinking red lights disrupt the night sky. They make it seem like we're living in a city or near a factory."
* "At night it is very irritating because they flash in the windows."
* "We have to keep drapes closed at night."
* "Looks like a circus, live in the country for peace and quiet."

d. **Noise**

residents w/i 800 ft. - 1/4 mi.	residents w/i 1/4 mi. - 1/2 mi.
44% yes	52%yes

Additional write-in comments from survey:

* "Sounds like a gravel pit crushing rock nearby."
* "Sometimes so loud it makes it seem like we live in an industrial park. The noise dominates the 'sound scape.' It's very unsettling/disturbing especially since it had been so peaceful here. It is an ongoing source of irritation. Can be heard throughout our house even with all the windows and doors closed."
* "The noise can make it impossible to fall asleep. It makes an uneven pitch not like the white noise of a fan. Can be heard through closed windows making it hard to fall asleep anytime of the year."
* "You can hear them at times as far as two miles away."
* "It is the annoyance of never having a quiet evening outdoors. When the blades occasionally stop its (sic) like pressure being removed from my ears. You actually hear the quiet, which is a relief."

The most illustrative description of turbine noise was that of reverberating bass notes from a neighbor's stereo that penetrate the walls and windows of a home. Now imagine having no recourse for asking anyone to turn down that noise, whether it's during the day or in the middle of the night.

As the result of so many noise complaints, WPSC paid for a noise study. However, residents are still upset that the study was inadequate in that it measured decibel levels for a maximum of five days per season, sometimes only for a few minutes at some sites, and included days when rain and high winds blotted out the noise from the turbines. In addition, many measurements were taken when the turbines were not running. WPSC claimed it did not have the funds for a more comprehensive study, according to resident Mike Washechek, whose home is victim to some of the worst noise caused by the turbines, due to its location downhill and downwind from the WPSC turbines.

e. **Other problems**

On the survey, several residents showed concern over the perceived problem of increased lightning strikes in the area.

Additional write-in comments from survey:

* ". . . bring lighting (sic) strikes closer to our home."
* "More concern over seeing more lightening (sic) than in the past -- before generators were erected."

According to Township Chairperson Monfils, the wind developers declared prior to construction that lightning would not affect the turbines; however, lightning later struck and broke a blade that had to be replaced. In addition, Mrs. Yunk said that one month after the turbines went online, in July, 1999, a lightning and thunderstorm sent enough electricity through the power grid that Mrs. Yunk and Mrs. Heling both lost their computers to what the service technician called a "fried electrical system" -- even though both computers were surge protected. The reason that Mrs. Yunk attributes the electrical surge to lightning striking a turbine on that particular night is that on the night of the storm, her relative, Joseph Yunk, whose television set was also "fried" that same evening, reported seeing lightning move from one of the turbines along the power grid to the nearby homes, which is a common occurrence with wind factories since nearby strikes to either turbines, external power systems or the ground can send several tens of kilovolts along telephone and power lines. Replacements for the computers and television were paid by the residents.

e. Other problems (continued)
On the survey, several residents showed concern over hazardous traffic conditions during and after construction of the turbines. Additional write-in comments from survey:
* "People driving and stopping."
* "While they were being installed the destroying of the roads, noise, and extra traffic have been negative."
* "More traffic and have to back out of driveways (live on hill, hard to see)."
* "More traffic. I used to feel safe walking or riding bike (sic)."
In addition, Mrs. Yunk said that especially when the turbines first went up, other drivers would be looking up at them and they would "dead stop in front of you." She said she narrowly avoided colliding with a car that had stopped abruptly in front of her.

Question: In the last year, have you been awakened by sound coming from the wind turbines?

residents w/i 800 ft. - 1/4 mi.	residents w/i 1/4 mi. - 1/2 mi.
67% yes	35% yes

Additional write-in comments from survey:
* "Enough to go to the doctor because I need sleeping pills. Sometimes it absolutely drives you 'nuts.'"
* "I wake up with headaches every morning because of noise. Causes my (sic) to have very restless sleep at night!"
* "We have no way of knowing long-term affects (sic). Growing concerns with stray voltage and its affect (sic) on health. We've had frequent headaches, which we didn't have before. Especially in the morning, after sleeping at night. We need answers!"
* "Not awakened but found it hard to fall asleep!!!"

Question: How close to the wind turbines would you consider buying or building a home? The results for all survey respondents in the study, including those living over 2 miles away are as follows:

* 61% would not build or buy within 1/2 mile of turbines
* 41% would have to be 2 or more miles away from turbines in order for them to build or buy
* 74% would not build or buy within 1/4 mile of turbines

These are people who know first-hand about the problems caused by the wind factories. They have lived with the turbines for three years. Again, 74% responded that they would not build or buy within1/4 mile of turbines. Common sense dictates that if a 38-story skyscraper is built next to any home and it obstructs the view, that home would not be as valuable on the market as an equivalent home sited away from such an obstruction. Common sense also dictates that if the skyscraper had moving parts that contribute to or have the potential to contribute to blinking lights, strobing, noise, stray voltage, ice throws, and health problems, that home would not be as valuable as it had been previously. The above numbers from Lincoln Township corroborate that common sense.

Additional write-in comments from surveys:
* "Ugly, would not buy in this area again."
* "25+ miles. They can been seen from this distance."
* "Would never consider it. Plan on moving if we can sell our house."
* "No where near them never ever!! Not for a million dollars."

A sampling of some of the overall write-in comments from the survey is as follows:
* "I live approximately 1 1/2 miles from the windmills. On a quiet night with the right wind direction, I can hear the windmill noise. People living within a 1/4 mile should probably be compensated for the noise and the nuisance."
* "The noise, flashing lights, interrupted TV reception, strobe effect and possible effect of stray voltage has created a level of stress and anxiety in our lives that was not present before the turbines' installation. From the beginning there has been a lack of honesty and responsibility."
* "Let other counties or communities be the guinea pigs with the long-term effects or disadvantages of having the windmills. All the landowners who put the windmills up have them on property away from their own homes but on the fence lines and land near all other homeowners."
* "Our whole family has been affected. My husband just went to the doctor because of his stomach. He hates them. We have fights all the time about them. It's terrible. Why did you put them so close to our new home and expect us to live a normal life. If it isn't the shadows it's the damn noise. The only people that think they are so great and wonderful are those who really don't know."
* "When we were dating back in the 1970's we always said that someday we were going to build a home here. It was great and then you guys did this . . This should have never happened. If only you would have taken the time and study this more. Everyone was thinking about themselves and money. No one cared about anything else."

WPSC's buyout offer

During the two years of the Moratorium Committee work, Wisconsin Public Service Corporation made offers to buy houses and property to six property owners around the WPSC wind factory site. Offers were made to property owners who vocalized complaints about the wind factory's effects on their quality of life after construction. According to Lincoln Township Supervisor John Yunk, some of these residents were identified on the Noise Complaint Log record kept by the township. Over 90 complaints were logged in one year.

According to the Moratorium Committee report, WPSC publicly stated the buyout was to establish a buffer zone around the wind factory. The Noise Complaint Log was discontinued by WPSC after the buyout offer.

According to the Moratorium Committee report, WPSC's intention was to bulldoze the houses and subsequently keep the property from being developed for rural residences. Owners were allowed only one month to consider the offer.

According to the Moratorium Committee report, "This tactic did not sit well with the Committee. In response the Committee drafted and approved a resolution condemning the WPSC ploy, and requesting that WPSC meet with the town board to develop a better solution for the township."

WPSC officials met with the town board and concerned citizens at the August 6, 2001, regular board meeting, reiterated their policy to purchase property and destroy the homes, and stated that they had no intention of meeting with the town board or changing their policies at the request of the town board.

Mrs. Heling was offered the buyout, but she said she and her family were allowed only one month to make the decision and only six months to move. In addition, the buyout offer was based solely on an appraisal by someone hired by WPSC. Mrs. Heling said WPSC refused to consider independent appraisals. Mrs. Heling said she couldn't obtain another property within six months, so she and her family rejected the buyout.

* The Gabriel household was set back 1000 feet from the nearest turbine. The family took the buyout. The county no longer receives property taxes on that raised homestead. The family no longer lives in the area
* The Kostichka household was set back 1200 feet from the nearest turbine. The family took the buyout. The county no longer receives property taxes on that raised homestead. The family no longer lives in the area.
* Four remaining homeowners are suing WPSC.

The most recent development is that one homeowner contacted Township Supervisor Yunk during the week of September 11, 2002, and asked what the process would be to request MG&E to buy out her home. She said she has a new baby and two other young children and that she does not want to live in her house any longer because she is too scared about the effects on her family by electronic radiation, stray voltage and other electricity associated with the turbines.

Property values

The following information will directly refute the "Market Analysis: Crescent Ridge Project, Indiantown & Milo Townships, Bureau County, Illinois" report submitted by Michael Crowley to this board. Mr. Crowley, a paid consultant to the Crescent Ridge developers, alleges in his report that property values won't be affected in Bureau County, based on his analysis, in part, of property values in Kewaunee County.

However, Town of Lincoln zoning administrator Joe Jerabek compiled a list of properties that have been sold in the township, and their selling prices. The list compared the properties' selling price as a function of the distance to the wind factories, using real estate transfer returns and the year 2001 assessment roll.

Conclusions were as follows:

* "Sales within 1 mile of the windmills prior to their construction were 104 percent of the assessed values, and properties selling in the same area after construction were at 78 percent, a decrease of 26 points."

* "Sales more than 1 mile away prior to construction were 105 percent of the assessed values, and sales of properties 1 mile or more after the construction of the turbines declined to 87 percent of the assessed value, an 18 point decline."

Furthermore, not taken into account in Mr. Jerabek's conclusion are the homes that were bought out and bulldozed by WPSC.

Also not taken into account is the fact that of the homes that sold within one mile of the turbines since their construction, four of them were owned within the Pelnar family as the family members shuffled houses. One brother sold to another brother. One brother purchased his father's home. The father built a new home. And a sister purchased land from one brother and built a home. It is important to note that two of the family members are turbine owners themselves.

Subsequent to the zoning administrator's report, homes have gone on the market that are still for sale.
* 1 home, sited across the road from the wind factory, was constructed after the turbines were built and has been on the market for over 2 years
* 2 homeowners adjacent to the turbines are contemplating selling to WPSC, which may bulldoze the homes, according to neighbor Scott Srnka.
* 1 homeowner is in the process of finding out if MG&E will buy out her home
* 1 homeowner, Mrs. Heling, who previously was offered the WPSC buyout, said she would sell if she thought she could get fair value for her home and if it would sell quickly enough that she wouldn't be paying on two properties at once. She said she doesn't believe that can happen, so she has not put up her home for sale.
* 1 homeowner, Mrs. Yunk, who lives across from the WPSC turbines, said she and her husband have decided that after having lived in their home for 28 years, they will be putting it up for sale to move to property farther away from the turbines. She said they are worried about selling their current property because of its proximity to the turbines. They will have to find a buyer who doesn't mind the turbines, she said.

Stray voltage
Another issue addressed by the Moratorium Committee is that of stray voltage and earth-current problems that may be exacerbated by the wind factories. This issue was brought to the attention of the Lincoln Town Board by the committee and concerned residents. An ordinance was passed by the Town Board to study the potential effects and to declare a moratorium on any further turbine development. The Committee agreed that any study of earth currents and stray voltage issues must include an analysis of the distribution system, analysis of the wiring from the utility's grid to the wind turbines, and an analysis of the grounding system used for the wind turbines. They also drafted a request for proposals to identify an expert that could help pinpoint the issues surrounding stray voltage and earth currents. The issue has yet to be resolved.

In the meantime, farmers and their livestock in Lincoln Township have been suffering. There are over four farms that are battling -- among other problems -- herd decline due to diseases that were not present in the herds prior to turbine construction, but are present now, according to farmer Scott Srnka. These problems are not limited to non-participating leaseholders. Farms with turbines have been affected as well, as evidenced by the trucks, which have grown more and more frequent, hauling away animal carcasses, Mr. Srnka said.

Mr. Srnka is a former supporter of the WPSC wind power project that is across the road from his family farm. His dairy herd is about 175 cows on 800 acres of land. Mr. Srnka said, "Thirteen turbines were proposed for my land, but we decided to wait. Thank goodness we did or we'd be out of farming."

Mr. Srnka has traced the decline of milk production and increase of cancer and deformities in his formerly award-winning herd to an increase of electrical pollution on his farm after turbine construction. He also has seen the same chronic symptoms that are in his herd in his family

Animal health problems in the Srnkas' formerly award-winning herd include cancer deaths, ringworm, mange, lice, parasites, cows not calving properly, dehydration, mutations such as no eyeballs or tails, cows holding pregnancy only 1 to 2 weeks and then aborting, blood from nostrils, black and white hair coats turning brown, mastitis, kidney and liver failure.

Within a few months in the first year after the turbines were erected, 8 cows died of cancer. No previous cases of cancer were detected ever before in the Srnka herd, which is a closed herd, according to Mr. Srnka.

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Mr. Srnka also detected a change in well water on his property, and there has been a definite change in taste, he said, which has contributed to the decrease in water consumption by his herd. In the past his cows consumed 30 gallons of water a day, but that figure declined to 18 to 22 gallons of water a day after turbine construction. As a result, cows became dehydrated and terminally ill.

Video: What the Zoning Board of Appeals members saw was a brief, unedited video interview with Mr. Srnka in his dairy barn, taken this spring. In it there were some of the cows in his herd and Mr. Srnka talking about some of the rewiring that he has had to install to try to combat problems of electrical pollution. Mr. Srnka said that he has had to resort to insulating the farm through electrical wiring to put his farm, in effect, on what he calls its own island.

Dr. Pettegrew, testifying before the Bureau County> Zoning Board of Appeals, said he would be remiss as a doctor if he didn't tell the board that he thought the weaknesses and illness he saw in the cows in the video were most likely caused by EMFs or electrical pollution. Dr. Pettegrew also said the risk would be greater in Indiantown and Milo for animals and humans to become ill than in Wisconsin because the proposed turbines would be taller and would produce more electricity

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Back to what Mr. Srnka has personally experienced.

Mr. Srnka and neighbors report serious health effects on not just dairy cows. Health problems in residents include

* sleep loss
* diarrhea
* headaches
* frequent urination
* 4 to 5 menstrual periods per month
* bloody noses: Mr. Srnka had cows bleed to death from uncontrollable bleeding from the nostrils
* inability to conceive

Sometimes even short-term visitors to the farms or homes contract the symptoms, including construction workers on the Srnka property who broke out in nosebleeds after only a few hours. One of the workers left and refused to return. The Srnkas are so concerned with health effects that they "aren't going to have kids anymore because we're so afraid."

At the time of his testimony before the Bureau County ZBA in October, Mr. Srnka said he had spent upwards of $50,000 of his own money to try to remedy the electrical pollution in his home and on his farm. Mr. Srnka stated that in his opinion, there were three other farms in the area facing enough problems with their herds in the aftermath of the turbines going online that those three farms are "almost ready to sell out."

Representatives of WPSC have denied that there are stray voltage or earth currents affecting Mr. Srnka's family or livestock and will not compensate him for his family health bills, electrical system upgrades, loss of herd or decrease in milk production.

How did the situation become so grave when wind factory developers swore there would be no problems?

Even if a wind developer may claim that the wind factories, substations and power grids will not contribute to stray voltage or electrical pollution because 1) insulated cable will be used, 2) all cable will be buried feet beneath the surface, and 3) cables are laid in thick beds of sand -- these statements should be viewed with suspicion because of poor project track records, according to Larry Neubauer, a master electrician with Concept Electric Inc., in Appleton, Wisconsin. Mr. Neubauer, who has customers who are dairy producers, who are homeowners with stray voltage problems, and who are farmers with turbines on their property, said that currents from each ground on the cables and project substations, as well as the regional transmission lines that receive electrical energy and that are electrically tied together, do not harmlessly dissipate into the soil. Energy disperses in all directions through the soil and these currents seek out other grounded facilities, such as barns, mobile homes and nearby residences. Only in California is it illegal to use the ground as an electricity conductor. In the rest of the country, including Wisconsin and Illinois, power companies are allowed to dump currents into the ground, according to Mr. Neubauer.

Residential properties that are in a direct line between substations and the ground conduits are particularly at high risk since electricity takes the path of least resistance. Mr. Neubauer said that burying the cables, as the Illinois Wind Energy, LLC, project intends to do, "makes it worse," citing the short lifespans of buried cables, frosts that wreak havoc on the cables, and the problems of locating trouble spots that cannot be seen without digging up the cables.

Two of Mr. Neubauer's clients, who were interviewed in October, are dairy farmers who have spent over $250,000 and $300,000 trying to rewire their farms to reduce stray voltage. That cost does not included herd loss or losses from diminished milk production. Mr. Russ Allen owns 550 dairy cows in DePere, Wisconsin. His farm is in a direct line between nearby WPSC turbines and a substation. Mr Russ said he was losing one or two cows a day during the three years prior to his installing electrical equipment to help reduce currents on his farm. About 600 cows died, he said. Mr. Russ said he has so much electrical current on his farm that he laid a No. 4 copper wire around his farm for 5,000 feet. The wire is not attached to any building or additional wires; yet it can light up a lightbulb from contact with the soil alone. Mr. Russ has scheduled a media day on October 24 to draw awareness to the problems of stray voltage and he said to encourage everyone in Bureau County to attend.

"What scares me more is that I know . . . they're pumping current through people. They're pumping current through kids," Mr. Allen said

It is important to note that Mr. Noe and his electrical engineer, Mr. Pasley, deny that there will ever be EMFs or stray voltage resulting from the proposed Indiantown/Milo turbines. Just as WPSC has dismissed any problems in the face of mounting evidence, Mr. Noe testified that he will never implement electrical pollution studies and that he thinks they would be a waste of money.

Moratorium Committee findings

As a result of the aforementioned concerns and problems with wind factories in Lincoln Township, the Moratorium Committee recommended, in brief, the following changes from the original conditional use permit:

* **Insurance.** The town is named as an additional insured and the town is held harmless in any litigation.

* **Fees.** Wind developers pay for all costs associated with the permitting process, including hearing costs plus attorney fees -- up front.

* **Wells.** Residents' wells are protected against damage from any type of foundation construction, not only blasting, within a 1-mile radius of each turbine. This includes the requirement that wind developers will pay for independent testing of wells within 1 mile of the project for flow rate and water quality. Developers also must pay for remediation and fix problems within 30 days of complaints.

It is important to note that no well water studies of properties adjacent to the proposed Indiantown/Milo project are planned to assure that all well wills retain the same quality of water before and after turbine construction

* **TV reception.** Wind developers will pay for testing of television reception prior to construction and pay to correct degradation of TV signals. Wind developers will expand the potential problem area to a 1-mile radius for all complaints -- period.

It is important to note that despite claims that television reception would not be affected, the wind factory developers in Lincoln Township had to pay for power boosters and reception equipment to counteract the effects of the turbines. The residents also had to fight with the utilities when an additional local station was added and the utilities refused to pay for any more TV reception improvements for the duration of the 30-year turbine contract. Residents had to fight to get the power company to add the station. Three years later, residents are still unhappy about how the turbines continue interfere with their reception, in many cases observable in unclear stations and in the color flashes that coincide with the turning of the blades, according to Mrs. Heling.

It also is importation to note that no television reception testing is planned prior to turbine construction in Indiantown or Milo townships and that Mr. Noe said steps taken to correct reception problems would have to be reasonable.

* **Noise.** 50 decibels for noise is too great. Noise shall not exceed 40 to 45 decibels, though 35 decibels was recommended unless there is written consent from affected property owners. It is important to note that the noise study submitted by Illinois Wind Energy, LLC, uses theoretical generalizations about topography and noise conduction and does not use the same height or turbine models proposed for Indiantown and Milo.

As a side note, according to Walgreens Drug Store Web site, the "most sensitive" earplugs they sell only block out noise at 30 decibels.

* **Tower removal**. Turbines and all relegated aboveground equipment shall be removed within 120 days after the date the generators reach the end of their useful lives, the date the turbines are abandoned, the termination of the landowner lease, or revocation of the permit. An escrow account will be established or bonding provided by the wind developers to ensure tower removal.

* **Tourism**. Wind developers are banned from promoting the project as a tourist destination, will not provide bus or tourist parking and will not provide promotional signs located at the projects or elsewhere.

It is important to note that despite the ordinance prohibiting promotion of the wind turbine project, WPSC was caught red-handed by Township Supervisor Yunk last month in August filming a promotional video with child actors riding bicycles in front of the turbines. Mr. Yunk ordered the film crew to leave, but they refused and continued filming. The township has found that once the turbines were constructed, it has been practically impossible to enforce the ordinance or gain cooperation from WPSC or MG&E.

* **Road damage**. Wind developers will pay for the total cost to return the towns' roads to town standards, not just pay for damaged areas. Any road damage caused by the wind developers during the repair, replacement, or decommissioning of any wind turbines will be paid for by the wind developers. An independent third party will be paid by the wind developers to pre-inspect roadways prior to construction.

It is important to note that Township Chairperson Monfils said that it's not a matter of "if" there will be road damage. There will be road damage. The wind factory developers in Lincoln Township said originally that they would fix the roads if there were damage. But when it came time to fix the roads, the township had to "scrap with them to get it done," according to Mr Monfils. He said the developers disputed the costs and he had to battle with them two or three times to get repairs paid.

* **Periodic review**. Every year the project will undergo a periodic review for the purpose of determining whether wind developers have complied with the permit and whether wind projects have had any unforeseen adverse impacts. Any condition modified or added following the review will be of the same force and effect as if originally imposed. Wind developers will send a representative at least once a year to report the operating status of the projects and to receive questions and comments from the governing body and township residents.

It is important to note that even with the review, Lincoln Township residents reported being dissatisfied with the developers' response to their complaints. Mrs. Yunk said the developers were readily available prior to construction, but afterward were scarce. She said she fielded calls from residents who could not reach developers and residents who were given the run-around, being told they needed to contact other people within the organization. She said residents' concerns and problems were deflected by the developers, who said residents had to prove that problems did not exist previously and residents had to prove that without a doubt the problems were the result of the turbines.

* **Health and safety** If a serious adverse unforeseen material impact develops due to the operation of any of the turbines that has a serious detrimental effect on the township or a particular resident, the township has a right to request the cessation of those turbines in question until the situation has been corrected.

* **Setbacks**. The minimum suggested setback from the nearest residences or public buildings is 1000 feet, though 1500 feet was recommended. Setbacks from adjacent property lines will be no less than the tower height plus the length of an extended blade. Minimum distance between turbines will never be less than 800 feet.

* **Strobing effect**, blade shadows and stray voltage earth currents are some other issues to be addressed.

In effect, with these guidelines, Lincoln Township is making construction of new turbines unattractive to further development. They are finding it almost impossible to remedy problems with the current turbines and restore a former quality of life to residents. However, they are trying to ensure no more mistakes will be made.

As Mrs. Yunk plainly said, "Anyone that thinks there aren't going to be problems resulting from the turbines has got another guess coming." She said that she and other residents felt like the bad guys for opposing the turbine project and warning other residents that the project would spell disaster. She said she hates now that what they feared has come true; there isn't any self-satisfaction in being able to say, "I told you so."

The board must weigh heavily the situation of Kewaunee County and the voices and experiences of residents who have no vested interest in wind development in Bureau County. They have no vested interest in telling anything but the truth. They are telling it like it is, and unfortunately, like it was.

For additional information
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A Problem With Wind Power

[illegible]

by Eric Rosenbloom

Output figures from wind developers are typically annual averages expressed in the vague figure of "number of homes provided for." Homes, however, account for only a third of all electricity use, and electricity represents only a third of all energy consumption (only a fifth in Vermont). Further, home use of electricity varies widely through the day, week, and year, but wind plants generate electricity by the whims of the wind rather than the actual needs of the grid.

As averages, the figures ignore the fact that hour to hour, day to day, season to season, even the most windy sites experience periods of calm when the turbines are producing no electricity at all and cycles of slower wind when they are producing far less than their maximum capacity. When the wind is too fast, the turbines must shut down to avoid damage.

This variability, they say, is balanced by wiring up a multitude of sites, one of which at any time must surely be producing significant power. Instead of a "free and clean" source of energy, then, the necessary proposal is an expensive network of redundant installations that must fill most of our land and seascapes to have any impact at all.

Despite local variabilities, however, the overall rise and fall of the wind is generally the same over the larger region. The grid must plan for the likely low point, i.e., the least power it may see from all of the attached wind plants. Large power plants cannot respond quickly to the hourly variations of the wind, so they must be already going when the power from the wind plants drops off.

There are solutions to this on a small scale, but for most grid systems, any power produced by wind plants is therefore in practice superfluous. The backup generation is already providing it.

On top of this uselessness, the turbines use a great deal of electricity themselves. Most of them cannot even run without input from the grid. Although they produce electricity intermittently, they consume it continuously. In every report I've seen, input from the grid is not accounted for in the figures of net output. Specifications from turbine manufacturers do not include the amount of electricity they require.

It may be that large wind turbines use as much electricity as they produce. Whether the wind is blowing in the desired range or not, they need power to keep the generator magnetized, to keep the blade and generator assembly (92 tons on a 3.5 MW GE) facing the wind, to periodically spin that assembly to unwind the cables in the tower, to heat the blades in icy conditions, to start the blades turning when the wind is just getting fast enough to keep them going, to keep the blades pitched to spin at a regular rate, and to run the lights and internal control and communication systems.

It is clear that industrial wind generation is not able to contribute anything against the problems of global warming, pollution, nuclear waste, or dependence on imports. In Denmark, with the most per-capita wind turbines in the world, the output from wind facilities equals 15%-20% of their electricity consumption. The Copenhagen newspaper *Politiken* reported, however, that wind provided only 1.7% of the electricity actually used in 1999. The grid manager for western Denmark reported that in 2002 84% of their wind generated electricity had to be exported, i.e., dumped at extreme discount. The turbines are often shut down, because it is so rare that good wind coincides with peaking demand. A director of the western Denmark utility has stated that wind turbines do not reduce CO_2 emissions, the primary marker of fossil fuel use.

But industrial wind facilities are not just useless. They destroy the land, birds and bats, and the lives of their neighbors. Off shore, they endanger ships and boats and their low-frequency noise is likely harmful to sea mammals. They require subsidies and regulatory favors to make investment viable. They do not move us towards more sustainable energy sources and stand instead as monuments of delusion.

-- *December 2004*

A Problem With Wind Power

Eric Rosenbloom – August 23, 2005

Wind power promises a clean and free source of electricity. It will reduce our dependence on imported fossil fuels and reduce the output of greenhouse gases and other pollution. Many governments are therefore promoting the construction of vast wind "farms," encouraging private companies with generous subsidies and regulatory support, requiring utilities to buy from them, and setting up markets for the trade of "green credits" in addition to actual energy. The U.S. Department of Energy (DOE) aims to see 5% of our electricity produced by wind turbine in 2010. Energy companies are eagerly investing in wind power, finding the arrangement quite profitable

A little research, however, reveals that wind power does not in fact live up to the claims made by its advocates (see part I), that its impact on the environment and people's lives is far from benign (see part II), and that with such a poor record and prospect the money spent on it could be much more effectively directed (see part III).

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In 1998, Norway commissioned a study of wind power in Denmark and concluded that it has "serious environmental effects, insufficient production, and high production costs."

Denmark (population 5.3 million) has over 6,000 turbines that produced electricity equal to 19% of what the country used in 2002. Yet no conventional power plant has been shut down. Because of the intermittency and variability of the wind, conventional power plants must be kept running at full capacity to meet the actual demand for electricity. Most cannot simply be turned on and off as the wind dies and rises, and the quick ramping up and down of those that can be would actually increase their output of pollution and carbon dioxide (CO_2, the primary "greenhouse" gas). So when the wind is blowing just right for the turbines, the power they generate is usually a surplus and sold to other countries at an extremely discounted price, or the turbines must be shut off.

A writer in *The Utilities Journal* (David J. White, "Danish Wind: Too Good To Be True?," July 2004) found that 84% of western Denmark's wind-generated electricity was exported (at a revenue loss) in 2003, i.e., Denmark's glut of wind towers provided only 3.3% of the nation's electricity. According to *The Wall Street Journal Europe*, the Copenhagen newspaper *Politiken* reported that wind actually met only 1.7% of Denmark's total demand in 1999. Besides the amount exported, this low figure may also reflect the actual *net* contribution. The large amount of electricity used by the turbines themselves is typically not accounted for in the usually cited output figures.[1]

Denmark is just dependent enough on wind power that when the wind is not blowing right they must import electricity. In 2003 they imported more electricity than they exported. And added to the Danish electric bill are the subsidies that support the private companies building the wind towers. Danish electricity costs for the consumer are the highest in Europe.[2]

The head of Xcel Energy in the U.S., Wayne Brunetti, has said, "We're a big supporter of wind, but at the time when customers have the greatest needs, it's typically not available." Throughout Europe, wind turbines produced on average less than 20% of their theoretical (or *rated*) capacity. Yet both the British and the American Wind Energy Associations (BWEA and AWEA) plan for 30%. The figure in Denmark was 16.8% in 2002 and 19% in 2003 (in February 2003, the output of the more than 6,000 turbines in Denmark was 0!). On-shore turbines in the U.K. produced at 24.1% of their capacity in 2003. The average in Germany for 1998–2003 was 14.7%. In the U.S., usable output (representing wind power's contribution to consumption, according to the Energy Information Agency) in 2002 was 12.7% of capacity (using the average between the AWEA's figures for installed capacity at the end of 2001 and 2002). In California, the average is 20%. The Searsburg plant in Vermont averages 23%, declining every year. This percentage is called the *load factor* or *capacity factor*. The rated generating capacity only occurs during 100% ideal conditions, typically a sustained wind speed over 30 mph. As the wind slows, electricity output falls off exponentially.

(1 megawatt (MW, 1 million watts) of power output × 24 hours × 365 days = 8,760 megawatt-hours (MW-h) energy per year; if a 1-MW wind turbine actually produces 1,752 MW-h over a year, owing to the variability of the wind and other factors, its capacity factor is 1,752/8,760 = 0.20, or 20%.)

In high winds, ironically, the turbines must be stopped because they are easily damaged. Build-up of dead bugs has been shown to halve the maximum power generated by a wind turbine, reducing the average power generated by 25% and more. Build-up of salt on off-shore turbine blades similarly has been shown to reduce the power generated by 20%–30%.

Eon Netz, the grid manager for about a third of Germany, discusses the technical problems of connecting large numbers of wind turbines in their 2004 "Wind Report": Electricity generation from wind fluctuates greatly, requiring additional reserves of "conventional" capacity to compensate; high-demand periods of cold and heat correspond to periods of low wind; only limited forecasting is possible for wind power; wind power needs a corresponding expansion of the high-voltage and extra-high-voltage grid infrastructure; and expansion of wind power makes the grid more unstable.

Despite their being cited as the shining example of what can be accomplished with wind power, the Danish government has cancelled plans for three offshore wind farms planned for 2008 and has scheduled the withdrawal of subsidies from existing sites. Development of onshore wind plants in Denmark has effectively stopped. Because Danish companies dominate the wind industry, however, the government is under pressure to continue their support. Spain began withdrawing subsidies in 2002. Germany reduced the tax breaks to wind power, and domestic construction drastically slowed in 2004. Switzerland also is cutting subsidies as too expensive for the lack of significant benefit. The Netherlands decommissioned 90 turbines in 2004. Many Japanese utilities severely limit the amount of wind-generated power they buy, because of the instability they cause. For the same reason, Ireland in December 2003 halted all new wind-power connections to the national grid. In early 2005, they were considering ending state support. In 2005, Spanish utilities began refusing new wind power connections. In 2005, Spanish utilities began refusing new wind power connections. In 2004, Australia reduced the level of renewable energy that utilities are required to buy, dramatically slowing wind-project applications. On August 31, 2004, Bloomberg News reported that "the unstable flow of wind power in their networks" has forced German utilities to buy more expensive energy, requiring them to raise prices for the consumer.

A German Energy Agency study released in February 2005 after some delay stated that increasing the amount of wind power would increase consumer costs 3.7 times and that the theoretical reduction of greenhouse gas emissions could be achieved much more cheaply by simply installing filters on existing fossil-fuel plants. A similar conclusion was made by the Irish grid manager in a study released in February 2004:[2] "The cost of CO_2 abatement arising from using large levels of wind energy penetration appears high relative to other alternatives."

In Germany, utilities are forced to buy renewable energy at sometimes more than 10 times the cost of conventional power, in France 3 times. In the U.K., the *Telegraph* has reported that rather than providing cheaper energy, wind power costs the electric companies £50 per megawatt-hour (MW-h), compared to £15 for conventional power.[3] The wind industry is worried that the U.K., too, is starting to see that it is only subsidies and requirements on utilities to buy a certain amount of "green" power that prop up the wind towers and that it is a colossal waste of resources. The BWEA has even resorted to threatening prominent opponents as more projects are successfully blocked. Interestingly, long-term plans for energy use and emissions reduction by both the U.K. and the U.S. governments do not mention wind.[4] Flemming Nissen, head of development at the Danish utility Elsam, told a meeting in Copenhagen, May 27, 2004, "Increased development of wind turbines does not reduce Danish CO_2 emissions."

Installation of wind towers can not hope to keep up with the continuing increase of energy use (not only are they very expensive for their output, they also require huge swaths of land). Denmark's annual production from wind turbines increased 28 petajoules (PJ, 1 PJ = 278,000 MW-h) from 1990 to 1998, but total energy consumption increased 115 PJ. The International Energy Agency reports that from 1990 to 2002, Denmark's annual production from wind turbines rose 3,689 GW-h, but total electricity production rose 12,730 GW-h. The Danish government's National Environmental Research Institute reported that in 2003 greenhouse gas emissions increased 7.3% over 2002 levels.[5]

In the U.K. (population 60 million), 1,010 wind turbines produced 0.1% of their electricity in 2002, according to the Department of Trade and Industry. The government hopes to increase the use of renewables to 10.4% by 2010 and 20.4% by 2020, requiring many tens of thousands more towers. As demand will have grown, however, even more turbines will be required. In California (population 35 million), according to the state energy commission, 14,000 turbines (about 1,800 MW capacity) produced half of one percent of their electricity in 2000. Extrapolating this record to the U.S. as a whole, and without accounting for an increase in energy demand, well over 100,000 1.5-MW wind towers (costing $150–300 billion) would be necessary to meet the DOE's goal of a mere 5% of the country's electricity from wind by 2010.

The DOE says there are 18,000 square miles of good wind sites in the U.S., which with current technology could produce 20% of the country's electricity. This rosy plan, based on the wind industry's sales brochures, as well as on a claim of electricity use that is only three quarters of the actual use in 2002, would require "only" 142,060 1.5-MW towers. They also explain, "If the wind resource is well matched to peak loads, wind energy can effectively contribute to system capacity." That's a big *if*—counting on the wind to blow exactly when demand rises, especially if you expect the wind to cover 20% (or even 5%) of that demand. As in Denmark and Germany, you would quickly learn that the prudent thing to do is to look elsewhere first in meeting the load demand. And we'd be stuck with a lot of generally unhelpful hardware covering every windy spot in the U.S., while the developers would be looking to put up yet more to make up for and deny their failings.

As in Denmark and Germany, the electricity from those towers—no matter how many—would be too variable to provide the predictable supply that the grid demands. They would have no effect on established electricity generation, energy use, or continuing pollution. Christopher Dutton, the CEO of Green Mountain Power, a partner in the Searsburg wind farm in Vermont and an advocate of alternative energy sources, has said (in an interview with Montpelier's *The Bridge*) that there is no way that wind power can replace more traditional sources, that its value is only as a supplemental source that has no impact on the base load supply. "By its very nature, it's unreliable," says Jay Morrison, senior regulatory counsel for the National Rural Electric Cooperative Association.

As Country Guardian, a U.K. conservation group, puts it, wind farms constitute an *increase* in energy supply, not a replacement. They do not reduce the costs—environmental, economic, and political—of other means of energy production. If wind towers do not reduce conventional power use, then their manufacture, transport, and construction only increases the use of dirty energy. The presence of "free and green" wind power may even give people license to use more energy.

II.

Size

Pictures from the energy companies show slim towers rising cleanly from the landscape or hovering faintly in the distant haze, their presence modulated by soft clouds behind them. But a 200- to 300-foot tower supporting a turbine housing the size of a bus and three 100- to 150-foot rotor blades sweeping over an acre of air at more than 100 mph requires, for a start, a large and solid foundation. On a GE 1.5-MW tower, the turbine housing, or *nacelle*, weighs over 56 tons, the blade assembly weighs over 36 tons, and the whole tower assembly totals over 163 tons.

FPL (Florida Power & Light) Energy says, "a typical turbine site takes about a 42 × 42-foot square graveled area." Each tower (and a site needs at least 15–20 towers to make investment in the required transmission infrastructure worthwhile) requires a huge hole filled with tons of steel-reinforced concrete (e.g., about 1,000 tons, well over 500 cubic yards, in each foundation at the Te Apiti facility in New Zealand). According to Country Guardian, the hole is large enough to fit three double-decker buses. At the 89-turbine Top of Iowa facility, the foundation of each 323-foot assembly is a 7-feet-deep 42-feet-diameter octagon filled with 25,713 pounds of reinforced steel and 181 cubic yards of concrete. At Buffalo Mountain in Tennessee, each foundation is at least 30 feet deep and may contain more than 3,500 cubic yards of concrete (production of which is a major source of CO_2). On Cefn Croes in Wales the developer built a complete concrete factory on the site, as well as opened quarries to provide rock for new roads—neither of which activities were part of the original planning application.[7]

On many such mountain ridges as well as other locations, it would be necessary to blast into the bedrock, as Enxco's New England representative, John Zimmerman, has confirmed, possibly disrupting the water sources for wells downhill. At the Waymart plant in Pennsylvania, the foundations extend 30-40 feet into the bedrock. At Romney Marsh in southern England, foundation pillars will be sunk 110 feet. For each 6-feet-deep foundation at the Crescent Ridge facility in Illinois, another 24 feet was dug out and filled with sand. Construction at a site on the Slieve Aughty range in Ireland in October 2003 caused a 2.5-mile-long bog slide.

(Building on peat bogs is recognized as a serious disruption of an important carbon sink; the Royal Society for the Protection of Birds opposes wind development on the Scottish island of Lewis because the turbines would take 25 years to theoretically save the amount of carbon that their construction will release from the peat (not to mention the threat to birds—see below). Clearing forests for facilities on mountain ridges is an analogous situation. Such mountain-top clearing has serious runoff implications as well as documented at the Meyersdale plant in Pennsylvania.)

FPL Energy also says, "although construction is temporary [a few months], it will require heavy equipment, including bulldozers, graders, trenching machines, concrete trucks, flatbed trucks, and large cranes." Getting all the equipment, as well as the huge tower sections and rotor blades, into an undeveloped area requires the construction of wide straight strong roads. Many existing roads, particularly in hilly areas, are inadequate. For the Buffalo Mountain project, curves were widened, switchbacks were eliminated, and portions were repaved. The weight of the material has damaged existing roads. Many an ancient hedgerow in England has been sacrificed for access to project sites.

The destructive impact that such construction would have, for example, on a wild mountain top, is obvious. Erosion, disruption of water flow, and destruction of wild habitat and plant life would continue with the presence of access roads, power lines, transformers, and the tower sites themselves. For better wind efficiency, each tower requires trees to be cleared. Vegetation would be kept down with herbicides, further poisoning the soil and water. Each tower should be at least 5–10 times the rotor diameter from neighboring towers and trees for optimal performance. For a tower with 35-meter rotors, that is 1,200–2,400 feet, a quarter to half of a mile. A site on a forested ridge would require clearing 50–100 acres per tower to operate optimally (although only 4–6 acres of clearance per tower, the towers spaced every 500–1,000 feet, is typical). The Danish grid operator Eltra has found that a turbine can decrease the production of another turbine 5 kilometers (3.1 miles) away. The proposed 45-square-mile facility on the Scottish island of Lewis represents 50 acres for each megawatt of rated capacity. FPL Energy says it requires 40 acres per installed megawatt, and the U.S. Environmental Protection Agency (EPA) says 60 acres is likely. Facilities worldwide generally use 30–70 acres per megawatt, i.e., about 120–280 acres for every megawatt of likely *average* output (25% capacity factor).

GE boasts that the span of their rotor blades is larger than the wingspan of a Boeing 747 jumbo jet. The typical 1.5-MW assembly is two stories higher than the Statue of Liberty, including its base and pedestal. The editor of *Windpower Monthly* wrote in September 1996, "Too often the public has felt duped into envisioning fairy tale 'parks' in the countryside. The reality has been an abrupt awakening. Wind power stations are no parks." They are industrial and commercial installations. They do not belong in wilderness areas. As the U.K. Countryside Agency has said, it makes no sense to tackle one environmental problem by instead creating another.

In Vermont, billboards are banned from the highways, and development—especially at sites above 2,500 feet—is subject to strong environmental laws, yet many who call themselves environmentalists absurdly support the installation of wind farms on our mountain ridge lines as a desirable trade-off, ignoring wind's dismal record as described in part 1.

Even if one thinks that jumbo jet-sized wind towers dominating every ridge line in sight like a giant barbed-wire fence is a beautiful thing, many people are drawn to wild places to avoid such reminders of human industrial might. Many communities depend on such tourists, who will now seek some other –as yet unspoiled– retreat.

Birds, Bats, and Other Wildlife

The spinning blades kill and maim birds and bats. The Danish Wind Industry Association, for example, admits as much by pointing out that so do power lines and automobiles. (The argument follows the æsthetic one that the landscape is already blighted in many ways, so why not blight it a little more?) The industry claims that moving from latticework towers, which provided roosting and nesting platforms, to solid towers as well as larger lower-rpm blades solved the problem, and that studies find very few dead birds around wind turbines. They ignore the facts that the larger blades are in fact slicing the air faster (over 100 mph at their tips), that scavengers will have removed most injured and dead birds before researchers arrive for their periodic surveys, and that many areas where dead and injured birds (and bats– see below) might fall are inaccessible..

Especially vulnerable are large birds of prey that like to fly in the same sorts of places that developers like to construct wind towers. Fog– a common situation on mountain ridges—aggravates the problem for all birds. Guidelines from the U.S. Fish and Wildlife Service (FWS) state that wind towers should not be near wetlands or other known bird or bat concentration areas or in areas with a high incidence of fog or low cloud ceilings, especially during spring and fall migrations. It is illegal in the U.S. to kill migratory birds. The FWS has prevented any expansion of the several Altamont Pass wind plants in California, rejecting as well the claim that new solid towers would mitigate the problem.[3]

A 2002 study in Spain estimated that 11,200 birds of prey (many of them already endangered), 350,000 bats, and 3,000,000 small birds are killed each year by wind turbines and their power lines. Another analysis[4] found that it is officially recognized (and obscured, generally by implying monthly figures as annual) that on average a single turbine tower kills 20–40 birds each year. The U.S. FWS estimates that European wind power kills 37 birds per turbine each year. The wind industry, in contrast, cites the absurdly low results of a single very spotty study at one site as gospel.

Windpower Monthly reported in October 2003 that the shocking number of bats being killed by wind towers in the U.K. is causing trouble for developers. The president of Bat Conservation International, Merlin Tuttle, has said, "We're finding kills even in the most remote turbines out in the middle of prairies, where bats don't feed." At least 2,000 bats were killed on Backbone Mountain in West Virginia in just 2 months during their 2003 fall migration. Continuing research has found that rate to be typical all year, or even low, for wind turbines on forested ridges.

Wildlife on the ground is displaced as well. Prairie birds are especially affected by disturbance of their habitat, and construction on mountain ridges diminishes important forest interior far beyond the extent of the clearing itself. A visitor to the Backbone Mountain facility wrote,[10] "I looked around me, to a place where months before had been prime country for deer, wild turkey, and yes, black bear, to see positively no sign of any of the animals about at all. This alarmed me, so I scouted in the woods that afternoon. All afternoon, I found no sign, sight, or peek of any animal about."

Noise

The same West Virginia writer found the noise from the turbines on Backbone Mountain to be "incredible. It surprised me. It sounded like airplanes or helicopters. And it traveled. Sometimes, you could not hear the sound standing right under one, but you heard it 3,000 yards down the hill." Yet the industry insists such noise is a thing of the past. Indeed, new turbines may have quieter bearings and gears, but the huge magnetized generators can not avoid producing a low-frequency hum, and the problem of 120-foot rotor blades chopping through the air at over 100 mph also is insurmountable (a 35-meter [115-foot] blade turning at 15 rpm is travelling 123 mph at the tip, at 20 rpm 164 mph). Every time each rotor passes the tower, the compression of air produces a deep resonating thump. Only a gravelly "swishing" may be heard directly beneath the turbine, but farther away the resulting sound of several towers together has been described to be as loud as a motorcycle, like aircraft continually passing overhead, a "brick wrapped in a towel turning in a tumble drier," "as if someone was mixing cement in the sky," "like a train that never arrives." It is a relentless rumble like unceasing thunder from an approaching storm. Some people have also described an eerie screeching when the blade and nacelle assembly turns to catch the wind.[21] Enxco's John Zimmerman admitted at a meeting in Lowell, Vt., "Wind turbines don't make good neighbors."

The penetrating low-frequency aspect to the noise, a thudding vibration, much like the throbbing bass of a neighboring disco, travels much farther than the usually measured "audible" noise. It may be why horses who are completely calm around traffic and heavy construction are known to become very upset when they approach wind turbines.[13] Many people have complained that it causes anxiety and nausea.The only way to reduce it is to reduce the efficiency of the electricity production, i.e., reduce the illusion of profitability. It can't be done.

Advocates, when not denying the noise outright, suggest that the wind itself masks any noise the turbine assembly makes. Rustling leaves, however, are a very different sound than the thumping of a wind facility. And in developers' output projections, they point out that the wind is very much more steady and stronger up at the top of the towers, so even that rustling down on the ground is not always there when the turbines are turning. This is often the case at night and always the case in winter. In Oregon, wind developers complained they could not comply with regulations limiting the increase of noise in rural and wild areas. In May 2004, the state weakened the noise regulations so installation of wind facilities could go ahead.

The European Union (E.U.) published the results of a 5-year investigation into wind power, finding noise complaints to be valid and that noise levels could not be predicted before developing a site. The AWEA acknowledges that a turbine is quite audible 800 feet away. The National (U.S.) Wind Coordinating Committee (NWCC) states, "wind turbines are highly visible structures that often are located in conspicuous settings ... they also generate noise that can be disturbing to nearby residents." The NWCC recommends that wind turbines be installed no closer than half a mile from any dwelling. German marketer Retexo-RISP specifies that turbines not be placed within 2 kilometers (1.24 miles) of any dwelling.

Communities in Germany, Wales, and Ireland claim that even 3,000 feet away the noise is significant. Individuals from Australia to the U.K. say they have to close their windows and turn on the air conditioner when the wind turbines are active. The noise of a wind plant in Ireland was measured in 2002 at 60 decibels 1 km (3,280 feet) upwind. The subaural low-frequency noise was above 70 dB (which is 10 *times* as loud on the logarithmic decibel scale). A German study in 2003 found significant noise levels 1 mile away from a 2-year-old wind farm of 17 1.8-MW turbines, especially at night. In mountainous areas the sound echos over larger distances. A neighbor of the 20-turbine Meyersdale facility in southwest Pennsylvania found the noise level at his house, about a half mile away, to average 75 dB(A) over a 48-hour period, well above the level that the EPA says prevents sleep. In Vermont, the director of Energy Efficiency for the Department of Public Service, Rob Ide, has said that the noise from the 11 550-kilowatt Searsburg turbines is significant a mile away. Residents 1.5 and even 3 miles downwind in otherwise quiet rural areas suffer significant noise pollution. A criminal suit has been allowed to go forward in Ireland against the owner and operator of a wind plant for noise violations of their environmental law. Also in Ireland, a developer has been forced to compensate a homeowner for loss of property value, and many people have had their tax valuation reduced. In the Lake District of northwest England, a group has sued the owner and operator of the Askam wind plant, claiming it is ruining their lives.

In January 2004, a couple was awarded 20% of the value of their home from the previous owners who did not tell them the Askam wind plant was about to be constructed 1,300 feet away: "because of damage to visual amenity, noise pollution, and the irritating flickering caused by the sun going down behind the moving blades." The towers of this plant are only 40 meters (130 feet) high, with the rotors extending a further 24 meters (75 feet). Steve Molloy of West Coast Energy responded that loss of value of a property, although unfortunate, was not a material planning consideration and did not undermine the industry's argument that the benefits of sustainable energy outweighed the objections.[13]

Don Peterson, senior director of Madison Gas & Electric, which operates 31 wind towers in Kewaunee County, Wisconsin, similarly dismisses complaints, saying that most people, but not all, will get used to the sound of the machines. "Like any noise, if you don't like it, your brain is going to focus on it," he comfortingly told the Beloit *Daily News*. Especially in relatively undeveloped areas, there can be no question that the unnatural noise from a wind facility will be prominent. Just a 10-dB increase over existing levels (a typical limit for such projects) represents the subjective perception of a *doubling* of noise level.

It has been reported that one of the farmers who leases land for the wind towers had to buy the neighbors' property because of the problems (not just noise but also flicker and lights at night). Wisconsin Public Service, operator of another 14 turbines in Kewaunee County, in 2001 offered to buy six neighboring properties: two owners accepted, but two others filed a lawsuit in January 2004.[14] On January 6, 2004, the *Western Morning News* of Devon published three articles about noise problems, particularly the health effects of low-frequency noise, from wind turbines. Another interesting report, which notes that the Nazis used low-frequency noise for torture, was published in the January 25 *Telegraph*.[15]

Jobs, Taxes, and Property Values

Despite the energy industry's claim that wind farms create jobs ("revitalise struggling rural communities," says Enxco), the fact is that, after the few months of construction—much of it handled by imported labor from the turbine company—a typical large wind facility requires just one maintenance worker. Of the 200 workers involved in construction of the 89-turbine Top of Iowa facility, only 20 were local; seven permanent jobs were created.[16] The average nationwide is 1–2 jobs per 20 MW installed capacity.

The energy companies also claim that they increase the local tax base. But that is more than offset by the loss of open land, the loss of tourism, the stagnation or decrease in property values throughout a much wider area, the tax credits such developments typically enjoy, and the taxes and fees consumers must pay to subsidize the industry. Even surveys by wind promoters show that a quarter to a third of visitors would no longer come if wind turbines were installed. That is a huge loss in areas that depend on tourism. The wind developers say that the turbines themselves are an attraction, but visitor centers at wind farms in Britain are already closing for lack of business. A few people get more money from leasing their land for the towers (until the developer starts withholding it for some small-print reason, or even disappears after the tax advantages slow down—Altamont Pass in California is littered with broken down wind towers owned by companies long gone), but that's the opposite of an argument for the general good.

Wind advocates insist that property values are not affected by nearby industrial turbines, because there will always be a buyer as it's just a question of taste. That is small comfort to those who already own homes near potential wind-plant sites but whose taste militates against rattling windows and humming walls, flickering lights, 100-foot blades spinning overhead, and giant metal towers and supply roads where once were trees and moose trails.

Other Problems

The industry recognizes that the flicker of reflected light on one side and shadow on the other drives people and animals crazy. And at night, the towers must be lighted, which the AWEA describes as a serious nuisance, destroying the dark skies that many people in rural areas cherish (and that the state of Vermont is on the verge of specifically protecting). Red lights are thought to attract night-migrating birds.

Ice is another problem. It builds up when the blades are still and gets flung off–as far as 1,500 feet–when they start spinning. Accumulated ice on the nacelle and tower also falls off. John Zimmerman, the developer of Vermont's Searsburg facility, wrote the following to an AWEA discussion list in 2000. "When there is heavy rime ice build up on the blades and the machines are running you instinctually want to stay away ... They roar and sound scarey. One time we found a piece near the base of the turbines that was pretty impressive. Three adults jumping on it couldn't break. It looked to be 5 or 6 inches thick, 3 feet wide and about 5 feet long. Probably weighed several hundred pounds. We couldn't lift it. There were a couple of other pieces nearby but we wondered where the rest of the pieces went." Access to Searsburg is restricted when icing is likely. Even in good weather, they shut the turbines down when giving tours.[17]

The planners of giant wind installations in Valencia, Spain, mention the dripping and flinging off of motor oil (almost 200 gallons of which may be present in a single 2.5-MW turbine) and cooling and cleaning fluids. The transformer at the base of each turbine contains up to 500 more gallons of oil. The substation transformers where a group of turbines connects to the grid contain over 10,000 gallons of oil each.[18]

The International Association of Engineering Insurers warns of fire: "Damage by fire in wind turbines is usually caused by overheated bearings, a strike of lightning, or sparks thrown out when the turbine is slowing down. ... Even the smallest spark can easily develop into a large fire before discovery is made or fire-fighting can begin."

A 1995 study in Germany estimated that 80% of insurance claims paid for wind turbine damage were caused by lightning. Lightning destroys many towers by causing the blade coatings to peel off, rendering them useless. If the blades keep spinning, the imbalance can bring down the whole tower. The towers are subject to metal fatigue, and the resin blades are easily damaged even by wind. In Wales, Spain, Germany, France (Dec. 22, 2004), Denmark (Jan. 20, 2005), Japan (Feb. 24, 2005), New Zealand (Mar. 10, 2005), and Scotland (Apr. 7, 2005) parts and whole blades have torn off because of malfunction and fire, flying as far as 8 kilometers and through the window of a home in one case. Whole towers have collapsed in Germany (as recently as 2002) and the U.S. (e.g., in Oklahoma, May 6, 2005).[19]

Conclusion

All of these negative aspects will only become worse if even a small part of the industry's plans for hundreds of thousands of towers becomes reality. At every level, however, the negative impacts must of course be weighed against the benefits. As described in part I, these are neglible.

III.

It is wise to diversify the sources of our energy. But the money and legislative effort invested in large-scale wind generation could be spent much more effectively to achieve the goal of reducing our use of fossil and nuclear fuels.

As an example, Country Guardian calculates that for the U.K. government subsidy towards the construction of one wind turbine, they could insulate the roofs of almost 500 houses that need it and save in two years the amount of energy the wind turbine might produce over its lifetime.

Country Guardian also calculates that if every light bulb in the U.K. were switched to a more efficient one, the country could shut down an entire power plant– something even Denmark, with wind producing as much as 20% of their electricity, is not able to do. According to solar energy consultant and retailer Real Goods, if every household in the U.S. replaced one incandescent bulb with a compact fluorescent bulb, one nuclear power plant could be closed. John Etherington claims that switching the most-used bulb in every house of the U.K. would save as much as the entire output of all existing and proposed on-shore wind plants in that country.

The BWEA itself says that the cost of saving energy is less than half the cost of producing it. According to the California Power Authority (ignoring the subsidies that lower the market price of wind-generated electricity) conservation costs exactly the same per KW-h as wind power. John Zimmerman admitted at a February 2005 meeting in Kirby, Vermont, that we "could do much more for our energy balance by just tightening our belts a little."

As described in part I, wind farms do not bring about any reduction in the use of conventional power plants. Requiring the upgrading of power plants to be more efficient and cleaner would actually do something rather than simply support the image of "green" power that energy companies profit from while in fact doing nothing to reduce pollution or fuel imports. An April 2000 E.U. report found that, using existing technology, increased efficiency could decrease energy consumption by more than 18% by 2020. The U.N.-sponsored Intergovernmental Panel on Climate Change has stated that simple voluntary energy-efficiency improvements in buildings will reduce world energy use 10%–15% by 2020. They state that, with technology already in use, efficiency improvements in buildings, manufacturing, and transport can reduce world carbon emissions more than 50% by 2020.

In the U.S., 61.5% of the energy used is "lost," i.e., only 38.5% of the energy consumed is actually extracted.[40] In transmission alone, 7.34% of the electricity generated is lost. There is obviously much that can be improved in what we already have and will continue to live with for quite some time.

Electricity represents only 39% of energy use in the U.S. (in Vermont, 20%; and only 1% of Vermont's greenhouse gas emissions is from electricity generation). Pollution from fossil fuels also comes from transportation (cars, trucks, aircraft, and ships) and heating. Despite the manic installation of wind facilities in the U.K., their CO_2 emissions rose in 2002 and 2003. At a May 27, 2004, conference in Copenhagen, the head of development from the Danish energy company Elsam stated, "Increased development of wind turbines does not reduce Danish CO_2 emissions." Demanding better gas mileage in cars, including pickup trucks and SUVs, promoting rail for both freight and travel, and supporting the use of biodiesel (for example, from hemp) would make a huge impact on pollution and dependence on foreign oil, whereas wind power makes none. Some hybrid gas-electric cars (the ones that don't just add the electric motor just for a "green" acceleration boost) already use 60% less gasoline than average conventional new cars in the U.S.

Wind-power advocates often propose that wind turbines can be used to manufacture hydrogen for fuel cells. This may be an admirable plan (although *Windpower Monthly* dismisses it for several reasons in a May 2003 article) but is so far in the future that it only serves to underscore the fact that there is no good reason for current construction. And it must be remembered that as wind turbines are unable to produce significant amounts of electricity they would likewise be unable to produce significant amounts of hydrogen. On top of that, a 2004 study by the Institute for Lifecycle Environmental Assessment determined that hydrogen returns only 47% of the energy put into it, compared with pumped hydro returning 75% and lithium ion batteries up to 85%.

On a small scale, where a turbine directly supplies the users and the fluctuating production can be stored, wind can contribute to a home, school, factory, office building, or even small village's electricity. But this simply does not work on a large scale to supply the grid. Even the small benefits claimed by their promoters are far outstripped by the huge negative impacts.

We are reminded that there are trade-offs necessary to living in a technologically advanced industrial society, that fossil fuels will run out, that global warming must be slowed, and that the procurement and transport of fossil and nuclear fuels is environmentally, politically, and socially destructive. Sooner or later the realities of this modern life will have to reach into our own back yards, the commons must be developed for our economic survival, and it would be elitist in the extreme to believe we deserve better. So wilderness areas are sacrificed, rural communities are bribed into becoming live-in (but ineffective) power plants, our governments boast that they are looking beyond fossil fuels (while doing nothing to actually reduce their use), and our electric bills go up to support "investment in a greener future." And at the other end of this trade-off, multinational energy companies reap greater profits and fossil and nuclear fuel use continues to grow.

Many alternative sources of energy, as well as dramatic improvements in the use of current sources, are in development. But wind turbines exist, so they are presented by their manufacturers and managers as *the* solution. Every effort is made to maintain the illusion that they are in fact a solution when a few simple questions reveal they are not.

Notes

1. Actual information about energy consumption by the turbines themselves is difficult to discover. Their output to the grid is measured at a substation, but the meters do not "run backwards." Some information can be seen in the Greenpeace-sponsored "Yes2Wind" forum at http://www.yes2wind.co.uk/forums/showthread.php?threadid=60
2. A detailed and well referenced examination, "Unpredictable wind energy—the Danish dilemma," Vic Mason and the Danish Society of Windmill Neighbors, is available from Country Guardian at http://www.countryguardian.net/denmark.htm. A follow-up paper by Mason, "Danish wind power—a personal view," is at http://www.countryguardian.net/vmason.htm.
3. "Impact of Wind Power Generation in Ireland on the Operation of Conventional Plant and the Economic Implications," ESB National Grid, February 2004.
4. An article at wind-farm.org explains how wind power generators in the U.K. get paid over 3 times what they actually sell their electricity for: "Goldrush—Windfarms & Why They Are So Profitable," Ray Berry, available at http://www.wind-farm.org/modules.php?op=modload&name=News&file=article&sid=120.
5. See "¿Obsoleta Energia Eolica?," Mark Duchamp, available at http://www.iberica2000.org/Es/Articulo.asp?Id=1097.
6. "Progress toward the Kyoto targets—greenhouse gases," National Environmental Research Institute, Denmark, April 19, 2005.
7. A gallery of photographs showing the shocking destruction on Cefn Croes is available at http://www.users.globalnet.co.uk/~hills/cc/gallery/index.htm.
8. "Interim Guidelines To Avoid And Minimize Wildlife Impacts from Wind Turbines," U.S. Fish and Wildlife Service, Department of the Interior, March 13, 2003, available at http://www.fws.gov/r9dhcbfa/wind.pdf (3 MB)
9. "Genocidio de aves en los parques eólicos," Mark Duchamp, available at http://www.iberica2000.org/Es/Articulo.asp?Id=1753.
10. "The noise was incredible," Paula Stahl, available at http://www.greenberkshires.org/wind_power_plants_postings/stahl_letter.html.
11. "Our Wind Farm Story," Pam Foringer, available at http://www.geocities.com/windfarmstory.htm.
12. "Wind power or horse power?" Rosemary Dunnage, North Wales *Daily Post*, June 24, 2004, available at http://icnorthwales.icnetwork.co.uk/printable_version.cfm?objectid=14363358.
13. "Wind Farm Blows House Value Away," Justin Hawkins, The Westmorland *Gazette*, January 9, 2004, available at http://www.thisisthelakedistrict.co.uk/misc/print.php?artid=447706.
14. See "Excerpts from the Final Report of the Township of Lincoln Wind Turbine Moratorium Committee," available at http://www.aweo.org/windlincoln.html, for a report of the many serious ill effects of the Kewaunee County turbines.

15. "Wind farms 'make people sick who live up to a mile away,'" Catherine Milner, *The Telegraph*, January 25, 2004.

16. "Top of Iowa Wind Farm Case Study," Northern Iowa Windpower, 2003.

17. Issues of icing, noise, and structural damage and failure, particularly as they determine setback requirements, have been extensively documented by Jules Mollica in response to the proposed expansion of a wind facility on Wachusett Mountain in Massachusetts (between Princeton and Fitchburg). The paper is available at http://www.princetonwindfarm.com/diy/wind.nsf/newwind?readform.

18. Another overview of industrial wind power's environmental problems is provided by "Windfarms—an ecological and human disaster in the making," Mark Duchamp, available at http://www.iberica2000.org/Es/Articulo.asp?Id=1170.

19. "Une éolienne a explosé," *Le Dauphiné Libéré du Rhône à Provence*, December 23, 2004. "Gale-force winds snap wind turbine propellers," *Mainichi Daily News*, February 25, 2005. "Prototype blades blown away," *Manawatu Standard*, March 11, 2005. "Danger claim as turbine blade snaps off," *Berwickshire News*, April 14, 2005. "Experts try to determine why turbine broke in two and collapsed Friday," *Oklahoman*, May 10, 2005. An extensive documentation of accidents is available at http://www.caithnesswindfarms.co.uk/pages/accidentData_May2005.htm.

20. "U.S. Energy Flow Trends--2002," Lawrence Livermore National Laboratory, June 2004.

This paper, along with pictures, several supporting documents, and many more internet links, is available on line at www.aweo.org.

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Policy Comments on Point Petre Commercial Wind Turbine Generating Plant

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PREAMBLE

The development of commercial wind power that is currently fashionable is potentially misguided, ineffective and neither environmentally nor socially benign; but it is the right of citizens of rural areas to enjoy both clean and safe energy generation and an unspoiled countryside.

Wind energy has a role; rural communities are in constant evolution, however it may be argued that the environmental and social cost of the development of commercial wind energy is out of proportion to any benefit in the form of reduced emissions. The industrialisation of our least developed landscapes, irreversible ecological damage, loss of amenity and the social division of communities is too high a price for an insignificant and unreliable contribution to our energy supply and a s... ertain saving of pollution.

Wind power can be a very useful method of generation for installations at substantial distances from the grid. Turbines [8] may be acceptable where they are not in conflict with the scale and character of the local environment but they must not blight the lives of those living nearby with noise and flicker or endanger residents or visitors; they must not create economic disadvantage through reduced property values; they must not damage the tourist industry or the local economy; and they must not divide communities.

Public planning must ensure that functions relating to land have due regard to the desirability of conserving the natural beauty and amenity of the countryside, and while local policy may be supportive of renewable energy there is a duty to ensure that there is no undue adverse impact on the countryside.

1. CURRENT STATUS OF THE BACKGROUND TO WIND ENERGY

There are no claims whatsoever that wind turbines produce electricity more cheaply or more efficiently than conventional power stations. Being unpredictable and uncontrollable the wind is a difficult energy source to work with. Merchant ships are no longer powered by sail; airlines do not use hot air balloons.

Three premises are commonly advanced explain the benefits of wind energy:

a) that energy is produced without harmful emissions - various oxides of carbon, nitrogen and sulphur - gases associated with global warming and acid rain

b) that the energy is produced without attendant depletion of finite resources of fossil fuels

c) that this energy obviates the problems associated with nuclear power - risk of accident, problems of waste storage

For these arguments to be valid it is clear that wind farms, if developed in sufficient numbers, must effectively and significantly reduce emissions, must measurably slow the depletion of other fuels which may soon be exhausted, or must close a nuclear power station. Let us examine these three premises:

A) CO2 emissions and global warming

The burning of fossil fuels is a major source of CO2 emissions, which have risen dramatically over the last twenty five years, and have been linked by many scientists to global warming. Estimates vary about how much the world will warm over the next century, about what the effects will be and about the extent to which human activity rather than natural cyclical effects are the cause of climate change. However, there is probable broad agreement that the global average temperature will rise by 1.5 degrees by 2100.

Public opinion is beginning to look at the issue and policy makers are starting to examine methods to head off potential dangers. But it is inevitable that governments risk avoiding the more difficult political decisions. If we accept that global warming is a major threat to humankind, we must question Canadian shale/sand strip mining, US policy statements against the Kyoto accords, and recent British cash subsidies to the coal industry. In North America, public policy shuns reductions in emissions from cars (our fastest growing source of CO2 with air travel not far behind). Insulation material is subject to PST and GST (total 15%) while our gas and electricity bills are subject only to GST. And although nuclear power is highly unpopular and carries obvious risks, it generates more than one third of our electricity (Ontario) and produces virtually no CO2; yet there is little discussion of what is to replace our current nuclear capacity as it reaches the end of its working life over the next twenty years.

A government fearful of taking the politically difficult decisions on energy may be tempted to hide behind some green window-dressing; this, in our view, is what the encouragement of wind farms has constituted over the last few years. While support for renewable energy must be encouraged, not all the renewable energy is to come from wind. Other sources are hydro, energy crops, waste incineration and other biomass - and Canada already uses hydroelectric power for some 60% of energy requirements [1]. Even allowing for renewable sources to be the fastest growing sector at 1.8% per annum [3], and allowing for wind energy to be the leading resource in this sector, it appears not unreasonable to assume that wind may eventually account for between 2.0% and 3.8% (according to the constraints put on the development of wind farms) of total Canadian electricity consumption - these figures fall mainly in line with various Provincial and Federal forecasts used in a Kyoto context. Wind farms could lead to a reduction of between 3.2 and 6.1 million tonnes of carbon emissions per year - between 0.006% and 0.011% of global CO_2 emissions. Clearly that will have no measurable effect whatsoever on global warming or climate change.

Bringing this down to more understandable figures, a single 500 kW gearless Enercon turbine, with an annual output of about 1.1 million kWh, generates not only during the day, when it might displace oil- or coal-fired generation, but also at night when mainly nuclear and gas generation are operating. Disregarding the fact that 60% of Canadian power is hydro-electricity (already zero emission), it is logical to assume that this turbine displaces a mix of fuels, rather than only coal or oil. British Department of Trade and Industry figures indicate that an average weighted fossil 80%/nuclear 20% generating fuel mix produced an average of 620g. of CO_2 per unit of electricity generated [26] - the UK has virtually no hydroelectric power.

Thus, calculation shows that this turbine saves about 682 tonnes of carbon emissions each year, or 0.078 tonnes per hour.

The 18-wheel truck doing 100kph on Highway 401 produces a minimum of 0.08 tonnes of CO_2 per hour. Given the uncontrolled growth of road traffic, the erecting of turbines may be seen as a futile exercise. How many turbines would we have to build each year to merely to keep pace with traffic growth?

B) Fossil Fuel Depletion

Fossil fuels are certainly finite resources. The question is whether they are in such short supply as to cause us concern. A Club of Rome report in 1972 predicted they would run out by 1990.

The Director General of the UK Petroleum Industry wrote to The Times in late 1999: "Current known reserves-to-production ratios range from about 50 years for oil and gas to over 200 years for coal." He suggested, too, that undiscovered fields of oil and gas, tar shales and oil sands will extend the availability, albeit with higher extraction costs.

Reserves of coal will probably never be exhausted, because: "coal became obsolete, with huge and useless British and world reserves" [4] These stocks, however, along with uranium reserves, will assure continuity of electricity supply.

Don Huberts who heads Shell Hydrogen, a division of Royal Dutch Shell, is convinced that new energy sources will soon begin to replace fossil fuels. He wrote in The Economist: "The stone age did not end because the world ran out of stones and the oil age will not end because the world runs out of oil."

Apart from conventional gas reserves, hydrates (compressed methane) found in immense quantities on the ocean floor are alone sufficient to power the world for another millennium. The problem at the moment is how to recover them without releasing the gas once the pressure is off, but a Japanese company is experimenting with new drilling methods at a known deposit 40 miles off Japan's Pacific coast.

The logical conclusion is that there is no rush promote an unpredictable and intermittent energy source like wind, which can never supply more than about 10% of our electricity without causing major disruption to the system as it cuts in and out. If at some period in the future it becomes clear that even this marginal quantity of electricity is vital, then at least wind turbines have the virtue that they can be erected much more speedily than conventional hydrolytic dams, nuclear facilities or even fossil fuel sources.

C) Wind Power and Nuclear Power

The nuclear question, in relation to the wind, is relatively straightforward. The United Kingdom has researched underlying factors at great length; a Select Committee on Wind Energy examined specifically whether the development of wind technology would close a nuclear power station and concluded that existing nuclear power stations would continue to the end of their working lives regardless of wind farms. Indeed, wind power can never close a power station of any sort; the fallibility of the "wind supply" necessitates full capacity (plus contingency reserve) back up from a power station if there is not to be a power cut (or risk thereof). There is no government, industry body or research organization worldwide that disputes this position.

Again taking the British situation, the percentage of nuclear electricity has grown during the last decade whilst wind turbines have been constructed in large numbers. In 1990 there were no wind farms and 20% of electricity came from nuclear; in 1997, there were more than 700 turbines and 30% of electricity came from nuclear (in Ontario, a comparable 48% of our electricity was nuclear in the same year [6] although we have a number of reactors on stand-down [26]). There is no possibility of wind and other renewables making up such a shortfall in electrical generation. A European Commission report published in April 2000 indicated that over the next 20 years at least 85 new nuclear power stations will have to be built in Europe if carbon emission targets are to be met. As current nuclear capacity ages, it will be replaced either by Combined Cycle Gas Turbine (CCGT) technology or by modern nuclear plants. The political debate may be intense, but the wind industry will play no part since, as the report concludes, renewables will not be able to meet the shortfall.

Since Chernobyl no one has been able to ignore nuclear risks and a limited number of recent problems have underlined them (Indian Point, Sellafield). It is incorrect of the wind industry to use such risks to frighten people into accepting wind turbines that can form no part of the solution. The chairman of the British Wind Energy Association is on the record: "The future can only be renewables and nuclear in some sort of combination".

2. THE SCALE OF DEVELOPMENT REQUIRED

The wind industry suggests that up to 10% of our electricity could be generated by wind turbines. Even if only a smaller proportion is produced by wind, there are those who would regard the contribution toward Kyoto type goals (however infinitesimal in global terms) as worthwhile. Several European Union member countries have pledged to increase the use of renewables, and the European Union itself has pledged to increase installed wind capacity on the continent to 10 gigawatts by 2010 [1]. Overall, however, the International Energy Agency projects that some 853 gigawatts of total installed electricity generating capacity will be required by European members of the Organization of Economic Cooperation and Development by 2010 [12]. The wind energy contribution to this total is therefore only 1.17% - and E.U member countries are held to be leaders in this field - not the 10% suggested by the wind turbine industry

We would suggest that the environmental cost involved in this magnitude of wind energy development outweighs the savings in emissions. At the core of the problem lies the exceedingly small output of even the largest wind turbines, the prominence of the sites necessary if they are to fulfil their limited generating potential and the high numbers of turbines required to generate modest amounts of electricity.

Wind turbine output figures in 1998 confirmed that their average output is about 25% of their theoretical [nominal] capacity - the largest turbines currently proposed for Point Petre have a theoretical capacity of 1.8 MW with an average output of under one half MW. Two of the biggest operational wind farms in Europe are the neighbouring sites at Llandinam and Carno in Wales using 159 half-megawatt turbines [nominal total 79.5 Mw] on several thousand acres. Together, they have an output averaging 20 MW - we will retain 25% as the current, proven baseline [16].

Let us return to Ontario, which has for the next ten years a forecast peak demand of between 25,000 and 30,000 MW [9]; taking the wind industry's figure of 10%, wind farms would have to produce some 2,500 MW necessitating some 20,000 "smaller" turbines with a proven track record, or some 5,000 of the much larger ones (example Vestas' V80, 387 feet high - advertising for this machine claims operation at 38% efficiency [16], a number previously only dreamed of, which would reduce the required number to some 3,500.)

Wind Power Monthly reported in January 2000 that the installed capacity of turbines on a world-wide basis at the end of 1999 was 12,455 MW - the theoretical maximum output of nearly 40,000 turbines erected over a period of some 30 years [10]. Recalling that the average output of a wind turbine is only 25% of its capacity, all the world's wind machines are on average producing 3,100 MW or well less than half of the installed hydroelectric capacity of Ontario alone (7,300 MW). This achievement was only possible with governments around the world encouraging the construction of turbines with subsidies or tax credits; hence the suggestion that at best wind energy is a barely relevant side-show, at worst a deception that something worthwhile is being done to combat emissions.

3. THE PROBLEM OF INTERMITTENCY

The following three points with regard to electrical power are paramount.

- it has to be generated at the same time as it is used,
- it has to be delivered to strict standards governing voltage levels and frequency,
- security and continuity of supply is extremely important

Wind is an intermittent source of power and currently the only form of energy generation which we cannot control. If there is no wind, there is no generation; if there is too much wind the turbines must be shut down before structural damage occurs. At this point in time, turbines generate such a statistically insignificant amount of energy that their intermittent supply causes no problems for consumers and those who manage supply simply ignore their existence.

However, if wind industry production of 10% of our supply is successful, there would be major implications. For example, on August 16, 2002 demand in Ontario peaked at over 25,000 MW. There was no wind. Had we been relying on wind to provide any considerable portion at that point, there could have been widespread power cuts, with consequent work layoffs, school closures, added need for emergency generation at hospitals and other critical sites, etc

Such security, economic and social disasters cannot be permitted, therefore:

- enough fossil fuel generating capacity must always be kept on stand-by ("spinning reserve" [30]) to supply the shortfall as and when the wind drops
- any emission / pollution reductions are thus virtually nullified
- no power station could ever close because of development, even major, of wind energy
- wind farms constitute an increase in energy supply, not a replacement, an extra environmental cost to add to that of fossil fuel

4. LANDSCAPE QUALITY OF WIND FARM SITES

Developers tend to target areas with the highest wind speed because these will guarantee the greatest output and the highest return. The map of National Parks, Federal and Provincial, protected wildlife sites, and other areas of intrinsic natural beauty along the shores of Lake Ontario, the St. Lawrence and Georgian Bay are already limited, and being further encroached upon by urban sprawl, yet this is almost exactly the map of high wind speed sites.

It would appear logical that wind farms should be sited neither within such parks and natural areas nor where they would be clearly visible from such areas, yet there is in practice no restraint over where developers may seek to erect wind turbines.

If we, the community, retain only the idea of perceived emission reductions, with no other reference to environmental acceptability, then the system itself will tend to produce developments in environmentally sensitive sites.

The result is that wind developments will threaten much of our remaining natural landscape: whether or not Point Petre is seen as just scrubland or an intrinsic part of the County's rural heritage, any turbines will be visible from a distance extending not just to Picton Heights, but, on a clear day, to the United States

If between 5,000 and 20,000 turbines are to be built in such locations, there will be hardly any part of our most valued landscape which is not affected. Apart from the turbines themselves, many miles of transmission lines and hundreds of pylons will be needed for connection to the grid.

In 1996 the U.K. Countryside Commission, a government landscape watchdog, warned that England's scenic countryside was in danger of becoming a "wind farm wilderness." The wind industry has responded to concerns such as these by proposing offshore installations [see 6 below].

Few voices question the importance of wild, unindustrialized landscape as a County asset, but anyone with a concern for the environment should consider preserving wilderness areas; thus, both from a desire to protect our fragile ecosystems, and from a recognition of their capacity to enrich human life through spiritual and poetic inspiration and through self-sufficient adventure.

The issue of wind turbines has led a section of the "green" movement to dismiss landscape as a secondary concern - "The modern wind turbine is a mighty intrusive beast. It's not into nestling, blending in or any of those other clichés beloved of rural romantics" [14] - but maybe in an area of tourism, artists and natural beauty, we need a better appreciation of what the loss of "rural romanticism" might mean?

The founder of the National Parks movement, John Muir, wrote: "Thousands of tired, nerve-shaken over-civilised people are beginning to find that wilderness is a necessity and that parks and reservations are useful not only as fountains of timber and irrigating rivers, but as fountains of life."

5. AESTHETIC CONSIDERATIONS

Aesthetic judgments are subjective and beauty is in the eye of the beholder. Is a wind turbine beautiful or ugly? That is not the issue: a wind farm is an industrial installation of vast proportions and the proposed turbines are nearly 400 feet high. A similarly tall 30 floor building by a leading architect might be very beautiful, but on planning grounds would most probably be unacceptable in Prince Edward County.

Wind Power Monthly, the magazine for the wind industry and its supporters, has recognised that the reason for the growing unpopularity of wind power is that a heavy industry has tricked its way into unspoiled countryside in "green" disguise: "Too often the public has felt duped into envisioning fairy tale wind "parks" in the countryside. The reality has been an abrupt awakening. Wind power stations are no parks." [11] The Editor went on to point out that in Denmark turbines are treated within the planning process in the same way as motorways, industrial buildings, railways and pig farms.

6. OFFSHORE WIND TURBINES

European scenarios for renewable energy by the year 2010 suggest that between 60 and 70% of wind-generated electricity could come from turbines sited offshore. Much larger turbines are envisaged at sea than on land - Enercon are developing a turbine with an installed capacity of 5 MW, 190 metres high and they are likely to have a greater capacity factor because of more dependable wind speeds. Meeting this offshore wind target will require between 3,800 and 4,500 turbines.

From the latest information available (Section 16 below) it is not clear where the finance for this target in a pioneering field might come from. The whole sea is not available for wind turbine development. Water depth has to be less than 40 m and the sea bed nearly flat. Shipping lanes, military zones, pipelines, helicopter flight paths, ferry routes, and fishing grounds are expected to be no-go areas. Uneconomically long distances to grid connections and the absence of local port facilities would also be constraints. There are additional safety and ecological considerations.

Current recommendations by the E-U (enforceable, pending or guideline only) to ensure that coastlines are not damaged by the scale, location or cumulative impact of turbines, include:

- special care with the visual impact, specifically including the night-time illumination
- distance from shore:

  3 - 5 km off industrial coasts;
  10 - 20 km off National Parks and similar 'heritage' coasts; out-of-bounds in largely undeveloped estuaries.

Developers are likely to be interested in sites within 5 km of coasts, where the water is shallowest, the wind speeds the most favourable and the cable connections the shortest. These constraints are not necessarily contradictory, and a recent study [15] has estimated that nearly half of off-shore turbines will be within 10 km of the coast, with fewer than 18% beyond the 20 km line.

How environmentally acceptable turbines at sea turn out to be will depend on their proximity to the coast - particularly those in areas of prime tourism - and the impact of cable landing sites and pylons to carry cable to grid connections. Public opinion appears to be favourable to reducing pressure on land-based sites, but there certainly is no general acceptance of offshore wind turbines - electrical costs will certainly be higher and reliability is not much less unpredictable than that of on-shore developments.

7. NOISE POLLUTION AND HEALTH

The noise from a wind turbine comes from both the mechanical gearing and from the aerodynamic properties of the rotating blades. The former can to a degree be controlled and insulated and some makes of turbine are quieter than others.

The more intrusive blade noise is unavoidable, and increases with the number of turbines installed. Vestas refers to a choice of blades, one set with a sound output at 2.5dB: "For developers almost half the measured sound level means that two V80 turbines with low sound levels can be placed at nearly the same distance to a sound sensitive location as one turbine with a higher sound level" [21]

While the study of cumulative sound levels, particularly harmonics, is complex, this manufacturer's statement virtually implies that two turbines are twice as noisy as a single one. However, we will not claim here that the increase at any single point is purely proportional to the number of turbines, there should be some attenuation.

Noise levels, particularly the low-frequency 'thump' each time a blade passes the turbine tower, are the subject of much research, and the UK regulatory authority spends more of its budget researching noise from wind turbines than on all other environmental noise problems. "For existing wind farms we are satisfied that there are cases of individuals being subject to near-continuous noise during the operation of the turbines, at levels which do not constitute a statutory nuisance or exceed planning conditions, but which are clearly disturbing and unpleasant and may have some psychological effects." [22]

The genuine difficulty that developers face is that noise levels cannot be predicted in advance - and the industry has had little success in controlling blade noise. Again from Vestas: "The new design allows the blades to cut so aggressively through the wind that the kilowatt counter runs as much as 17-19% faster than even its highly competitive predecessor. Development work on this turbine has focused on one factor, profitability." Some of these turbines were erected in England in 1999, and it was reported: "Barrow's chief Environmental Health officer said the council was taking action against the noise nuisance." [23]

Local resident reaction has not always been kind. [24]

Noise is recognized as a significant cause of stress and stress-related illness in modern society, and health problems have been reported by local residents. What started as anecdotal references to harm from noise levels, has become statistically significant, and while there appears to be little or no clinical proof of causality, research in Denmark and Holland is continuing.

This is particularly apparent from New Zealand Standard 6808 [39] Note to para 1.3 "WTGs (Wind Turbine Generators) may produce sound at frequencies below (infrasound) and above (ultrasound) the audible range" and the statement from the Darmstadt Manifesto: "More and more people are describing their lives as unbearable when they are directly exposed to the acoustic and optical effects of wind farms. There are reports of people being signed off sick and unfit for work, there is a growing number of complaints about symptoms such as pulse irregularities and states of anxiety, which are known to be from the effects of infrasound."

Recent reports from Denmark indicate government buy-back of residential property in an increasing radius from wind turbines, particularly down-wind.

8. RADAR, RADIO AND TELEVISION INTERFERENCE

That wind turbines can disrupt TV reception was noted as early as 1994; The New Scientist accused the government of not insisting on curative measures and leaving viewers at the mercy of developers. Effectively turbines cause a reception shadow of up to 10 km when they stand between a TV transmitter and dwellings with TV antennas pointing through the wind turbines towards the transmitter. Viewers in such locations will have their signal scattered, causing loss of detail, loss of colour or buzz on sound. In addition, viewers situated to the side of turbines may experience periodic reflections from the blades, giving rise to "ghosting" and flicker as the blades rotate

Turbines also disrupt microwave communications links and for this reason the Swedish armed forces blocked 15 wind farms in Norrtalje and have argued against wind developments on the coast between Stockholm and Uppland. (The UK Ministry of Defence also recently opposed a wind farm, their opposition being confirmed on appeal [40].)

There is growing evidence that marine radar can be affected by wind turbine generators, and today (21 Aug 2002) it is reported that To day the Belgian media are widely reporting that the Dutch province of Zeeland just over the border is using a special privilege of appeal at the Belgian State Counsel to block the installation of a huge windmill park offshore. The main argument is that this park, being situated in the Scheldt approaches, would present a serious danger to navigation by jamming the radars on the ships. As the Dutch are responsible for a part of this channel and maintain a series of VTS radar observation stations, they know something about this problem. There are anecdotal reports of military aircraft radar being affected, but details are currently classified.

Developers can sort out most of the television problems, but only at the cost of building a new relay station. Developers, who at first deny that there is a problem, are now being asked to agree to a clause being written into the planning agreement whereby they will finance remedial work if it proves necessary. The other problems may have no remedy in the immediate vicinity of the generating plant (wind farm).

9. GEOLOGICAL AND OTHER ENVIRONMENTAL CONSEQUENCES

Wind farms are such a recent phenomenon that it is hard to be certain of their long-term ecological impact. However, a citizens' group in the UK commissioned a hydrologist and a number of engineers to examine the Ovenden Moor wind farm. They found that the erection of turbines 200 feet high had cracked the bedrock, diverted natural watercourses, dried layers of peat that were likely to simply blow away and elsewhere formed deep pools of peat "soup" (fetid surface water), and they concluded that there was certain to be a knock-on effect on flora, insects and birds. [25]

The hole normally excavated for a turbine's foundation has a volume of 250 to 1,000 cubic yards - but at the 21 August meeting the developers mentioned that the Point Petre project will not blast, but sink anchor holes, but, one way or another, this involves the bedrock. The extracted material has to be discarded and replaced with sand, aggregate and cement [35]; service roads and cable trenches need to be constructed; pylons and overhead transmission lines will have to be erected, reinforced or upgraded to connect to the grid. A recent Dutch study [36] claims that wind turbines produce significant amounts of CO2 - if the emissions created during manufacture, erection and maintenance are averaged over the lifetime of a turbine, the CO2 cost is 50 grams per Kilowatt hour.

10. SAFETY

The rotor of a Vestas V80 turbine weighs 77,175 lbs., or a little over 35 tonnes, with a blade tip speed of 300 kph. The rotor blades sweep a surface area the size of a football field.

When they have broken off they have planed up to 400 metres (9 Dec 1993, Cemmaes, Wales). At Tarifa, Spain, blades broke off on two occasions in Nov. 1995 - the first in gusty, high winds, the second in only light wind (report, Windpower Monthly, Dec. 1995).

In an article written in January 1996 Professor Otfried Wolfrum, professor of applied geodesy at Darmstadt University, wrote of a significant number of blade failures in Germany, detailing four particularly severe ones where fragments of blade weighing up to half a tonne were thrown up to 200 m.

The civic authorities in Palm Springs, USA, as early as the late 1980s made developers move turbines to a distance of half a mile from the highway for safety reasons.

Apart from the danger of blades becoming detached or disintegrating, there is a risk that lumps of ice can form, and then be thrown significant distances when the wind rises and the blades begin to move. Professor Wolfrum wrote on this subject: "Some ice layers 150mm thick have been detected and their mass has been as high as 20 - 23 kg/m" [37]. He demonstrated that these fragments could travel up to 550 m and land with impact speeds of 170 mph. This has led to "Falling Ice" warning notices at some wind turbine sites.

In April 2000, three UK wind farms were reported as being closed for safety reasons, apparently because of metal fatigue in the turbine towers. The sites in question are at Cold Northcott in Cornwall and Cemmaes and Llangwyryfon in Wales [38].

The Countryside Agency has called for turbines to be sited away from bridleways - a distance of three times the height of the turbines normally and four times the height of the turbines near National Trails (height to blade tip) - because noise and flicker can startle horses and endanger their riders and because of risk from thrown ice. The British Horse Society has expressed similar concerns.

11. TOURISM, JOBS, PROPERTY VALUES

The main adverse impact that wind farm development is likely to have on the economy of an area relates to tourism.

- A National Tourist Board survey shows that 90% of British holiday makers who go to the countryside do so to enjoy it for its own sake and seek no further attractions like theme parks [18].

- Denmark has reported a 40% fall in tourist numbers where wind power stations have been established.

- Holland (survey by the University of Leiden in the late 1980s) found that the majority of those questioned felt that a landscape lost its interest as turbines accumulated in it.

- The Welsh Tourist Board's policy on wind turbines reads: "The Board endorses the policies of the Countryside Council for Wales which oppose the introduction of commercial wind turbines and wind turbine power stations in primary designated areas (i.e. National Parks, AONBs, Heritage Coasts and Marine, National and International Nature Reserves). We consider that elsewhere proposals should be considered on their merits, the effects upon tourism being a material issue for consideration."

If wind farms threaten to destroy jobs in the tourist industry, they create few if any compensating jobs elsewhere. A typical turbine requires less than one day's maintenance per year; it is most unlikely that the proposed Point Petre generating plant could sustain anywhere close to 1 FTE.

All the proposed turbines are of foreign manufacture. Creative accounting is used by the wind industry to arrive at employment figures "relating to" wind, but it is difficult to find employees who only work when the wind is blowing - without which, of course, any employment relies upon traditional power generation.

The only visible benefit to the County would be some local labour, excavation and concrete pouring during installation, and the site rent paid to the ten landowners involved. We also understand that many of the Hydro One workers involved in the grid extension will be temporarily brought to the County from elsewhere. Will any benefit be outweighed by a decline in tourist numbers? Tourism has also become an important element of farm diversification, encouraged by OMAFRA, with campgrounds and holiday cottages. What one farmer gains another may lose.

In terms of the impact on house values there can be no doubt. A partner in Durrants, a chartered surveying firm, wrote (May 1998): "I can confirm that the outlook from a property does have a major bearing on its value and if this outlook is tarnished by a wind turbine or any similar structure, the values would be significantly decreased." International property consultants FPD Savills wrote in May 1998: "Any structure that can be viewed as an intrusion into the countryside such as electricity pylons or wind turbines will have a detrimental effect [on property values]. Usually, it will not only effect the value but also saleability which is not necessarily the same thing. Generally speaking, the higher the value of the property the greater the blight will be ... As you go up the value scale, buyers generally become more discerning and the value of a farmhouse may be affected by as much as 30% if it is in close proximity to the wind turbine. Those houses that are within earshot are likely to be affected worst of all."

In Denmark, the National Association of Neighbours of Wind Turbines say that most estate agents estimate a 25 - 30 % fall in property value when turbines are put up nearby. In the UK Lake District, house prices fall by up to 40% if their outlook is affected by a wind power development [18].

Lastly, while the visibility of wind turbines may reduce the value of a property, noise levels may render it totally unsaleable.

12. THE EFFECT ON BIRDS

It should be noted that the proposed wind turbine generating plant will be directly adjacent to an internationally recognized Important Bird Area (IBA).

There appear to be widely differing opinions on this subject. Industry and government minimize the effects; for example, the European Union Planning Policy Guidance 22 (PPG 22): "Evidence suggests that the risk of collision with moving turbine blades is minimal both for migrating birds and for local habitats."

However, the number of documented reports on unacceptable kill rates has possibly gone beyond being anecdotal, and approaches statistical significance. Some examples:

- Tarifa, Spain, significant numbers of birds of 13 species protected under European Union law have been killed by turbines (Windpower monthly, 2 February 1994).
- Altamont Pass, California, average kill of 200-300 Redtail Hawks and 40-60 Golden Eagles each year; estimate of 7000 other migrating birds kills at other wind turbine sites in Southern California. (California Energy Commission).
- £2 million invested in Scotland to encourage a pair of Golden Eagles to hunt without risk from turbine blades (The Times, May 1999)
- Kintyre, Scotland, the inspectors at the Scottish Office overturned planning consent for wind turbines to protect White-Fronted Geese (November 1998)
- Nasudden, Sweden, 49 dead birds at one turbine during one night of migration (Winkelman and Karlsson)
- Holland, 49 new bird sanctuaries were designated in February 2000, proving a major impediment to plans for turbines.

The potential hazards for birds and wildfowl, include habitat loss and degradation, indirect disturbance from noise, potential for mortality due to collision with wind turbines, effect on nocturnal patterns of movement and danger to birds during periods of poor visibility and severe weather.

One point that is of relevance to local planning, is that the County Official Plan encourages wineries. It is our understanding that any changes in nesting and habitat for certain bird species could influence insect populations and negatively impact existing and future vineyards.

13. PUBLIC OPINION

The wind industry constantly claims that surveys demonstrate that 70% of the population are in favour of the technology. The surveys they refer to, however, are of a general nature: questions are not site-specific, and, while it is obviously possible to support the idea of wind energy in principle while rejecting it as an option in a particularly fine landscape, a national park or next to a bird sanctuary, it is unreasonable to use such general approval to support industrialization of sensitive locations.

Where surveys have been site-specific the results are very different - we have been unable to find one single survey result giving approval. Opinion surveys are useful tools for pressure groups but not a sensible basis for sound planning, since they are often snapshots of ill-informed opinion. Respondents to surveys about wind can be shown to be ill-informed, believing that wind-generated electricity is cheap or even free, or that wind farms are an alternative to nuclear power stations.

Informed opinion is very much more critical of wind power development. Planning committees in the UK, advised by professional planning officers who have to evaluate every aspect of a proposal objectively, have rejected more than 80% of wind turbine applications. Appeals have usually upheld the planning refusals. Of 2400 MW of wind power proposals up to March 2000, only 200 MW had got through the planning process as planners and inspectors considered the environmental impacts too big and the clean energy benefits too small to permit the remainder [25]

Former leader of the Labour Party Neil Kinnock wrote in 1994: "My long-established view is that wind-generated power is an expensive form of energy. It can only provide a very small fraction of the output required to meet total energy needs and it unavoidably makes an unacceptable intrusion into the landscape."

In 1998 the Norwegian Government commissioned a report on the experience of wind energy in Denmark in order to inform its own decisions on developing the technology. It noted: "serious environmental effects, insufficient production [and] high production costs."

Finally, we would draw attention to the Darmstadt Manifesto on the exploitation of wind energy in Germany, compiled and signed by over 100 leading academics in fields including Mathematics, Electrical Engineering, Physics, Medicine, Chemistry, Mechanical Engineering and Thermodynamic Science, Land Management, Agricultural Science and Geography. Fearing that young people are "growing up into a world in which natural landscapes are breaking up into tragic remnants" the manifesto undertakes a cost/benefit analysis of wind energy. They state that "wind energy is running a race which is already lost in an economic order orientated towards growth" and conclude that "Wind energy is therefore of no significance whatever either in the statistics for energy or for those of pollutants and greenhouse gases".

14. FINANCIAL LOGIC OF WINDFARM DEVELOPMENT AND VERs.

Despite government (taxpayer) subsidies of various forms, industry is not going to plan for and install commercial wind turbine electricity generating plants without a profit motive. World leader Denmark now sees the manufacture and export of the turbines themselves as their core business, as "electricity from wind turbines was too expensive" (see recent remarks by the Danish Energy Minister in para 21, Conclusion, below).

How can a Canadian project develop a positive business plan? Fiscal incentives are a necessity, including accelerated depreciation, on both capital investment and sales to Hydro One, where the Wind Power Production Incentive (WPPI) [34] program and other subsidies start to apply

However, substantial gains can be made from the sale of "pollution credits". This is a developing market with the obvious outcome of promoting CO_2 and other GHG emissions. How does it work? A wind turbine electricity producer sells "credit certificates" for tons of CO_2, which authorize unregulated pollution by the buyer.

The following information is taken from Vision Quest's web site [35] (paragraphs re ordered for clarity):

> Verified Emissions Reductions (VERs) are a new product. VERs are the quantified reduction in air pollution, owned by the entity that took the action to reduce the emissions. Vision Quest VERs are expressed as kgs of carbon dioxide equivalent, or greenhouse gases (GHGs).
>
> Around the world, markets are being developed to trade emissions reductions. Already, trades between industrial customers are taking place in Australia, New York and in Canada. As these markets become more common, VER customers could offer their certificates for sale, and if demand increases, could realize gains on their investments.
>
> We (Vision Quest) have industrial customers that purchase Green Energy® (VERs) specifically to offset their emissions. Vision Quest has sold VERs only to industrial

> customers, on a confidential basis. We have offered VERs into markets in the US, Canada, and overseas.
>
> Vision Quest is now offering small blocks of VERs to customers anywhere in the world. $9.50 Cdn per 100 kg/month ($114 Cdn for 1,200 kgs on an annual basis - one year minimum) or $68 Cdn per 1,000 kg/month ($816 Cdn for 6 metric tonnes annually - one year minimum). For larger volume commercial or industrial blocks, please contact our offices. Vision Quest does sell large blocks or streams of VERs to qualified customer groups.

Various studies have confirmed that all wind energy developments throughout the world are subsidised in one form or another. It has cost anything from 116% to 440% of the price of conventionally generated electricity. And with Natural Resources Canada stating: "the WPPI encourages participation from prospective producers in all regions and is expected to leverage approximately $1.5 billion in capital investments across Canada" it is not surprising that we see a number of developers jumping on these incentives.

15. CANADIAN GOVERNMENT POLICY

Canada continues to confirm agreement with the Kyoto accords, but ratification has not yet been signed. Provincial disagreement, particularly Alberta, is one obstacle.

At the end of 2000, there was an estimated 137 megawatts of total installed wind capacity in Canada. At present, the provinces of Quebec and Alberta have the largest shares of Canada's wind capacity. There are, however, new government incentives to increase wind power projects throughout the country and as a result several projects are expected to be examined in the near future. In Saskatchewan's Gull Lake, the first phase of the $20 million SunBridge Wind Power Project has begun generating electricity [32]. Three of the 17 wind turbines began generating in August 2001, and the remaining turbines should be operational by June 2002 [unconfirmed?], when total installed capacity should reach 11.2 megawatts.

The Canadian government has agreed to purchase electricity from emerging renewable sources in Saskatchewan and Prince Edward Island, and for the Gull Lake wind project this will mean a taxpayer investment of around $7.9 million over a 10-year period. In June 2001, the Canadian government, the Prince Edward Island provincial government, and Maritime Electric Company, Ltd. announced that an agreement had been signed for the development of a wind farm at North Cape to be constructed by the Prince Edward Island Energy Corporation. The project, which is expected to cost the taxpayer $5.9 million, will generate an estimated 16.6 million kwh of electricity annually.

In December 2001, Canada implemented a Wind Power Production Incentive (WPPI) [34]. Wind projects installed between April 1, 2002, and March 31, 2007, will be eligible for a government incentive payment of about 1.2 cents per kilowatthour of generation. The payment will gradually decline.

Provincial Select Committee on Alternative Fuel Sources:

In November 2001, this committee set out a number of recommendations in its "Final report" after gaining "first hand exposure" in Alberta and California, thus showing great interest in wind energy possibilities for Ontario, but admitting that assessment of potential was in its early stages. Some excerpts:

"Wind power may be able to augment, or partly displace, diesel power sources in remote northern communities"

"Public attitudes will have to adjust to this emerging technology" - this is a quite remarkable statement, implying that any choice by a community is null and void - "The Committee was concerned that the only significant proposal to date for a private wind farm in Ontario was blocked by local planning and zoning concerns" - one can only hope that the Committee will have the democratic decency to accept that a community has the absolute right to decide that certain aspects of local planning are against the communities best interests.

Although specifying Crown Lands, it is stated that the "Ministry of Environment and Energy and Natural Resources shall develop a standardized policy for wind energy development" by 31 December 2002. It would appear prudent for this community to examine Provincial policy before being used as a test-bed or guinea pig for private commercial enterprise.

"The Ministry of Finance shall match the Federal wind power production incentive for new wind power projects" - more taxpayer money being spent.

Local municipal details:

The Official Plan for Prince Edward County, which has been consistent for many years, states inter alia:

a) "It is the intent of the Plan to maintain the natural and scenic qualities of the rural designation and to preserve its rural character and lifestyle and significant open lands"

b) "Very limited new development will be permitted in rather isolated areas of the County such as Long Point and Point Petre."

Given that our Official Plan is absolutely specific for Point Petre, it defies logic to imagine how an exception can be made that is not incontrovertibly in the absolute interest of the public, or subject to an in depth economic impact analysis, or subject to meaningful, extended public consultation and plebiscite. And the holiday period of July and August is not exactly suited to full, open and public discussion, or investigation, analysis and recommendations by concerned organizations.

The amendment to the Official Plan, as currently requested, would be pure rubber-stamping of private interests. This is contrary to the very principles of public planning - which should be looking for a broad based enquiry into possible amendments of the Official Plan itself. Without this, we indulge in ad hoc planning and ad hoc rezoning, as a blatant exception to public policy which has openly and democratically evolved as in a) and b) above.

The County Weekly of June 19 quoted Councillor Paul Johnson as saying, "This is a Prince Edward County issue in my opinion and not specific to one area. It impacts the entire County"

It should also be noted that a number of notions put forward to justify the amendment/rezoning request appear to apply to a single experimental turbine. Either the request is for a single turbine (this is what the environmental survey by Jacques Whitford refers to) or for 32 turbines, which Mr Whitford did not study. It is contrary to good planning principles to leave any doubt (sound levels, bird protection, electronic interference, etc) as to what is being permitted.

16. EUROPEAN UNION AND U.K. POLICY

[This section for information only, and as a comparison to Canadian Policy, Section 15 above]

The European Commission has been trying for some time to implement a directive on renewable energy. Two proposals had to be abandoned after opposition from member states, industry and environmental groups. Finally on 10 May 2000 the Commission announced its proposals to double the proportion of 'green' energy from 6% to 12% of primary energy supply by increasing the share of renewably generated electricity from 14% to 22% by 2010.

Member states will have to "reduce regulatory barriers" which are seen as hampering renewables development - including establishing a fast track through planning procedures. These "regulatory barriers" were formerly known as safeguards for unspoiled landscape - a respect of nature which has worked against many inappropriate wind farm proposals.

It must be remembered too that there are renewables other than wind, though many of them have a major environmental cost attached just as wind does

In the U.K., government has a ten-year strategy to ensure, through a rising series of targets, that 10% of UK electricity is generated from renewable sources by 2010. These sources are diverse and include hydroelectricity, on- and off-shore wind, energy crops, waste incineration, landfill gas and other biomass sources.

Electricity suppliers must supply specific proportions of their electricity each year from renewable sources; if they fail to fulfil their obligation, the Dept of Trade and Industry has indicated that a penalty of 2p per unit (~cdn$0.044) will be levied - however with a base price of 2.3p (cdn$0.056) the end result is that if renewable energy cannot be produced for less than 4.3p (cdn$0.10), it is cheaper for the supplier to buy conventional electricity and pay the penalty

This 4.3p per unit price cap makes significant off-shore wind development unlikely, since the associated costs of off-shore generation - construction difficulties, maintenance, cabling, grid connections - will put the price above that level. The government is said to be considering supplementary support for off-shore wind.

Renewable source electricity [19] is exempt from the Climate Change Levy (CCL) which came into force in April 2001 adding 0.43p (1 cent Canadian) per unit to the business use of electricity from fossil or nuclear fuel generation.

17. KYOTO

At Kyoto in 1997, the developed countries agreed to a legally-binding commitment to reduce greenhouse gas emissions by 5.2 per cent below 1990 levels over the period 2008-2012. Various nations and groups of nations have indicated, within the accord, differing (higher) targets, for example: the EU Member States collectively agreed to a 8 per cent reduction, within which the UK's contribution to this target has been set at a 12½ per cent on a basket of six greenhouse gases.

These targets have run into problems. By December 1999 only 16 nations had ratified the protocol. The US, which has 5% of the world's population and produces 20% of its pollution, shows little sign of co-operating with the target. Meantime, countries like India and China in their race to industrialize are massively increasing their coal-burn. Kyoto perhaps represents an easier target for Canada, thanks to our "dash for gas", our vast hydroelectric industry, and possible expansion of clean nuclear production, but it throws into stark relief the dichotomy of producing credits in Ontario to counterbalance open strip shale/sand mining in Alberta, much of which is for export to the USA.

18. THE PLANNING SYSTEM AND WIND FARMS

Good planning is about balance. Very large industrial units producing a very small, unpredictable supply of electricity which is "as well as" not "instead of" fossil fuel and nuclear power represent bad planning. Commercial wind turbine generating plants do not displace "a significant amount" of CO2 emissions and are an unnecessary degradation of the countryside.

Commercial wind turbine generating plants represent a dispersion of technology - like abandoning our merchant marine and returning to sail powered clipper ships. Along the 401 corridor, concentrating our main power generation (i.e. connected to the Hydro grid) in a few places is much less destructive of the general environment.

Because wind energy is uneconomic, its development depends on subsidy. Wind developers have to jump two hurdles before erecting a wind farm - first to secure a subsidized business plan encompassing a guaranteed market and a premium price for the electricity generated, and secondly to secure planning consent.

However, wind energy developments must be subject to exactly the same planning controls as any other form of development. If the government wants to encourage the development of clean and renewable energy, then that must still be planned here in the County as an economically attractive and environmentally acceptable project.

The official Plan for the County imposes a responsibility to preserve the countryside and local government must be encouraged to become increasingly aware of the tourist and amenity value of unspoiled landscape. In most other communities, Development Planning tends to restrict industrial development to specific areas, usually those already industrialized. This makes life difficult for wind developers who seek sites precluded by the local plan. They are required to find "substantive material reasons" why restrictions should be set aside, rezoning allowed and plant installed prior to the approval of Federal or Provincial guidelines. The only plausible reason might be the reduction in fossil fuel pollution, but the reduction achieved by even the largest commercial wind turbine generating plants is so small as to be in no sense "substantive".

Effective planning must, at the very least, ensure that any commercial wind turbine generating plants established in rural surroundings

1. do not detract from the natural scale and character of the local and neighbouring environments
2. do not endanger or create health hazards for people living nearby, or those visiting the adjacent countryside
3. do not blight the lives of people living nearby with noise, flicker and moving shadows.
4. do not create divisions amongst local people.
5. do not lead to people becoming economically disadvantaged through reduced property values.
6. do not disadvantage the local economy and tourist industry.
7. is contractually obligated to the municipality/community to an environmental clean-up at the end of operations, whether premature or not (this should carry insurance or other financial guarantee against insolvency)
8. is contractually obligated to the municipality/community to state, ahead of time, the environmental standards to be respected, to publish a bi-annual report card on the respect of these standards and to remedy any shortfalls or terminate operations (under g. above)

We would also draw attention to

a) the proposed wind farm, at a height approaching 400 feet spread over 700 acres would be physically the largest single development ever constructed in Prince Edward County. As a comparison, Essroc covers a total of about one thousand acres, but the building footprint is very much smaller, and the highest roof is at less than 200 feet.

b) the fact that no economic impact study has been carried out by the County (net short and long term tax-base gain/loss, implications for tourism and retirement, employment figures, possible health and environment costs, possible legal liability for clean-up)

c) no statement concerning the cost and impact of the Hydro One connection has been made publicly

19. THE FUTILITY OF SUPPLY-SIDE SOLUTIONS

We cannot reduce emissions while our consumption of energy grows. The C02 released during the manufacture of wind turbines and the construction of a wind farm gives an average C02 cost of 50 g per unit generated over the lifetime of a turbine (cf. 400 g for gas-generated electricity, 7 g for nuclear).

The Western world is profligate in the use of energy. America has approximately 5% of the world's population and is responsible for about 20% of its energy consumption. Electric consumption has risen five fold in half a century, and is currently rising at about 10% every four years. Traffic growth on the roads and in the air are the fastest growing sources of such emissions.

Globalization is leading to a growth in the economies of formerly poor [underdeveloped, third world] countries which will allow their population of 1.5 billion to acquire the same goods as the rich and consume energy in the same profligate way. It is unthinkable that the countries of America and Europe should deny energy use to others while continuing to abuse energy themselves. And it is equally unthinkable that the technology of the wind turbine is going to supply the needs of the world.

Wasted energy in domestic environments is variously estimated at between 50% and 60%, yet we pay little attention to conserving energy. If every household in Canada replaced the conventional electric light bulb with a low energy bulb, nearly one million tonnes of C02 could be saved. We pay only GST on our electric and gas bills, yet PST + GST on insulation for our homes - a reversal of this fiscal situation might be instructive.

Road traffic is the fastest-growing source of CO2 emissions, with aviation a close second. Yet where is the encouragement to be frugal? Individual and corporate endeavours in this direction should be promoted [in the County, we have a shining example with Essroc using water transport, by far the most CO2 friendly in terms of tons/miles, for 97% of their output].

In the end, there will have to be steep rises in energy prices for consumers who, in Canada, have become used to ever-cheaper (disregarding inflation) energy. There will have to be radical restrictions on private car consumption/use and the end of cheap air travel - these are the two fastest growing sources of CO2 emission.

We are forced to draw the conclusion that the government does not regard greenhouse gases and global warming as a very serious problem - certainly not serious enough to offend voters by making energy use expensive or taxing personal and commercial road and air transport. Instead, we see inappropriate encouragement of wind turbines which, statistically, do nothing significant to tackle the problem, but which are highly visible and, as politicians will note from the wind industry's opinion polls, popular with 70% of the voters. Inevitably, many consumers will see the turbines, consider the problem solved and turn up the thermostat.

20. MEETING ELECTRICITY DEMAND

Even if we reduce our electricity consumption and emissions from road and air traffic, there will still be a need to generate electricity, reliably and in large quantities

In Canada, more than 60% of our needs are currently met by hydroelectric projects; this can be extended (see the Churchill 2 project), but as a percentage of total needs may diminish. Nuclear power, currently providing 12% [26] of Canadian needs, is politically unpopular despite near zero CO2 emissions and is in regression despite Canada being a world leader in nuclear technology and uranium production [27]. Conventional oil, gas and coal fired electricity accounts for 26%.

The most environmentally-friendly solution is Combined Cycle Gas Turbine (CCGT) generation, a reliable source of 500 Mw can be built on 15 acres, at a cost of between $430-$600 per Kw [29]. The Point Petre site covers 700 acres, and will produce a random, intermittent output of less than 8 Mw; scaling this up to 500 Mw would require 750 of the bigger turbines (2045 of the smaller V47 turbines) on 44,000 acres, or about one fifth of the total area of the County - and we would still need the conventional power plant, running on standby [30] for when the wind is calm.

Erecting a few thousand wind turbines in Ontario is simply fiddling while the world burns - how is the developing world going to meet its generation targets? With dirty local coal? With nuclear? As stated above, wind turbine electricity generating plants are likely to develop a dangerously complacent perception in parts of the public that the problem is being addressed and that they need do nothing further.

21. CONCLUSION

Wind turbine energy is unpredictable, intermittent and dependent on low-output machines. Further, it is an attractively dangerous distraction as a piece of 'green' window dressing. Natural features, adequate undeveloped open space and wildlife areas [31] are non-renewable resources crucial to the well-being of the community and we would argue that it is unacceptable that our landscape should be industrialized in a futile political gesture.

Following a study visit to Denmark in February 1998, Asle Selfors [20] reported that the Danish initiatives in wind turbine farms suffered from "inadequate controls" and "massive and unrestrained funding" which in turn had led to "serious environmental effects, insufficient production, high production costs, high grid costs, and wind farms where there is too little wind". The main advantage of the Danish investment in wind power would appear, he wrote, that it had "laid the foundations of an industry for the production of wind turbines".

Prince Edward County is now being presented with just such a Danish technology proposal.

In February this year, Economy Minister Bendt Bendtsen announced that Denmark will concentrate on competitiveness, instead of a green image and not subsidize installation of new wind turbines from 2004. Installation of wind turbines had depended heavily on subsidies, not only in Denmark, but all over the world.

"I'm of the opinion that Denmark shouldn't continue to subsidize installation of new wind turbines after 2003," Bendtsen said in an interview.

He added that electricity from wind turbines was too expensive, denting Danish firms' competitiveness, and that Danish wind turbine makers have gained from the former government's pro-wind attitude over the past decade and Denmark now hosts some of the world's largest manufacturers, such as Vestas, NEG Micon and Bonus Energy.

And Economy Minister Bendt Bendtsen has scrapped the plans for three more wind farms of 150 Mw each to be installed before 2008. It would surely be logical for Prince Edward County to listen to the country that has more experience in wind turbine development, technology and use per capita, than anywhere else in the world.

Danish experience and expertise concerning the exact same turbines that are being proposed for Point Petre, indicate that we should not be the first small, rural, community - relying on tourism, the arts, culture, heritage and quality of life - to act as a social, legal, political, ecological and environmental test bed for an unreliable and costly technology based on false assumptions and promises. We strongly recommend extreme caution and express our opposition to the uncritical promotion of a technology which will have long-term, far reaching, adverse effects on this community's lifestyle, wellbeing and surroundings for this and future generations.

NOTES and REFERENCES:

[1] Electricity, Canada: Canada, in the year 2000, consumed a total of 500 Billion KilowattHours (bkwh), of which nuclear 70 bkwh, mostly in Ontario. Canadian electricity generation in 1999 totaled 567.2 bkwh. of which 60% was hydroelectric power, 26% was conventional thermal power (oil, gas, and coal), 12% was nuclear generation, and 1% was derived from other renewable sources. Canada is the largest producer of hydroelectric power in the world, and hydroelectric sources are not yet believed to be fully exploited. Trends in coming years are expected to favor thermal power generation, mainly from natural gas. The Canadian nuclear power industry has declined to 69.8 bkwh in 1999 since its peak of 102.4 bkwh in 1994. Ontario contains the bulk of Canadian nuclear capacity.

[2] Carbon emissions, Canada: In 1999, Canada emitted 151 million metric tons (mmt) of energy related carbon emissions. The industrial sector accounted for 40% of this, within which the six energy-intensive industries (chemicals, petroleum refining, iron and steel, smelting and refining, pulp and paper and cement) accounted for over 80% of carbon dioxide emissions. Emissions from the transportation sector in 1998 totaled 48.8 mmt. While on-road vehicles are currently the primary consumer of fuel, off-road vehicles' (including activities associated with oil sands mining), contributions to carbon dioxide emissions are projected to grow appreciably in the future. The residential sector carbon emissions measured 20.6 mmt in 1998, while commercial sector carbon emissions were 18.8 mmt.

[2b] VQ's advertizing of the V80 turbine suggests - "approximately 6 million KW" and "almost 6,000 tonnes", a figure closer to 1,000 than 620. However, there is no indication that this is correctly weighted and not based on "worst case" assumptions regarding fossil fuel usage

[3] Outlook. Canadian energy consumption is expected to increase at an average annual percent change of 1.2%. Natural gas consumption is expected to grow at a rate of 1.5%, nuclear energy at a rate of 1.7%, coal consumption will grow at an average annual rate of 0.4%, renewable at 1.8%. Canadian carbon emissions are expected to grow at an average annual rate of 0.9%.

In August 2001, Ontario Power Generation commissioned North American's largest wind turbine at the Pickering Nuclear Generating Station. The 1.8-megawatt turbine is supposed to generate enough energy to supply 600 average Canadian homes. The company is also planning a 9 Mw (five Vestas 1.8 turbines) wind farm on Bruce Power's Tiverton site near Kincardine, which is now delayed until early 2003. Ontario Power Generation has committed to increasing its total renewable generating capacity to 500 megawatts by 2005, from a present 138 megawatts.

[4] Dr A McFarquar of Cambridge University to The Times in 1999

[5] Welsh Affairs Select Committee on Wind Power

[6] In Canada nuclear power contributes about 14% of the total electricity supply. In the province of Ontario in 1997 about 48% of the electricity supply was nuclear (along with 27% hydro, 24% fossil, 1% "other"). The other two provinces with nuclear power, New Brunswick and Québec, receive about 21% and 3%, respectively, of their supply from nuclear. (source: Electric Power in Canada 1997, Natural Resources Canada)

[7] 30 March 1994, Mr Ian Mays, Chairman of the British Wind Energy Association, giving evidence to the House of Commons Welsh Affairs Select Committee on Wind Energy.

[8] "Turbine" is in fact a misnomer for "airscrew generator". Turbines, whether water, steam or gas have three common characteristics: a) a casing is vital to their operation; b) operation at very high speed (rpm); c) and very high electrical generation for their size. The wind "turbine" is designed to produce power at low to moderate wind speeds with commensurate output. Beyond a certain power output (wind speed) structural engineering constraints oblige them to be shut down for safety reasons.

[9] 10-Year Outlook. An Assessment of the Adequacy of Generation and Transmission Facilities to Meet Future Electricity Needs in Ontario from January 2003 to December 2012, IMO (Independent Electricity Market Operator), April 3, 2002

[10] BERLIN, Aug 6, 2002 (Xinhua via COMTEX) -- Germany now has 12,000 wind-propelled generators with a total capacity of 10,000 megawatts, Environment Minister Juergen Trittin said Tuesday. The German government has planned to double the capacity of wind-propelled generators to 20,000 megawatts in total by the year 2010. But the development of wind-propelled generators in Germany is not without controversy as they are noisy and expensive. The German government also came under criticism for subsidizing 1.1 billion Euros (770 million US dollars) annually on the wind energy production.

[11] American Wind Energy Association, "World Wind Industry Grew by Record Amount in 1997", says AWEA web site <www.igc.org/awea/news> (press release, January 30, 1998).

[12] International Energy Agency, World Energy Outlook 1998 (Paris, France, November 1998), p. 423.

[13] The Editor, Wind Power Monthly, September 1998.

[14] Jonathan Porritt, Forum for the Future

[15] The Energy Technology Support Unit (an agency of the UK Department of Trade and Industry)

[16] Turbine production depends on the size of the turbine and the wind speed of its site, so estimates vary. But the California Energy Plan of February 2002 is more pessimistic at 20%: "Installed capacity of wind power will increase by 1000MW. But in view of the unreliability of wind, they shall only be counted as 200MW in California's 'dependable capacity'"

[17] at the opening of the Pickering 1.8 Vestas on August 29 2001, Graham Brown, OPG's Chief Operating Officer noted that renewable energy was not in a position to displace traditional forms of generation, such as nuclear power. "The wind doesn't always blow, the sun doesn't always shine. We expect this turbine will produce some power two days out of three, and should run flat out about 10 per cent of the time."

[18] http://garsmeth.members.beeb.net/fells.htm

[19] http://www.bwea.gov.uk/forms/notices/ee11.htm

[20] Norbye, V.H., 1998: Vann og Energi. 2-98 (Norwegian Water Resources and Energy Administration, (NVE)). "Dyrekjøpte vindkrafterfaringer i Danmark" - "Expensively bought wind power experiences in Denmark"

[21] Vestas: <http://www.vestas.com/produkter/pdf/ves_V80_usa.pdf>

[22] Report from the Welsh Affairs Select Committee

[23] The Westmorland Gazette - and this was after Windcluster, the developing company, wrote a letter to householders about their plans in advance of the application reading in part: "The design and control systems will ensure that there will be no noise nuisance." (March 1995)

[24] Letter from C. Kerkham to The Daily Telegraph 21 October 1993: "The impact of wind farms on landscape may be significant, but noise is more relevant to those of us living next to this new industry ... We live 350 metres from the nearest turbine and about 750 metres from six or seven others. The "thwump" of the blades and the grinding gears is driving us to distraction. My kitchen chimney amplifies these noises sickeningly ... the house has frequently vibrated with sickening sound waves. At night, these disrupt sleep even when all the windows are closed ... For my family and those in a similar plight ... there

is a distressing human cost for this supposedly 'environmentally friendly' electricity. For us, this is no brave, new, clean energy but a rapacious industrial giant."

[25] Country Guardian, Penlan, Llandeilo Graban, Builth Wells, Powys LD2 3YX

[26] 2001: Canada met 11.8% of electricity needs with nuclear; France, 76.4%, Belgium 55%, Sweden 39%, Switzerland 38%. Conversely, Mexico, China, Brazil and Pakistan are all at less than 2%. Canada has 14 reactors in operation for an output of 10,298 Mw out of the world's 435 reactors, producing 349,479 Mw. We also have idle/unused capacity of a further 8 reactors of 5,136 Mw. Sources: UI/WNA, IAEA

[27] 2001: Canada produced 10,682 tU out of a world production of 34,746 tU, followed by Australia with 7,578 tU. Sources: UI/WNA, IAEA

[28] Capital costs are US$300-400/KW (upgrade) compared to $500-700 for a Combined Cycle Gas Turbine (CCGT) or A$1000-1250 for new technology coal - Australian Nuclear Science and Technology Organization

[29] USA: Nuclear electricity production costs continue to fall in America. In 2000, North Anna PWR was the most efficient plant in the country producing electricity at US 1.09 cents/KWh. [Australian Nuclear Science and Technology Organization]

[30] This in fact is not quite possible, for various technical reasons (as a "spinning reserve" the turbines have to be kept at certain temperatures, etc) a fully functional, instantaneous standby capability is onerous financially and from a CO_2 point of view.

[31] "Rural land" as designated in the County Official Plan.

[32] The Saskatchewan Association of Rural Municipalities <http://www.sarm.ca/Rural_Councillor/Backissu/Volume%2036%202001/V36n5_1001/v36n5art15.htm>

[33] <http://www.greenenergy.com/vers.html>

[34] Wind Power Production Incentive (WPPI) program (Draft, February 21, 2002, Natural Resources Canada and Finance Canada): "Selected wind energy producers will receive a maximum financial incentive of $0.012 for every kilowatt-hour produced during the first 10 years of activity of their new wind farms." - valid for Qualified Wind Farms commissioned before 31 March, 2003, with a diminishing scale for subsequent commissioning dates.

[35] the concrete industry is the biggest man-made source of CO_2 on the planet - about 7% of the world's total

[36] Algemeen Dagblad, 8 February 2000

[37] Proceedings BORKAS 11, Helsinki, 1994, p219)

[38] <http://www.windfarm.fsnet.co.uk/brecon.html> and <http://www.landskapsskydd.nu/vind/vind035.htm>

[39] New Zealand NZS 6808:1998 "Acoustics - the assessment and measurement of sound from Wind Turbine Generators", generally accepted as a solid reference to noise levels, their study and their control.

[40] Paul Brown Environment correspondent Thursday May 31, 2001 The Guardian

Attachment: The Darmstadt Manifesto: A Paper on Wind energy by the German Academic Initiative Group, Press Release dated 1 September 1998

[At today's press conference at the Bruningstrasse Press Club in Bonn the Initiative Group presented the Darmstadt Manifesto on the Exploitation of Wind energy in Germany. The manifesto, which was originally signed by more than 60 college/university lecturers and writers (subsequently another hundred or more signatures have been added), demands the withdrawal of all direct and indirect subsidies in order to put a stop to the exploitation of wind energy. (It claims that) the exploitation of wind energy promotes the type of technology which is of no significance whatever for the purpose of supplying energy, saving resources and protecting the climate. The money could be put to far more effective use in increasing the efficiency of power stations, in ensuring effective energy consumption and in funding scientific research into fundamental principles in the field of energy. Many citizens, both male and female, are greatly concerned to see the progressive destruction caused by the ever increasing number of wind 'farms'. This destruction affects both the countryside and our towns and villages with their surrounding areas whose characterisitc appearance reflects their development throughout the history of civilisation. The Darmstadt Manifesto is directed in particular at politicians, those concerned with our cultural well-being, environmental organisations and the media.]

Our country is on the point of losing a precious asset. The expansion of the industrial exploitation of wind energy has developed such a driving force in just a few years that there is now great cause for concern. A type of technology is being promoted before its effectiveness and its consequences have been properly assessed. The industrial transformation of cultural landscapes which have evolved over centuries and even of whole regions is being allowed. Ecologically and economically useless wind generators, some of which stand as high as 120 metres and can be seen from many kilometres away, are not only destroying the characteristic landscape of our most valuable countryside and holiday areas, but are also having an equally radical alienating effect on the historical appearance of our towns and villages which until recently had churches, palaces and castles as their outstanding features to give them character in a densely populated landscape.

More and more people are subjected to living unbearably close to machines of oppressive dimensions. Young people are growing up into a world in which natural landscapes are breaking up into tragic remnants. The oil crisis in the 1970s made everyone very aware of the extent to which industrial societies are dependent on a guaranteed supply of energy. For the first time the general public became aware of the fact that the earth's fossil fuel resources are limited and could be exhausted in the not too distant future if they continue to be consumed without restraint. In addition came the recognition of the damage which was being caused to the environment by the production and consumption of energy. The loss of trees due to pollution, the Chernobyl nuclear reactor accident, the legacy of the ever accumulating piles of nuclear waste, the risks of a climatic catastrophe as a consequence of carbon dioxide emissions have all established themselves in the public consciousness as examples of the growing potential threat.

The real problem of population growth and above all the resultant phenomenon of escalating land use and consumption of drinking water supplies is however being pushed aside and being considered instead as a marginal phenomenon. With few exceptions it is not the subject of any political action. On the contrary, the public interest is becoming even more limited, focusing less on energy consumption as a whole and concentrating its fears and criticisms predominantly on the generation of electricity. Admittedly nuclear risks do doubtless exist here. However electrical energy plays more of a minor role in the balance sheet of energy sources. In Germany three quarters of the energy consumed consists of oil and gas. But it is precisely these energy sources whose resources will be exhausted the soonest. If it were really a question of concern for future generations then immediate, decisive action to protect supplies of oil and natural gas would be imperative. Instead petrol consumption continues unchanged, and the idea that we are leaving nothing for our great grandchildren is dispelled with the vague presumption that there will one day be substitutes for fossil fuels. On the other hand hard coal and brown coal, which are the main primary sources of electrical energy, are available in such abundance world-wide, and in many cases in deposits which are as yet unexploited, that electricity production is guaranteed, even with growing consumption, for centuries, possibly even for a period of over a thousand years.

With regard to the exhaustion of energy sources for fossil fuels the development of electricity production using wind bypasses the problem. Although Germany has taken the lead in the expansion of wind energy use, it has not been possible to date to replace one single nuclear or coal-fired power station. Even if Germany continues to push ahead with expansion it will still not be possible in the future. The electricity produced by wind power is not constant because it is dependent on meteorological conditions, but electricity supplies need to be in line with consumption at all times. For this reason wind energy cannot be used to any significant degree as a substitute for conventional power station capacities.

Insufficient attention is also being paid to pollutant levels. Whereas until a few years ago it was chiefly the coal-fired power stations' sulphur dioxide emissions due to poor filtering which caused problems, it is now mainly road traffic which is polluting the forests' ecosystems with nitrogen oxides and nitrous oxide. Added to which the effectiveness of power stations is improving with technological progress and as a result the level of pollutants given off per unit of energy is decreasing. The latter is also true of carbon dioxide emissions, with the result that electricity production in Germany is today responsible for only a fifth of the greenhouse gases emitted.

The energy capacity of wind is comparatively low. Modern wind turbines with a rotor surface area the size of a football field make only tiny fractions of the energy that is produced by conventional power stations. So with more than five thousand wind turbines in Germany less than one per cent of the electricity needed is produced, or only slightly more than one thousandth of the total energy produced. The pollutant figures are similar for the same reason. The contribution made by (the use of) wind energy to the avoidance of greenhouse gases is somewhere between one and two thousandths. Wind energy is therefore of no significance whatever both in the statistics for energy and in those for pollutants and greenhouse gases.

At the same time we must take into account the fact that economic growth always brings with it, to a greater or lesser extent, an increasing energy requirement - despite all the efforts made with technology towards greater efficiency in the transformation and consumption of energy. This means that because it makes such a small contribution to the statistics, wind energy is running a race which is already lost in an economic order orientated towards growth. At present total energy consumption in Germany is growing about seventy times(!) faster than the production potential of wind energy.

The negative effects of wind energy use are as much underestimated as its contribution to the statistics is overestimated. Falling property values reflect the perceived deterioration in quality of life - not just in areas close to the turbines, but even all over Schleswig-Holstein. More and more people are describing their lives as unbearable when they are directly exposed to the acoustic and optical effects of wind farms. There are reports of people being signed off sick and unfit for work, there is a growing number of complaints about symptoms such as pulse irregularities and states of anxiety, which are known to be from the effects of infrasound (sound of frequencies below the normal audible limit).

The animal world is also suffering at the hands of this technology. On the North Sea and Baltic coasts birds are being driven away from their breeding, roosting and feeding grounds. These displacement effects are being increasingly observed inland too. From the point of view of the national economy the development of wind energy is far from being the "success story" it is often claimed to be. On the contrary, it puts a strain on the economy as it is still unprofitable with a low energy yield on the one hand and high investment costs on the other. And yet, as a result of the legal framework conditions which have been set, private and public capital is being invested on a large scale - capital which is not least unavailable for important environmental protection measures, but also ties up purchasing power. This in turn leads to job losses in other areas. The only way in which the investors can realise their exceptionally high returns is by means of the level of payment for electricity produced by wind which has been determined by law, and which represents several times its actual market value, and by taxation depreciation.

For more than twenty years now German politicians have been under pressure to react to urgent problems concerning the environment and preventative measures, and have been promoting a seriously erroneous evaluation of wind energy. This has allowed the use of wind energy to become established in the view of public opinion as some sort of total solution which supposedly makes a decisive contribution towards a clean environment and a guaranteed supply of energy for the future, and also towards the evasion of a climatic catastrophe and the avoidance of nuclear dangers. This false picture raises hopes and results in a general acceptance of the use of wind energy which is strengthened further by the fact that people are not expected to make any savings. The negative effects of the wind energy industry in our densely populated country are suppressed, scientific knowledge is ignored and there is a taboo on criticism. Only a few people are willing to break away from these political and social trends. After fighting for decades with great commitment for the preservation of our countryside the majority of the large organisations for the protection of nature now stand idly by watching its destruction. Together with groups of thoughtless operators, a policy orientated towards short term success was able to clear the way in the following manner: as a result of amendments to planning law and the law on nature conservation, our countryside is almost unprotected against the exploitation of wind energy and is therefore left at the mercy of material exploitation by capital investment. At the same time the people who are directly exposed to this technology which is hostile to man have to a large extent been deprived of their constitutionally guaranteed right to a say in the matter of the shaping of the environment in which they live.

As all efforts to influence those with political responsibilities have been without success, the signatories of this manifesto see no other solution other than to make their concerns public. In view of the serious harm threatening our countryside, which has evolved through history and which is the foundation of our cultural identity, we appeal for an end to the expansion of wind power technology which is pointless from both an ecological and an economical point of view. In particular we are demanding the withdrawal of all direct and indirect subsidies to this technology. Instead public funds should be made available on a larger scale for the development of more efficient technology and for the kind of research into basic principles which is likely to provide real solutions to the problems of producing energy in a way which is environmentally friendly and lasting. We issue an urgent warning against the uncritical promotion of a technology which will in the long term have far reaching adverse effects on the relationship between man and nature. We are particularly concerned about a change of attitude, which is more difficult to perceive as it is evolving slowly and which gives us less and less ability to recognise how important it is for man to live in an environment which is predominantly characterised by nature.

LIST OF SIGNATORIES:

Prof. Udo ACKERMANN (Design) Prof. Dr. Dr. h.c. Karl ALEWELL (Economics) Prof. Dr. rer. nat. Rudolf ALLMANN (Mineralogy) Prof. Wilhelm ANSER (Electrical Engineering) Prof. Dr. Clemens ARKENSTETTE (Biology, Agricultural Science, Physiology) Dr. paed. Joachim ARLT (Science of Art, Landscape Aesthetics) Prof. Dr. rer. nat. Benno ARTMANN (Mathematics) Prof. Dr.-Ing. Eckhard BARTSCH (Geodesy, Landmanagement) Prof. Dr. rer. nat. Bruno BENTHIEN (Geography) Dr. jur. Manfred BERNHARDT (District President) Prof. Dr. jur. Dr. jur. h.c. Karl August BETTERMANN (Jurisprudence) Prof. Dr. agr. Dr. agr. h.c. mult. Eduard von BOGUSLAWSKI (Agronomy) Prof. Dr. rer. nat. Reinhard BRANDT (Physical Chemistry) Prof. Dr. rer. nat. Günter BRAUNSS (Mathematics) Prof. Dr.-Ing. Stefan BRITZ (Mechanical Engineering) Prof. Dr. Dr. phil. Harald BROST (Institute of Colour, Light and Space) Prof. Dr. med. Joachim BRUCH (Industrial Medicine) Günter de BRUYN (Writer) Prof. Dr. phil. Dr. h.c. Hans-Günter BUCHHOLZ (Archeology) Prof. Dr. rer.nat. Karl Heinz CLEMENS (Electrical Engineering) Prof. Dr. phil. Dietrich DENECKE (Geoscience) Prof. Dr. rer. nat. Dietrich von DENFFER (Botany) Prof. Dr.-Ing. Frank DÖRRSCHEIDT (Automatic Control, Electrical Engineering) Prof. Dr. Wolfgang DONSBACH (Science of Communication) Prof. Thomas DUTTENHOEFER (Design) Prof. Dr.-Ing. Rudolf ENGELHORN (Energy and Thermodynamic Science) Dr. techn. Hans ERNST (Electrical Engineering, National Economy) Prof. Dr.-Ing. Horst ETTL (Mechanical Engineering) Prof. Dr. Hermann FINK (English Philology, American Philology) Prof. Dr. Hans Joachim FITTING (Physics) Prof. Dr. med. Marianne FRITSCH (Internal Medicine, Rehabilitation) Prof. Hans Jürgen GERHARDT (Electrical Engineering) Prof. Dr. rer. nat. Gerhard GERUCH (Physics) Prof. Dr.-Ing. Bernhard von GERSDORFF (Electrical Engineering) Prof. Ph.D. H. S. Robert GLASER (Biology) Prof. Dr. Gerhard GÖHLER (Political Science) Prof. Dr. theol. Hubertus HALBFAS (Religion) Prof. Dr. Erwin HARTMANN (Physics, Medical Optics) Prof. Dr. rer. nat. Jürgen HASSE (Geography) Dr. rer.nat. Günter HAUNGS (Technique of Precision Measurement) Prof. Dr.-Ing. Horst HENNERICI (Mechanical Engineering) Prof. Ulrich HIRT (Mechatronics) Prof. Wolfgang HOFFMANN (Economical Information) Prof. Dr. rer. nat. Lothar HOISCHEN (Mathematics) Prof. Dr. med. Dr. rer. nat. Hans HOMPESCH (Hygiene, Micro-Biology, Pathology) Prof. Dr. Dr. h.c. mult. Rudolf HOPPE (Inorganic Chemistry) Prof. Dr. Peter KÄFERSTEIN (Thermodynamic Science, Energy Economics) Prof. Dr. Dipl. Phys. Günther

KÄMPF (Physics) Prof. Dr. phil. Thomas KÖVES-ZULAUF (Archeology) Dr. Christoph KONRAD (MdEP - Member of European Parliament) Prof. Erhard Ernst KORKISCH (Area Planning, Landscape Architecture) Prof. Dr. Dietrich KÜHLKE (Physics) Prof. Dr.-Ing. Bert KÜPPERS (Electrical Engineering) Prof. Dr.-Ing. Josef LEITENBAUER (Mining Academy) Prof. Dr. phil. Otto LENDLE (Archeology) Prof. Dr. rer. nat. Wilfried LEX (Information Science, Logic) Prof. Dr. Horst LINDE (Architecture) Prof. Dr. techn. Wladimir LINZER (Thermodynamic Science) Prof. Dr. rer.nat. Jörg LORBERTH (Chemistry) Prof. Dipl.-Ing. Horst LOTTERMOSER (Mechanical Engineering) Prof. Dr. h c. Manfred LÖWISCH (Industrial Law) Prof. Uwe MACHENS (Electrical Engineering) Dr. Heike MARCHAND (Physics) Prof. Dr. sc. phys. Dr.-Ing. Herbert F. MATARÉ (Physics, Electronics) Prof. Dr. Krista MERTENS (Science of Rehabilitation) Prof. Dr.-Ing. MOLLENKAMP (Mechanics of Fluids) Prof. Dr. rer. nat. Hans MULLER von der HAGEN (Chemical Technology) Prof. Dr. jur. Reinhard MUSSGNUG (Jurisprudence) Prof. Dr. Ing. Kurt NIXDORFF (Mathematics) Prof. Werner A. NÖFER (Design) Prof. Dr.rer. nat. Wolfgang NOLTE (Mathematics) Prof. Dr. rer. nat. Paul PATZELT (Chemistry) Prof. Dr. rer. nat. Siegfried PETER (Technical Chemistry) Prof. Dr. rer. nat. Nicolaus PETERS (Zoology) Prof. Dr. Dr. Hans PFLUG (Applied Geosciences) Prof. Dr. Thomas RAMM (Physics) Prof. Dr.med.Ludwig RAUSCH(Human Medicine, Radio Biology, RadiationProtection) Prof. Dr. rer. nat. Michael von RENTELN (Mathematics) Dr. phil. Karl Heinrich REXROTH (History) Prof. Dr. Hans Erich RIEDEL (Physics) Prof. Wilhelm RUCKDESCHEL (Mechanical Engineering) Dr. med. Rolf SAMMECK (NeuroAnatomy) Dr. phil. Monika SAMMECK (Psychology) Prof. Dr. Hans SCHNEIDER (Jurisprudence) Prof. Dr. Helmut SCHRÖCKE (Geosciences) Prof. Dr.-Ing. Herbert SCHULZ (Electrical Engineering) Prof. Dr. Ing. Kurt STAGUHN (Art Paedagogy) Prof. Dr.-Ing. Klaus STEINBRÜCK (Mechanical Engineering) Prof. Dr.-Ing. Rudolf STEINER (Technical Chemistry) Dr. h.c. Horst STERN (Television Journalist, Ecologist) Botho STRAUSS (Writer) Prof. Dr. rer.nat. Günter STRÜBEL (Geosciences) Prof. Dr.-Ing. Manfred THESENVITZ (Mechanical Engineering) Prof. Dr. rer. nat. Josef WEIGL (Botany) Prof. Dr. med. Hans Jobst WELLENSIEK (Medicine, Micro-Biology) Prof. Dr.-Ing. Herbert WILHELMI (Thermodynamic Science) Prof. Dr. phil. Walter WIMMEL (Archeology) Gabriele WOHMANN (Writer) Prof. Dr. rer. nat. Jürgen WOLFRUM (Physics) Prof. Dr.-Ing. Otfried WOLFRUM (Geodesy) Prof. Dr. rer. nat. Peter ZAHN (Mathematics)

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Section title: Wind turbines devalue adjacent properties

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... letter from Robert Bittner, Tiskilwa, Illinois, describing how he and his wife left their ancestral home in Tiskilwa because of the industrial turbines next door (letter dated 12-6-05)

Calvin Luther Martin

From: "Bob Bittner" <bbittner@stl-k12.com>
To: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Tuesday, December 06, 2005 11:07 AM
Subject: RE: Turbines & noise, property values, health issues, bird & bat deaths

Dear Calvin

The statement "you were forced to vacate your home in Tiskilwa. Can you give me more information on this?" is not technically correct.

The township where the wind farm is located was pioneered by my great great grandfather Calvin Cushing in 1835 -1835. On behalf of the Pawtucket Emigrating Society, he purchased all of the available land in Indiantown Township. Since then, many generations of my family have been raised. Now there are five turbines with a 1/2 mile of our family home, 33 within two miles, 30 more larger ones coming next year, and one just 1300 feet away.

To see the destruction and desecration of this land has been a traumatic experience for our family. We decided to acquire a second home in the woods eight miles away where we are able to escape and put this saga out of our minds temporarily. However, we still use the farm house occasionally for nine months but mostly in the winter time when we are in-doors most of the time and do not have to see them, hear them, or feel them looming 400' over us.

It has not been the noise, loss of TV, or flicker that have bothered us the most but the general depression that has been senselessly and needlessly forced upon us. We are over 65 and there is no way to tell how much our lives have been shortened by the stress.

We wish you the best with your fight. You must stop it before it gets approved. We took our case through the courts and never did get a ruling on the issues. Each court said we "did not have standing" to file. In other words, a home owner in our situation does not have recourse.

Good luck and
Best regards,

Bob Bittner

309-258-1434 Cell
800-844-0884 X2115 Work

Herald Sun Article

VICTORIA - AUSTRALIA

Blot on the landscape
Danny Buttler
environment reporter
21feb04

WIND farm developments could wipe millions of dollars from Victoria's coastal property market.

Real estate agents have claimed house prices near existing wind turbines have been slashed by up to 30 per cent.

And seaside homes that have their views obscured by the 100m tall turbines could face even greater devaluation.

Wind farms are planned for several areas on the Victorian coast, including developments near Portland, Warrnambool, Cape Liptrap, Welshpool, Queenscliff and Foster.

If the State Government approves all current proposals, more than 300 turbines could be built within sight of the coast.

Worries about noise pollution and obscured views have seen land holders within 2km of the existing Toora wind farm in South Gippsland struggle to sell their properties. Those who can find buyers have been forced to sell well below the pre-wind farm market price.

Bruce Richards, managing director of PBE Real Estate in South Gippsland, said Victoria's property boom was going backwards in the shadow of the giant turbines.

He said selling homes within 2km of Toora's 12 wind turbines was becoming increasingly hard.

"Anywhere close to the towers is very, very difficult to sell," he said.

Apart from complaints about noise, glare from the rotating blades was a major turn-off for prospective buyers.

"I showed some people a block three months ago and the flicker was as bad as the noise, if not worse . . . it would just drive you crazy," he said.

Proposed developments closer to the South Gippsland coast could see an even greater fall in prices if the giant towers obscured sea views.

Mr Richards said a planned wind farm near Cape Liptrap would have a devastating effect on land values, which are based on the spectacular coastal and rural scenery.

"Mate, that would just ruin it, you drive along Liptrap road and it's just fantastic, if you put these bloody windmills up who knows what it's going to do," he said.

"Cape Liptrap properties are prime, you're looking at more than 25 to 30 per cent there."

"If they go around the whole coast it will just ruin it . . . people come here for its beauty."

South Gippsland Shire mayor David Lewis said rate valuations had decreased on some properties near turbines, but could not confirm if it was just due to wind farms.

But there was no doubt they had had depressed the immediate property market. "My personal belief is that it does destroy property values," he said.

The Australian Wind Energy Association said it would like to see hard evidence of changes to property values, but admitted no research had been done in Australia.

Stanwell Corporation, which owns the Toora wind farm said it was unable to comment on property values because of insufficient data.

30th May 2000

Russell Baldwin & Bright

01874 623156

11 High Street,
Brecon, Powys LD3 7AH

01874 624314

DX 200560 BRECON

brecon.sales@rbbproperty.co.uk

www.rbbproperty.co.uk

* Dear

Further to our telephone conversation last week I confirm that I have withdrawn your property from the market.

As discussed since the proposed Windfarm planning application was published enquiries for your property have fallen off dramatically. It is obviously very disappointing that this situation has arisen after such a promising response to the early marketing which resulted in an excellent number of viewings. There is however, little point in continuing to market [redacted] as any serious purchaser will be immediately put off by the prospect of a nearby Windfarm.

On a more general note I have a prospective purchaser of a property at Merthyr Cynog having serious doubts over it's proximity to the proposed site.

I will keep the file pending until planning application is resolved at which time I trust we will be able to re-market the property.

Yours sincerely

Brockington Wade

Solicitors

Elm House, Shackleford Road
Elstead, Godalming
Surrey GU8 6LB

Tel. 01252 703770
Fax 01252 703787

Messrs Bambridges
27 Wide Bargate
BOSTON
Lincolnshire
PE21 6SW

BY FAX NO. 01205 310008 & POST

Your Ref: BJB.SEJB.HIC.23-3
Our Ref: STW.9920/Matthews

05 March 2002

Dear Sirs

Re: Reeds Cottage, Fore Lane, The Gauntlet, Bicker, Nr Boston
Hickson to Matthews – Subject to Contract

We are very sorry to have to say that our Client has withdrawn from the above proposed purchase. They are extremely distressed to do so due to having discovered by chance the existence of the proposed wind farm development. The decision was confirmed when they visited a wind turbine in operation in Swaffham and the visual intrusion from one tower was enormous. Apparently there is outrage in the area to the proposed development. Our Clients are obviously disappointed that they did not learn of this proposal earlier and that searches did not reveal such matters.

We return your paper herewith.

Yours faithfully

BROCKINGTON WADE

FPDSavills

05 May 1998

S Henry Esq
Church Farm
Stockton
Beccles
Suffolk

Dear Mr Henry

WIND TURBINES

You asked me about the effect on property values that a large wind turbine would have assuming it was within a reasonable proximity

In general terms any structure that can be viewed as an intrusion into the countryside such as electricity pylons or wind turbines will have a detrimental effect, however, it is very subjective and different purchasers will view the blight to lesser or greater degrees. Usually it will not only effect the value of the property, but also saleability which is not necessarily the same thing

Generally speaking the higher the value of the property the greater the blight will be and the effect on its value in percentage terms. Starting at the lower end of the scale most people looking to buy a house at £20,000 to £40,000 are not too concerned about its outlook particularly as many of these types of houses are situated on roads or in towns etc. As you go up the value scale buyers generally become more discerning and the value of a farmhouse maybe affected by as much as 30% if it is close proximity to the wind turbine. Those houses that are in ear shot are likely to be affected worst of all.

Interestingly the higher the value of the house, the greater the impact of the structure such as wind farm will have over a further distance. In other words at the lower end of the scale a house may only be affected if it has an outlook within half a mile, whereas with a larger house the effect may stretch up to a considerably longer distance, particularly where the house has a pleasant rural outlook at the moment. This would probably affect it over a much longer distance say of 2-3 miles.

Obviously the further away the less the impact on value.

I hope this is of some help in terms of a general pointer and it was certainly our experience at Winterton when that wind farm was built. Obviously, as I understand it, the structures there are nothing like as high as the ones proposed at Stockton.

Yours sincerely

I M MILES

A member of
FPDSavills International

ASHDALES

0112

Mr Cuthbert
Mill Cottage
Mill Lane
Hollym
HU19 2SE

31/03/99

Dear Mr Cuthbert

RE:- MILL COTTAGE, MILL LANE, HOLLYM, HU19 2SE

I write to inform you Mr & Mrs Caldera who viewed the property on the 10th March 1999 are no longer interested in your property due to the proposed Wind Turbine development in the area.

We are sorry for any inconvenience this may have caused you and thank you for your co-operation

Yours sincerely

PAM HALLEY N A E A
ASHDALES

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Calvin Luther Martin

From: "Cath" <cath@kingcon.com>
To: <Undisclosed-Recipient:;>
Sent: Tuesday, May 02, 2006 8:04 AM
Subject: #AU: Court bid to halt wind farm

----- Original Message -----
From: Lisa Linowes
To: Undisclosed Recipients
Sent: Monday, May 01, 2006 4:16 PM
Subject: #AUS: Court bid to halt wind farm

http://www.smh.com.au/news/national/court-bid-to-halt-wind-farm/2006/04/29/1146198389568.html
Court bid to halt wind farm
Email Print Normal font Large font By Alex Mitchell
April 30, 2006

COURT action will be taken tomorrow to halt Planning Minister Frank Sartor's bid to expand wind farms in the Southern Highlands.

Angry residents say they were not consulted about the installation of wind turbines near the township of Taralga, near Goulburn, and they are concerned about noise pollution from the machines.

They plan to take a Land and Environment Court injunction on a company called RES Southern Cross that has been given a licence by Mr Sartor to install 62 wind turbines on the Taralga hills

A recent poll by the Upper Lachlan Shire Council showed 72 per cent of voters are against their installation and there have been complaints the real estate values have collapsed from $4940 a hectare to $1729 a hectare since the Government's announcement.

Federal Environment Minister Ian Campbell is soon to announce a national code on wind farms, with a new power to veto any project that is opposed by local communities.

RE/MAX Professionals
The Estate Agency Leaders
16 Nott Square, Carmarthen, Carmarthenshire SA31 1PQ
Tel: 01267 221222
Fax: 01267 234250

REPORT

ON A SAMPLE

OF PROPERTIES

INSPECTED NEAR

A PROPOSED WIND FARM

AT ESGAIRWEN FAWR

Nr LAMPETER

Report carried out following an inspection of the respective properties.

From our inspection of the site, it is a skyline development, is set at the junction of the B4338 Llanybydder to Talgarreg road at Hwylgarn junction.

We understand that the proposal is for a total of 10 turbines, and we would report as follows on properties which were inspected by us.

THE VALUER

The Valuer has some 30 years experience in the sale and valuation of properties in the Carmarthenshire, Ceredigion and Pembrokeshire areas. He is a Senior Partner in a local firm of Estate Agents, and one in Llanelli. REMAX Estate Agents operate on a World Wide basis, and have been established since 1973, with each Office having a wealth of resources to draw from. The Valuer himself has done other projects, and has made a study of Wind Farms and Turbines over the past 5 or 6 years, and can, therefore, speak from authority on the subject of turbines and, indeed, the effect of turbines on surrounding land and values.

SAMPLE OF PROPERTIES INSPECTED

2. Bryn Awel, Mydroilyn

Within sight of proposed development and comprises a 3 bedroomed detached property, with Economy 7 heating, PVCu double glazed, rear lawn within view of property development, and the superb views would be spoilt.

The value as it stands is around **£175,000 (One Hundred and Seventy Five Thousand Pounds).** If the Wind Farm was constructed, the value would be reduced to around **£130,000 (One Hundred and Thirty Thousand Pounds).**

A loss of **£45,000 (Forty Five Thousand Pounds)**

SUMMARY AND CONCLUSION

The proposed development also towers over houses in Mydroilyn village.

Given a sample of properties inspected and reported as above, this represents an immediate loss of **£1,528,000 (One Million Five Hundred and Twenty Eight Thousand Pounds)** for the 8 properties mentioned, let alone all those which may be affected by the turbines, both by seeing them and hearing them.

It is also to be considered that all these properties will become more difficult to sell, and the small roads around the proposed development will become congested with traffic during construction work. The wind turbines also give an element of noise, and all the places mentioned will be affected by the noise and 99% of the places nearby within reach of the turbines will be affected and the construction and the development of the site will have an immediate loss on the values of the properties therein.

It is our recommendation as well, that should the development go ahead, that all of the households affected by the Wind Farm apply for a rate reduction, due to the fact that their fine views will be taken away from them, and the noise level and constant "whooshing" of the blades will affect the peace and tranquillity of the properties nearby.

At the recent development down in Llanboidy near Whitland, there were similar objections raised. The site, which had already been granted outline consent, was given the go ahead with detailed consent, and there was a strong objection to the proposed development, when people realized what it was, as opposed to the mythical windmills which were read about in books. In Llanboidy so much so, that one owner who was nearby when the site was constructed took the drastic step of ending his own life, and hung himself in the outbuilding, which was then in sight of the development.

The properties mentioned in this report are only a sample of some of the properties which will be affected by the proposed development, and although some of the properties are affected more then others, of the 8 listed, this represents over £200,000 for each property, and if this is taken to all the properties that are affected, although the average might come down, it will mean a substantial loss to the home owners, and invasion of their privacy, and the possible radiation danger, and a loss of revenue to the Local Authority with all properties in the area claiming a reduction in rates, due to the nuisance value, plus all the stress and anxiety caused by the proposed development.

The question also needs to be answered as to who pays the property owners compensation for the loss in values. Either the Local Authority, by granting permission, or the Developers, as this reduces the value of the respective properties.

Signed ....

Gareth Scourfield
Surveyor and Valuer
For R G Lewis & Company Estate Agents Ltd
T/A REMAX Professionals
Estate Agents, Auctioneers and Valuers
16 Nott Square, Carmarthen, SA31 1PQ

Dated 11th July 2005

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August 5, 2005

To the Editor
The Caledonian Record

To Whom This May Concern:

As producer and director of the documentary, Life Under a Windplant, a video shown widely in your area, I'd like to respond to the spurious claims about it wrought by your not-so-very local wind developer. But first, you should know I'm a retired university administrator who has no financial interest one way or another over this wind issue, nor do I nor any members of my family own property in the viewshed of any proposed windplant. On the other hand, wind developers hope to make a financial killing, and, despite their penchant for labeling opponents as NIMBYs, themselves live hundreds of miles from their project. The industry is in fact a spiritual descendant of Enron, the "energy" company that, before its demise, owned and operated the nation's largest collection of wind facilities; it pioneered the tax shelter as a commodity. After several years of researching the wind industry, I've concluded the relatively feckless energy it produces is a front for the real business of generating Enronesque tax avoidance schemes benefiting a few at the expense of many, while playing havoc with the environment (while claiming to be saving it). It's an environmental hoax and an economic sham. More than 2500- 400 foot 1.5 MW turbines, spread over many hundreds of miles of forested ridgetops, would not displace one 1600MW coalplant. The wind industry, as it targets huge powerplants along the uplands of our region, is a placebo solution to the problems wrought by our dependence on fossil fuels, distracting from the necessary level of discourse- --and political action-- for achieving genuinely functional responses.

About the video:

The prices Somerset Wind in Pennsylvania paid for the properties near its windplant were comparable to prices paid for similar properties in the area and in line with the price previous buyers had paid. Although the properties in the video were assessed for tax purposes at around $20,000 (as of 1997), they initially had sold for fair market value at $80,000 and $74,000 respectively—in 1998 and 1997. As every realtor and appraiser knows, assessed tax value lags considerably behind market value, often by as much as 500 percent. The property owners who precipitated the sale did so because of windplant-caused nuisances. In 2002, Somerset Wind bought these properties for $104,500 and $101,049 respectively—and within six months, sold them for $65,000 and $20,000 respectively—the first to a windplant employee and the second to an existing wind lessor. The quotes of the prices listed in the documentary are those listed in the deeds. The deeds are public records. And the reason the developer bought the properties in the first place was to forestall a lawsuit brought on because of the very real nuisances that the windplant created--nuisances actually named in an exculpatory easement in the new deeds. Your wind developer's chutzpa here is simply amazing....

Moreover, the claim that the windplant noise in the documentary was somehow rigged is a damnable lie. If anything, the actual sound was muted in the documentary. Note that the video several times indicates how far the recorded noise was from the wind turbines. Because we anticipated what the wind flaks would say about dubbing, we recorded the voice you hear over the sound, showing that one had to practically shout to be heard nearly a half mile from the windplant. You might also ask any of the Meyersdale participants in the documentary whether they think the sound was dubbed over or modified in any way. Or ask whether the wind developer puts language in his leases holding his company harmless from a variety of nuisances, including noise--as is the case in Berlin, Pennsylvania.

Wind noise is generally much less in the summer and early fall than at other times of the year in

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Calvin Luther Martin

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Tuesday, August 02, 2005 10:15 PM
Subject: ... windfarm co. pays farmer to move because of noise & vibration

... in New Zealand, windfarm company bought out a farmer because he couldn't stand the noise & vibration. Hmmm.

Calvin

http://www.stuff.co.nz/stuff/manawatustandard/0,2106,3364982a6003,00.html

Meridian pays family to move

02 August 2005
By LEE MATTHEWS

Meridian Energy has paid an undisclosed sum of money to shift a family from their farm where Te Apiti's wind turbines are located, because noise and vibration made it too difficult to live in their house.

Company spokesman Alan Seay would not say how much the compensation is, as it is a confidential agreement between Meridian and the Bolton family. He understands they will move off their farm and build elsewhere.

He also said the payout is not a surprise, as it had been anticipated in the initial lease agreements with the land owners. It is not part of any of the 20 conditions imposed by the wind farm's resource consent.

"Te Apiti is built on two farm properties. It was recognised right from the start that this family could have issues with noise . . . their house was only a few hundred metres from the turbines," Mr Seay said.

"The possibility of having to shift was part of the initial lease agreement. These were houses actually in the wind farm, as opposed to neighbouring (houses)."

Meridian has also made a confidential deal with the other farm owners affected. Mr Seay said he understands this has involved building alterations, such as double-glazing windows to reduce noise.

There are no other claims for any kind of compensation for nuisance from Te Apiti, and Mr Seay said he does not anticipate any in future. "This one was made because it was a foreseen situation."

Feedback from the Ashhurst community about Te Apiti has "all" been positive, apart from "one or two vociferous" opponents whom he understands to be working with people objecting to Meridian's proposed Makara wind farm.

"Nimby (not in my back yard) syndrome . . . it's what we've got to expect from some of these groups . . . it's misleading and distorting."

Last November, Ashhurst resident Colin Mahy complained that sun reflection flickering into his house from the Te Apiti turbines was "driving him mad". Meridian had told him to draw his curtains.

Mr Seay said that he had given that advice. "Sun flash is a very momentary thing, it only occurs in certain circumstances and it doesn't last long."

AGRICULTURAL RESOURCE CENTER

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UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY
This survey summary completed Thursday, May 16, 2001,
by David E. Kabes and Crystal Smith.

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

When we were dating back in the 1970's we always said that someday we were going to build a home here. It was great and then you guys did this. Thank you. Now its move or get a divorce after 26 years. I don't think so. I guess the real test will come in a couple of years when our son is out of school. With all the money that the township is making, if we can't sell it they can buy it and enjoy the sight, sound, and shadows. Believe me it sure made our lives here!! This should have never happened. If only you would have taken the time and study this more. Everyone was thinking about themselves and money. No one cared about anything else. Thanks Again.

They need to be kept away from homes. Perhaps we need other power supplies but not near people's homes.

It seems rather poor to send out a survey now when they are already up. We received nothing to state our opinions before the turbines went up! The survey mentions lower taxes in Lincoln township. Two years ago, homes were reassessed and everyone's taxes went up substantially. Now there is talk about assessing again. I will not pay more taxes to live near windmills! I and my family sure wouldn't want to see any more go up anywhere near this area. There is less and less country side left to enjoy with all the home building. We don't need to look at those unsightly things!

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LINCOLN TOWNSHIP WIND TURBINE SURVEY

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based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

5. How close to the wind turbines would you consider buying or building a home?

Question # 5
2 or more miles at best
The WPS hired sound, noise consultant said that 1 ½ to 2 miles distance is required to mitigate the low frequency noise of the generators.
More miles is better
I would not build by any of them!
No where near, further than 2 miles.
¾ - 1 miles or more
Any of the last three choices
All with mental safety is a factor.
Far enough away that I wouldn't see them but I am stuck with them.
As far away as possible.
Ugly, would not buy in this area again.
Own
No where near
I personally think they are an eyesore and would not want them near my home.
No where near them what so ever.
Cars stop on road in front of me to look at the wind turbines, almost hit one vehicle.
No where in sight of them.
30 miles
Where I could no longer see them or the flashing lights.
25+ miles. They can be seen from this distance.
Many
2 or more counties
2 or more miles - this is even too close.
No where near
Will never build another house.
2 miles is too close yet.
At least 2 miles.
No where near them never ever! Not for a million dollars.

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Calvin Luther Martin

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Wednesday, April 13, 2005 2:25 PM
Subject: Re: PROPERTY prices falling near WIND FARMS

... this in from a UK campaigner, on falling property values because of windfarms next door.

Calvin

http://www.cambridge-news.co.uk/news/letters/2005/04/11/529e6c57-a1ec-428b-ad0c-855515b543cc.lpf

Prices falling

From Lynwen Evans

I WOULD like to put my statement to you loud and clear in response to your article "properties not hit by wind farm" (News, April 5).

I for one am in the same position as lots of people in the UK at this moment with the wind farm growing in popularity.

The first thing I did when the news got out about the proposed wind farm, was invite an estate agent to value my property. You can imagine my response when I was told that the value of my "basic three-bedroom bungalow" was going to drop £45,000.

With that, I had a discussion with one of the farmers involved in this wind farm, and she herself told me that they have had their property valued, and yes, it will lose value, but of course the land will gain value because of the wind farm.

One of the villagers put their property on the market as soon as the news came out. They had three people interested, until they were told there was a proposed wind farm. At that, they all pulled out.

These estate agents don't like admitting that there is a fall in property values. Needless to say, they themselves will be out of pocket.

Two of the villagers went into an estate agent asking about the prospects of selling properties in the villages concerned, only to be told that "these areas are now a no-go area!"

It's time devaluation is made known, everyone should know of what's going to happen to all that they have worked for.

Lampeter
Ceredigion
Wales

1 30

This is a letter from a professional property evaluator. He knows the true value of land and homes. He wrote this to a Michigan State Government group that was writing rules for locating wind plants.

MATUREN & ASSOCIATES, INC.
Real Estate Appraisers – Consultants
1125 E. Milham Avenue
Portage, Michigan 49002
269-342-4800

DT: September 9, 2004

TO: Michigan Wind Working Group
c/o John Sarver, Energy Office

RE: Impact of Wind Turbine Generators on Property Values

First of all I wish to thank you for including me in your email distribution list relative to the proceedings of the Wind Working Group. I have an interest in the topic as a Kalamazoo County Commissioner concerned with land use and regulation and as real estate appraiser interested in the issue of external obsolescence (loss or depreciation to property value from outside the property boundary). That economic obsolescence can come from adverse (nuisance) impacts such as visual (loss of viewshed), blade flicker (strobe effect), noise, ice throw from blades in winter, and other environmental impacts from ancillary installations. I am not aware of any plans to put a wind farm in the vicinity of any property that I own, so I have no personal interest one way or the other in this matter, other than wanting the rights all parties to be respected and protected.

I understand that you have as an item of discussion at your September 9, 2004 meeting the issue of property values. I have had some experience with research on this matter. Unfortunately, I have a *prior* commitment that day and will likely not be able to attend your meeting. Perhaps your committee is already aware of these valuation issues and studies, but I think that they are important to note in the context of promoting wind farms in our state.
As the Vice Chair of the International Right of Way Association's Valuation Committee, I had the opportunity to moderate a session at our International Education Conference in Philadelphia this June. I invited the authors of the two most often quoted studies on the issue of wind farms and property values. Fred Beck of the Renewable Energy Policy Project (REPP) and Dr. David Tuerck of the Beacon Hill Institute at Suffolk College both presented the findings of their respective studies. Both studies are available on the internet: www.repp.org and www.beaconhill.org.

conclusions were 1) Sales within 1 mile of the wind farm prior to the installation were 104% of the assessed values and properties selling after the wind farm introduction in the same area were at 78% of the assessed value.

Anecdotal evidence from real estate agents near Victoria, Australia indicates a 20% to 30% decrease in property values for homes near WTGs.

A court case referenced in the February 14, 2004 edition of the Daily Telegraph (UK) refers to a house near Askam in the Lakes District. The buyers were not informed of the pending installation of 4 WTGs which were 360' tall and 550 yards from their new home. No mention was made in the seller's disclosure form, despite the fact that the seller had protested the proposed wind farm installation to the local government indicating a large loss in value to their property. The court, after listening to chartered surveyors (appraisers) for both sides, concluded that the property had suffered a 20% decline in value.

The above listing is not exhaustive, but a brief mention of studies that discuss the impact on communities and nearby property values by WTGs.

Is the "jury" still out on the impact of WTGs on property value? Yes, though there do appear to be several indications that a loss in value to neighboring properties is real possibility. Can any state agency conclude that wind farms do not have the potential for causing a nuisance and devalue nearby properties and cause a "taking"? No. Whatever report the Wind Working Group comes up with, it should be informational only, include the differing opinions that are out there, not be used to usurp local land use authority in regulating WTGs just like any other land use nor to deny property owners their rights. In our quest for 'energy independence" for our society in general, let us not forget the potential for economic loss to individuals as an unintended consequence. We should be prepared to compensate adjacent owners for any property rights (value) taken as a result of the introduction of wind farms.

Sincerely,

David C. Maturen, SR/WA
Certified General Real Estate Appraiser
Kalamazoo County Commissioner

Clouds gathering over wind farm plan

Almost every property in their street, apart from those of the farmers on whose land the turbines are being built, is for sale. "I've watched my husband work all his life to build this home," Mrs Cicero said. "We've never had loans, we've always worked and saved. And now we find everything that we've put in here, it's all worth nothing." The Ciceros had their home valued at $410,000 before the wind farm was taken into account. Afterwards, the estimated value dropped to $270,000. They have not received one offer for their property in two years.

January 9, 2006 by Natasha Robinson in The Australian
Web link: http://www.theaustralian.news.com.au/common/story_...

THE picturesque fields of Foster North, in Victoria's South Gippsland, have become a battleground with farmers and residents divided over a proposal to build a massive wind farm.

Farmers who will benefit from the 125m turbines being built on their land are pitted against their neighbours who bitterly oppose the 48-turbine, 2000-hectare Dollar Wind Farm project.

And as state governments grapple with energy demands amid a looming coal crisis, it is a fight likely to be played out in communities around the country.

Victoria's Government had "ridden roughshod" over the Foster North and Dollar communities in refusing to give their council a say on whether the proposal went ahead, Federal Environment Minister Ian Campbell said yesterday.

The Victorian Government made its decision before Christmas on the project, planned for the northern side of the South Gippsland Highway at Foster North and Dollar.

It is yet to publicly announce if it approved the wind farm. Premier Steve Bracks has pledged to source 10per cent of the state's energy from renewable sources by 2010.

The Dollar Wind Farm project was previously the work of a New Zealand-owned company but the project was sold last year to Australian company AGL.

The proposal is now with Senator Campbell, who will consider if it poses national environmental concerns.

In Frank and Theresa Cicero's quiet, winding street in Foster North, local opposition to the wind farm -- which will see a turbine built 800m from their bush retreat -- is easy to find.

Almost every property in their street, apart from those of the farmers on whose land the turbines are being built, is for sale.

"I've watched my husband work all his life to build this home," Mrs Cicero said. "We've never had loans, we've always worked and saved. And now we find everything that we've put in here, it's all worth nothing."

The Ciceros had their home valued at $410,000 before the wind farm was taken into account. Afterwards, the estimated value dropped to $270,000. They have not received one offer for their property in two years.

They say if the turbines are erected, they will have to cope with an incessant sun flicker, noise, and a viewing platform.

A spokeswoman for the Victorian Government said it was a complex issue and the Government understood that the community had concerns.

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Calvin Luther Martin

From: "Angela Kelly" <amk@clara.co.uk>
To: "Angela Kelly" <amk@clara.co.uk>
Sent: Tuesday, January 17, 2006 8.34 AM
Subject: AK Re: IMPORTANT ' Windfarms affect house prices' WMN January17, 2006

R9

The Royal Institution of Chartered Surveyors:-

http://www.rics.org/NR/rdonlyres/56225A93-840F-49F2-8820-0E8CCC29E8A4/0/Windfarmsfinalreport.pdf

"Once a windfarm is completed the negative impact continues but becomes less severe after two years or so after the completion."

Western Morning News

17 January 2006

Windfarms affect house prices

I WOULD like to correct the errors in the Wind Power News, Issue 2 recently distributed by npower to some 4,700 local residents regarding the effects of wind turbines on house prices. Npower claims that the effect on house prices was short-lived and prices recovered after two years, and that windfarm developments appear not to affect property prices in the long run.

This is far from the case. The Royal Institution of Chartered Surveyors' report to which they refer is clear on these points. Their chief economist, in summation of the results, says: "Our survey shows a clear majority who find that a windfarm nearby suppresses house prices."

Indeed, 77 per cent of RICS members who responded to the survey in the South West reported that prices are lower; further, the report continues: "Once a windfarm is completed the negative impact continues but becomes less severe after two years or so after the completion."

I am writing to npower to seek a full retraction of this misleading information, but I would ask your readers not to believe everything they are told by these power companies.

Neil Harvey

Tiverton

Calvin Luther Martin

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Sunday, September 11, 2005 11:07 AM
Subject: Scottish couple leaving home their ancestors have occupied since 1860, over windfarm next door

... sorrowful story about a couple considering leaving their ancestral farm owing to windfarm next door. Interesting observations about existing wind turbines, as you read through the article. Notice what's happening to property values.

Calvin

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http://www.hexham-courant.co.uk/news/viewarticle.asp?id=280704

COUPLE HIT BY WINDS OF CHANGE
Published on Friday, September 9th 2005

By BRIAN TILLEY

A COUPLE are on the verge of quitting the farm their family has occupied since 1860 rather than live in a forest of windmills.

But as they contemplate their future at Cornhills Farm at Kirkwhelpington, Richard and Lorna Thornton have fired a parting shot at their neighbours for agreeing to have a potential 117 windmills on their land.

"I'm absolutely disgusted that they have agreed to be party to the desecration of the Wanneys," said Mrs Thornton.

"We are the only landowners in the whole area who have turned down the offers from the developers."

There are proposals for four different windfarms in the Wanneys area, following its identification by the Government as a favoured site for wind power.

If they go ahead, there would be around 117 masts, each nearly 400 feet high covering much of the unspoilt landscape.

Most landowners in the area are happy to go along with the scheme, for they will be entitled to payments of £5,000 to £8,000 per windmill per year.

But Mr and Mrs Thornton have rejected approaches by the wind farm developers, despite the income it would guarantee.

Mrs Thornton said: "People think these windmills will be like the ones at Kirkheaton, but those are tiny by comparison.

"What is being proposed is 117 massive towers, nearly 400 feet high, and they will ruin the whole area."

The couple are actively considering leaving the farm, for the sake of Mr Thornton's health.

Mrs Thornton said: "He has a genuine phobia about windmills, and cannot pass the windfarm at Soutra (on the way to Edinburgh) without becoming ill.

"He just could not cope with all these mills, especially as six of them would be right in front of our house.

"It would be heartbreaking to leave after nearly 150 years, but we may have no choice.

"I can't believe the other landowners are going along with this."

Mrs Thornton questioned the need for the windfarms, pointing out the three windmills at Kirkheaton, some seven miles away, were hardly ever operating.

Similarly, the turbines at Blyth had been out of action for some time, and little effort was being made to repair them.

She said: "I think it's dishonest for the developers to say they are needed, when it seems they are not."

She was deeply concerned that the final say on whether the turbines were built rested not with either Tynedale or Northumberland County Council, but directly with the Department of Trade and Industry.

She said: "Local people aren't really going to have any say; the matter has been taken out of our hands."

She said the prospect of the turbines was already having an effect on property values in the Wanneys, with at least one house sale falling through as a direct result on the proposals.

She said: "Property prices are going to plummet, and it's affecting business too.

"We do bed and breakfast here, and clients we have contacted have said they will not be back if the wonderful view becomes a concrete jungle."

She also pointed out that the area was home to a rich variety of wildlife, including bats, owls and English crayfish, all of which could be affected by the development.

Representatives of one of the developers, the Banks Group, were meeting members of Kirkwhelpington Parish Council on Wednesday to expand on the proposals.

... the following e-mail was sent to Calvin Luther Martin by Suzan Askins, Steuben

County, New York

on 11-9-05

Calvin,

Thank you for all of the information your have sent me. We organized a group-"Concerned Citizens for Steuben County" and we held a public meeting on Monday night in our high school auditorium. I was the main presenter. We had about 50 people in attendance. Most of the landowners who have signed contracts were there-on attack. Before the meeting started, I went out in the lobby and was treated with total disrespect and sarcasm by a man whom I had always considered a dear family friend. I was shocked. It is amazing what greed does to people.
The contract signers were rude during the entire meeting, whispering and laughing.

I made the front page of our newspaper-a big picture of me with the headlines "What Is The Truth?".

Our community is very passive, and as you once put it- have fallen right in line with what the wind company wants.

We have uncovered so much deceit and underhanded behavior concerning the landowners who have signed. (I'm sure you've heard it all before.)

Our battle here has been lost. The IDA is meeting with the Board tonight. I feel so sick. We have a brand new home and will be downwind from at least 15 turbines.

We told a neighbor who has signed that we are selling our home. He just couldn't understand why we don't like the turbines. He stated we should be glad our property value is going down-we will be paying lower taxes. That's their mentality.

Mother Nature is being raped again-and no one here cares.

Thank YOU for caring so much!

Suzan

.. the following article was published in the Times Online (UK), 1-10-04

Times online

January 30, 2004

Wind farms ruin peace, says judge

By Lewis Smith

WIND farms can ruin the peace of the countryside and destroy the value of nearby homes, a judge has ruled.

The ruling is the first of its kind and damages the **wind** energy industry's assertion that it is "a myth" that property prices are affected.

District Judge **Michael Buckley** said that the noise, visual intrusion and flickering of light through the blades of turbines reduced the value of a house by a fifth. He said that the value of a remote house in Marton, in the Lake District, fell significantly because of the construction of a **wind** farm of seven 40m-high turbines 500 metres away.

"The effect is significant and it has a significant effect on the property," he said. "It is an intrusion into the countryside. It ruins the peace." Until now the industry has insisted that
wind-farm developments do not damage house prices and the British **Wind** Energy Association even suggests the massive turbines can increase the value of nearby homes.

On its website the association labels the idea that house prices can be damaged as one of the "top ten myths" about **wind** power. It states: "The proximity of a **wind** energy development does not adversely affect property prices. In fact, prices seem to be on the increase."

Alison Hill, of the association, said that a survey of property values near **wind** farms across the country was being planned to assess the impact and promised that the website would be amended.

She said: "This is the first documented evidence we are aware of that does show a decrease in property value."

Kyle Blue, a chartered surveyor and valuer who is leading a campaign against a 27-turbine farm in the Lake District, said the court ruling merely confirmed what householders already knew. "To me it's common sense," he said.

He added that he knew of at least two other properties worth less because of a proposed **wind** farm at Whinash in the Lake District.

Wind farms are not compelled to offer homeowners compensation in the way local authorities can be when pushing through projects, and Judge **Buckley**'s ruling does not pave the way for property owners to claim compensation.

A couple won a £15,000 compensation order because when they bought the property in Marton the vendors, who campaigned against the farm's construction, made the mistake of ticking a box on a form to state they had not been involved in negotiations about planning issues affecting the property.

http://www.thisisthelakedistrict.co.uk/misc/print.php?artid=447706

The Westmorland Gazette Friday 9th January 2004

Windfarm blows house value away

A FURNESS couple have won a legal ruling proving that the value of their home has been "significantly diminished" by the construction of a windfarm nearby, reports Justin Hawkins.

Barry Moon and his partner Gill Haythornthwaite live in the shadow of the wind turbines at the controversial Ireleth windfarm near Askam. When they bought Poaka Beck House in 1997, the couple were unaware the arrival of the windfarm was imminent. Previous owners David and Diane Holding failed to tell the prospective buyers in spite of the fact they had vigorously opposed the initial application for the windfarm in 1995 and objected at the subsequent public inquiry in March 1997.

District Judge Buckley decided that this amounted to "material misrepresentation" and ordered the Holdings to pay compensation of 20 per cent of the market value of the house in 1997, £12,500, plus interest, because of damage to visual amenity, noise pollution and the "irritating flickering" caused by the sun going down behind the moving blades of the turbines 550 metres from the house.

In so doing, he made what is believed to be the first ruling of its kind relating to windfarms. He also made the Holdings pay legal costs and a further £2,500 as compensation for "nuisance and distress".

News of the ruling comes as debate rages about West Coast Energy Ltd's application to build Whinash windfarm on fells between the A6 at Shap summit and Tebay. If it goes ahead, Whinash will be England's biggest windfarm with 27 turbines, each 115 metres tall.

Mr Moon and Miss Haythornthwaite are still fighting a battle with windfarm operators PowerGen Renewables over noise problems at their home, but Mr Moon said they decided to go public with details of their case because Whinash and other developments were now looming on the horizon.

They said their experience, and the judge's ruling, gave the lie to claims of the windfarm industry that turbines did not damage property values.

Miss Haythornthwaite said: "If this can prevent one windfarm being built in an inappropriate place it will be worth it."

Mr Moon said: "The windfarm industry is about one thing only and that is profit. People should know the facts for themselves rather than listen to the industry's claims that there is no impact on property values."

Steve Molloy, of West Coast Energy Ltd., said it was the first case of its kind to his knowledge. "I have no doubt it is going to be quoted by lots of people opposing windfarms once it becomes widely known," he said. But he added that loss of value of a property, although unfortunate, was not a material planning consideration and did not undermine the industry's argument that the benefits of sustainable energy outweighed the objections.

West Coast Energy has complained to the Advertising Standards Authority about claims in No Whinash campaign literature that property prices would be affected.

Mr Molloy said the company had just heard about the judge's ruling and would like to study it in detail, but he admitted it may now have to reconsider its approach to the ASA in light of it.

Kyle Blue from the No Whinash Windfarm group said he knew of two properties near the Whinash site where values were already being affected and said the judge's ruling would help the fight against the windfarm. He also said the industry's claims that tourism would be unaffected were as spurious as its claims about property prices.

9:04am Friday 9th January 2004

By Justin Hawkins

Tug Hill, NY, Windplant

Patricia Leviker
3849 Rector Rd.
Lowville, NY 13367
patricialeviker@aol.com
(315) 376 6804

by

Calvin Luther Martin, PhD
Malone, NY

November 4, 2005

I just got off the phone with Pat Leviker. I phoned her after having read her letter to the editor published last month in the *Lowville Journal Republican* (I had earlier read the letter written by her daughter in the *Watertown Daily Times*). In her letter, Pat had complained bitterly about the wind turbines going up around her home on Tug Hill.

Pat is a middle-aged woman. Quick to chuckle, full of common sense. High school education. She tells me she grew up on her dad's farm next door (though the farm has since been sold to someone else). She and her husband love their home and its splendid views of the mountains in the distance.

They do not love the view now, for she tells me she is "surrounded" by industrial wind turbines. The nearest one is across the road, mere yards away. She tells me she can see 15-20 within a mile radius of her home. PPM and Zilkha are installing 187 turbines in this first Phase, followed by more in Phase II and so on.

She is appalled by all this. She was appalled by the slick salesmanship of Bill Moore, a principal owner of Atlantic Renewable which since sold out to the Scottish company, PPM. Moore promised property owners and the Town of Martinsburg the sun and the moon, and people fell for it. Attending these meetings, Pat said she could not believe her neighbors and town leaders were believing Moore's sale's pitch, but they did. Pat said it was the lure of money. "If it sounds too good to be true, it probably is," was her advice.

Atlantic Renewable (PPM) & Zilkha (Horizon) rammed through the project within the community, with the Martinsburg Town Board singing loud hosannas. Atlantic Renewable & Zilkha got away with a

PILOT plan, much to Pat's disgust. And doubters were taken down to Fenner ("Go to Fenner and see for yourself," they were told). Fenner, she said, was minor compared to what they are experiencing on Tug Hill. A mere 20 turbines, not 187. Visiting Fenner, she recalled talking to a woman (named Claire, I think) who had leased land to the wind company. This woman and her husband are now suing the wind company, said Pat. Claire warned Pat, "Don't trust Mr. Moore. He's slick. He won't keep his promises."

Back in Martinsburg, the Town Board held a public hearing on the turbines, but Pat and her husband, although keenly interested in the process, were unaware of this meeting and floored to discover it had come and gone. Apparently few other people were aware of it, too, for it was sparsely attended.

With the way cleared and permits issued, the wind companies began construction. Pat said it has been a horror. Roads severely damaged. Noise. Truck noise.

She now lives a few yards from a power substation, in a ravine (pasture) she knew as a child. In a ravine routinely struck by lightning over the years (Pat wonders if the substation will get zapped: bad place to put it, she said). She said this substation is floodlit throughout the night, bathing their home in light. She called the project manager, Larry Miles, recently and asked him if these lights would ever go off at night. He was testy with her ("snotty," is how she phrased it), and informed her they need the lights on to work there. Miles said he would get back to her, but he has not.

Now she sees these monstrous towers everywhere she looks. It breaks her heart to drive home, to drive into this forest of towers & blades. She sees the blinking red lights at night, instead of a dark, star-lit sky. She told me she drove to Watertown the other day and took a road which allowed her to see the landscape without the devastation of the turbines. It was a relief.

The wind companies plan on getting the turbines on-line by the end of the year. So, right now, they're not operating. She dreads the day they begin operation: the shadow flicker and noise. She wanted to talk about this apprehension. Pat has sensitive hearing and she's worried about the noise. She noted that the footer supports were loaded with steel rebar (rods), about 15-20' deep and as wide.

While the building was going on this fall she took a walk one day over to her parents' old farm. It was devastated: trees chopped down, giant holes in the ground, gigantic towers going up, devastated roads. She stood there and simply wept.

Patricia is very angry. She feels lied to. She has a neighbor, a young man and his wife and little children, who is also outraged. The man has been building a lovely home; he moved here because of the magnificent location, the views, the beauty. Now, this.

Pat published a letter to the editor of the *Lowville Journal Republican* early in October. Mr. Moore (PPM) rebutted it. Pat's daughter published a similar letter in the *Watertown Daily Times* a week or so later and it, too, was rebutted by a wind company spokesman.

She feels helpless, and kept saying she thinks she will move—move from her home, from where she was raised. Yet she worries that no one will want to buy her home, or will do so at a fraction of its pre-turbine worth. She foresees taxes dropping, as people refuse to pay the tax on a depreciated property.

In the end, she said, she and her neighbors were not organized well enough to stop Atlantic Renewable (PPM) and Zilkha (Horizon). The farmers and property owners fell in line perfectly. Yet many of them don't live on their land, or they have moved elsewhere. Leaving Patricia Leviker and her husband and neighbors to deal with this "horror," as she put it.

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... note from Mrs. Barbara Kramer, Ellenburg, NY, about her visit to the Maple Ridge Windplant (Lowville, NY) the previous weekend, and her meeting with Mrs. Patricia Leviker, whose home is now surrounded by industrial wind turbines (note dated 11-7-05)

Calvin Luther Martin

From: "A B" <annie12966@yahoo.com>
To: "Dr. Calvin Martin" <rushton@westelcom.com>
Sent: Monday, November 07, 2005 5:17 AM
Subject: My outlook express wouldn't send this

Sent: Sunday, November 06, 2005 11:45 PM
Subject: Trip to Maple Ridge Wind Farm

We just got back from Lowville. Before we left I phoned Pat Levikor so she was expecting us. Anne, when we went up that hill and saw all those things I wanted to cry. I feel so sorry for those people. The monsters are all around them. They used to have such beautiful views, now all they see no matter which window they look out of are wind turbines. One is pretty close to their house and so is one of the substations (she referred to it as Emerald City because it is lit up at night). She gave us some pictures and a map which shows all the wind turbines.... both Phase One and Phase Two. Pat said they started putting them up in May and have about 80 up so far and hope to be operational by the end of the year. She and her husband are very upset. She said she has 4 more years before she can retire and as soon as they can they will move. The Lord only knows what they will get for their home. It had to be worth at least $100,000 before and we wouldn't give them $10,000 now. As I said it is such a crime. Pat said most of the land owners are farmers and they don't live up there, so why would they care. There is no way that they won't have the flicker, noise etc. She also said she was so glad to talk to Calvin and he gave her such good advise about getting things tested now before they become operational etc. I know I am rambling but the whole situation is so mind boggling and horrible. Unless someone sees these things for themselves "up close" pictures cannot give the whole affect. I know you don't see movies but we likened them to "The War of the World". Regards,
xxxxx

*The following letter from Realtor Russell Bounds to the Maryland Public Service Commission outlines in stark terms how industrial wind turbines do, in fact, dramatically lower property values.

Calvin Luther Martin

November 8, 2005

David Shipman, Esq.
Williamsport, PA

Dear Mr. Shipman:

I have been a full time realtor in Garrett County, Maryland for 13 years, with a sales volume over 100 million dollars, and rank as one of the most successful realtors in this area. I specialize in Rural Property Sales - specifically recreational property, woodland tracts, farms and mountain views.

I have recently testified in a Maryland Public Service Commission wind plant hearing as an expert witness regarding property devaluation caused by possible wind plant development.

Over the last two years, I have had more than 25 prospective buyers look at property in areas within 15 miles of proposed wind plant development. These properties are rural, mostly farms, cabins and mountain view homes and rural home sites.

As a realtor, I am obligated to disclose everything I know that may have a positive or negative impact on property. With respect to the possible development of wind power plants in this area, this is what I've disclosed to those prospective buyers: There are two proposed wind plant's to be located along approximately 20 miles of Backbone Mountain, the prominent ridge that is the dominant geographic feature in the area. The proposed turbines are over 400' tall and may be noisy and produce shadow flicker over the land --large-scale light and dark strobing effects-- depending upon the way the sun shines through the turbines' blades. I have seen how wind plants near Meyersdale, Pennsylvania have altered the beauty of the natural views and disrupted the quiet enjoyment of property, resulting in major property devaluations there.

After this disclosure, not one prospective buyer made any offer for these properties, although they did purchase properties elsewhere.

Sincerely,

Russell Bounds
Realtor

... testimony of Russell Bounds, Realtor in the State of Maryland, before the

Maryland Public Service Commission on windplants affecting property values (2005)

TESTIMONY OF RUSSELL BOUNDS

Please state your name and business address.

My name is Russell Bounds, Railey Realty, 2 Vacation Way, McHenry, Maryland 21541.

What is your education?

I received a Bachelor of Science degree in communication from Radford University in 1992.

Other than through college what education have you had?

I worked in consumer finance for Household Bank. While I was there, I took continuing education provided by Household Bank in such topics as underwriting, appraisals, market identification and consumer finance.

What were your duties at Household Bank?

I handled consolidation loans secured by home equity deeds of trust. My role was to estimate the property value to make sure there was substantial equity. I determined whether the owner had sufficient equity in the property to justify requesting a formal appraisal. I also investigated the entire financial history to make sure the customer qualified for the loan.

In the course of your duties did you appraise property?

My job was to make sure, based on the sales of comparable properties that the borrower had sufficient value in the property to support the loan. If I was confident the value in the was there, we sent out an appraiser.

How long were you at Household Bank?

About two years. I started in Chesapeake, Virginia, where I got most of my training. Then I went to Florida where I worked for the remainder of that time.

Do you hold a real estate license?

Yes. I am licensed in Maryland.

Was there course work involved with taking the exam for your real estate license?

Yes. There was 90 hours of education to prepare to take the test for a license in Maryland. The topics included real estate law, appraisals and market evaluation.

When did you take the exam for your real estate license?

That would have been fall of 1993.

Have you continued your license in good standing since 1993?

Yes.

Where did you start your career in real estate?

I started in and stayed in Garrett County, Maryland.

Is that the only place?

The only place.

With what brokers have you been associated?

In late 1993 or early 1994 I started with Four Seasons Real Estate. After about a year I moved to Railey Realty. I have been there since 1995.

Over your career in real estate, have you taken continuing education courses?

Yes. I have taken continuing education courses over the years to stay current with changes in the law, contract documents and changes in the business.

In the time you have been an active agent in Garrett County, how frequently would you come into contact with potential buyers or potential sellers?

I am in contact with several buyers or sellers virtually every day. With the volume I do, it is not uncommon to be on the phone most of the time with either a buyer or a seller.

On average, how many sales do you handle in the course of a year?

Anywhere from high 40 to 60 transactions a year. Approximately one-half the time I assist the seller and one-half the time I assist the buyer. I have a strong seller representation as well as a very strong buyer representation.

In the real estate business, how is business normally measured?

By dollar volume of sales.

Since you have been working in Garrett County do you know the total dollar volume of properties that you have sold?

Approximately $85,000,000.

On average, what would your sales be per year in recent years?

In 2004 my sales totaled more than $15,000,000 Over the last several years volume has averaged at about $12,000,000 per year

Of those dollars about what percentage would be mountain acreage properties versus properties related to Deep Creek Lake?

I would have to say a quarter to a third of the volume is mountain or acreage. Typically the lake properties are substantially more expensive, so fewer sales result in a greater portion of the total dollar volume.

In the course of representing a buyer or seller are you ever asked what your opinion of the beneficial characteristics of the property might be?

Every single time.

When it comes time for listing a property, how is the price that is put on the property determined?

First we look at comparable sales; what have similar properties sold for recently. Second we factor in unique features, good and bad, to adjust the price up or down. Is there something that makes the property special? A market evaluation is completed in a format similar to what an appraiser follows to justify a value to a lender.

Who does the market evaluation?

I do.

Who comes up with the suggested price or list price of the property?

I do.

What types of property do you sell?

The majority of Garrett County sales are in the vicinity of Deep Creek Lake or are mountain or acreage properties. I am known generally to handle both. I am probably one of the top three agents in Garrett County in large acreage or mountain sales.

When a Garrett County seller comes to you, what type of characteristics does the seller normally tell you about when describing their property and why someone should buy their property?

Garrett County is identified as a mountain landscape. A place of natural beauty. Typically the first things that are identified are the stronger features with respect to the esthetics associated with that property. If it is a lake front property, owners emphasize an unobstructed view of the water. If it is a large acreage parcel, owners emphasize views of the mountains, or of pristine woods or natural fields. Ultimately when dealing with larger acreage property, the primary consideration is the private, quiet nature of that type of property.

When a Garrett County buyer comes to you looking for acreage or mountain property, what features are usually sought by buyers?

Buyers emphasize the same features: pristine and natural views of the mountains, the woods or the fields. Many frequently do not even want to see houses or other buildings. Many buyers are from the Washington, Baltimore or Pittsburgh areas looking for a peaceful, quiet and natural mountain retreat.

What percentage of your sales of acreage or mountain properties is the primary residence of the buyer?

Very few. Most of these properties I deal with are second homes or what people will hope to be improved by a second home some day. Very few are primary residences.

Why do those particular buyers come to Garrett County for a second home?

To find a dream; to acquire a property they have thought about for years and years that typically must include natural beauty. Whether a wooded tract, small farm or recreational tract, buyers seek a private, quiet country setting.

When you assess the chances of selling an acreage or mountain property, what characteristics do you look for in a property?

Something that looks natural. Something that is picturesque, mountainous, quiet and private. Natural, not something that's been developed in any capacity. Railroad tracks, power lines, busy roads, or any type of industrial development detracts from saleability.

When you refer to mountain or acreage properties, what other kind of special characteristics would make the property more valuable?

Is it easily accessible? What is the balance between woods and pasture? Have the woods been timbered? Has the property been mined? Do power lines run through it? Is there a busy road near it? What are the surrounding properties and how do they impact this property? What is the topography? What are the views? Some people prefer fantastic views perched up on top of a mountain. Others look for something that is gently sloped and can see the mountains. What is the possibility of what may or may not be near it in the future? Does it border the State?

What would be the advantage or disadvantage of it bordering the property of the State of Maryland?

If property adjoins the State, you know that it is tucked up against a piece of property that will probably never have any development of any kind. No structures, no timbering, no mining, no human residents.

Have you had the opportunity to visit areas where there are wind turbines in place?

Yes. I have been to sites in nearby Pennsylvania, experienced the visual impact near the turbines and heard the noise impact from various distances. I have not had as much personal experience in nearby West Virginia.

Have you looked at any of the properties that may be considered mountain properties in those areas to determine what, if any, impact the wind turbines have had on their value?

I do not know the markets in West Virginia or Pennsylvania very well. If we were to move those turbines to Garrett County, however, value would be impacted. Any time you take a thing of natural beauty and you insert industrial development there is an adverse impact on what the property offers. It not only devalues but quite frankly, from my experience in Garrett County anyway, it may render the property unsaleable.

How close to the wind turbines were these properties if you recall?

Anywhere from three miles away up to very close by.

What effect, if any, has the wind turbines had on the special characteristics of properties that are nearby the wind turbines?

Within the view shed it ruins the horizon. The closer you get to the turbines the greater the visual impact. Those people who are looking for the natural views of the mountains find they are diminished or no longer exist. The turbines not only have a visual impact but, also impact the quality of life. The ones that I visited were very noisy. They impact a country setting with a rather large industrial wind plant that takes away from anything I would call heritage views, peace and quiet.

Have you heard from people in the vicinity of the wind turbines as to what problems they have as a result of the wind turbines?

Yes.

What is their primary complaint?

The primary complaint is noise. Second is the visual impact of the turbines. Going into the house and closing the door eliminates the view. It does not eliminate the sound. The constant drone cannot be escaped. The quiet of mountain living is gone. Their greatest concern is the substantial loss of value of their property. They do not believe they can sell without substantial loss and cannot afford to sustain the loss and move.

When you say the primary complaint is noise, is this noise that has any substantial impact on their use of the property?

Yes. It takes away the enjoyment of their property. It doesn't allow them to sleep at night. The attraction of a weekend or summer home in the mountains is the quiet. Buyers want some place to get away from the noise and sounds of industry and the city.

What impact does that type of change in the characteristics of the property have on its value?

It destroys it. It takes a property of substantial value and takes away all of the characteristics that are the strengths of that property. The visual impact takes away value.

The noise takes away value. The property owners complain that the wind turbines take away value and there is no way for them to escape.

You have included correspondence as Exhibit 1?

Yes. Exhibit 1 includes a letter to the County Commissioners for Meyersdale, Pennsylvania from Dr. Robert Larivee, a chemistry professor at Frostburg State University. He includes preliminary noise tests and locates his property and others in relation to the wind turbines. Exhibit 1 also includes letters from other property owners near Dr. Larivee's and shown on his diagram. Both the Hutzells and the Ervins own properties within a mile of the turbines.

Are you aware of any circumstances or transactions in nearby Pennsylvania involving properties that have been sold for substantially less than their prior sale price because of the impact of the wind turbines?

Yes.

Where are those properties?

Somerset, Pennsylvania.

Do you know what the circumstances are surrounding those transactions?

Two properties specifically that sold for substantially less than their original purchase price because of the nuisance issues that were created by wind turbines. The parcels adjoin property with wind turbines. The deeds documenting those transactions are attached as Exhibits 2 and 3. Somerset Windpower, LLC purchased the property of David Ray Sass for $104,447.50 and sold it to Jeffrey A. Ream for $65,000.00. See Exhibit 2. Keith and Billie Sarver sold their property to Somerset Windpower LLC for $101,049.00. Shortly thereafter it sold for only $20,000.00. See Exhibit 3. The tax map included as Exhibit 4 shows the parcels in relation to the parcels with the wind turbines. The Sarver property in Exhibit 3 is parcel 190-03; the Sass property in Exhibit 3 is parcel 190-02, the Will property with the turbines is parcels 190 and 189. Exhibit 5 is the agreement with Will with a drawing that shows the exact location of the wind turbines. Note particularly the agreement page recorded in Deed Vol. 1676, page 349.

Are there other recorded documents which show the impact of wind turbines on nearby property?

Don W. Paul and spouse acquired an acre of unimproved ground in 1997 for $12,600.00 by deed recorded in Deed Vol. 1371, page 405. See Exhibit 6. A memorandum dated April 2, 2003 recorded in Deed Vol. 1676, page 355 discloses that Somerset Windpower LLC had agreed to a "property value protection plan" because of the close proximity to wind power turbines. Unfortunately the terms of the "property value protection plan" are not disclosed. See Exhibit 7. Both the property owner and the wind power operator recognized that the wind turbines on the adjoining property would devalue the Paul property. The transaction clearly supports our contention that wind power development adversely impacts the value of nearby properties. The Paul property is parcel 188 on the tax map attached as Exhibit 4.

Did the Pauls sell their property?

By deed dated November 21, 2003 and recorded in Deed Vol. 1725, page 25, the Pauls sold the property for $67,000.00. See Exhibit 7. Since the house was five years old or less and in light of the sales prices of the Sass ($104,000.00) and Sarver ($101,000.00) properties to Somerset Windpower LLC, the property appears to have been sold for less than market value of the same home not located in proximity to the wind turbines. The wind turbines clearly had an adverse impact on the value of nearby properties.

You indicated that you went to the vicinity of wind turbines in West Virginia.

Right. I visited the wind turbines in West Virginia but we have not had the opportunity to investigate the records as well.

What effect, if any, does the visual impact of the wind turbines in West Virginia have on the value of the properties that are near them?

I would expect the impact to be the same as in Pennsylvania. Any time you take an industrial structure of that size and checker them across mountaintops that are often valued because of the views and the beauty they offer, that value is damaged. I am not as familiar with the West Virginia market but I am certain wind turbines will have an adverse impact on nearby properties in Garrett County, Maryland.

Have you heard the noise from the wind turbines yourself?

Yes, I have heard it. It was not what I expected. When you are right underneath, it doesn't seem to make much noise, just a swish. Further away from the structure the noise is more noticeable. It seems that it can echo through a hollow or a valley. Sometimes homes that are closer might not have the same noise impact as homes that are further out. I understand the noise changes day to day depending upon which way the wind is blowing and how the blades are positioned. Some days it may be noisier than others and some days it might not be as noisy.

Are you aware of any information that explains that phenomenon?

A study performed in the Netherlands is attached as Exhibit 9. It explains much better than I can why the noise varies and may be louder than predicted.

Are you aware of people near the West Virginia wind turbines who have concerns about the noise?

See Exhibit 10. Don Woods became aware that Jim Balow of the West Virginia Gazette was preparing an article on the impact of the wind turbines recently erected in West Virginia. He sent this message to indicate the impact on humans, but after Mr. Balow's deadline. It is my understanding there are others who have experienced the noise impact. Mr. Woods advised us others have been impacted by noise who will not come forward. They think since the turbines are in place with the blessing of the State of West Virginia that there is nothing they can do.

Considering your training and experience in real estate in Garrett County, Maryland, your personal observations of the operation of wind turbines in nearby Pennsylvania and West Virginia and the information you have obtained from the public record and from persons with properties near the existing wind turbines, do you have an opinion as to what will more likely than not happen with property values in Garrett County, Maryland, if the proposed wind turbines are installed?

Yes.

What is that opinion?

That property values of the natural and scenic properties within one-half mile and probably within a mile of the wind turbines will be negatively impacted. I cannot judge for certain how far the serious negative impact will extend. The visual impact and the noise impact will substantially diminish special attributes of a mountain view, scenic view, natural setting and peace and quiet. Undeveloped properties will be rendered undevelopable. Some parcels may be rendered unsaleable. The visual impact beyond a mile will likely adversely impact value. The sound impact will apparently vary outside one mile but, if the results of the study attached as Exhibit 9 are correct, the value of some properties outside one mile will be adversely impacted by the noise.

Section title: Turbines interfere with TV and other communications

WIRELESS COMMUNICATIONS ENGINEERING
SERVICES FOR A NEW MILLENNIUM
www.911radio.net

WHITE PAPER

WIND FARMS AND THEIR EFFECTS ON PUBLIC SAFETY RADIO SYSTEMS

Revised February 24, 2005

SUMMARY OF WHITE PAPER:

In many parts of the country, wind farms are being installed to alleviate the need to build more electrical generating plants. These wind farms can have a profound effect on your public safety, utility, and governmental microwave systems by chopping and reflecting the microwave beam. .

WHAT YOU SHOULD DO:

Notify your city and county zoning authority that any application for a wind farm can profoundly affect your emergency communications system and a design review focused on the wind farm's effects on critical communication systems.

BACK GROUND:

As a source for renewable energy, wind farms are being installed throughout the upper Midwest. Being subsidized by the US Government heightens the interest of entrepreneurs in building these for profit. Some wind farms contain hundreds of windmills. One of the biggest is on Buffalo Ridge between Marshall and Pipestone, Minnesota. Other large farms are northwest of Mason City, Iowa near Joice and northwest of Algoma, WI. The largest of the windmills and farms are in the western US.

The zoning laws of each state vary based on the generating size of the group of windmills, called a wind farm. Below a certain size in generating capacity, local city and county planning and zoning regulate these farms. Above a megawatt threshold, the state enters the picture especially in Minnesota.

Wind farms have their down side that is often overlooked by champions looking for clean renewable energy and profits.

1. Windmills have aviation hazard flashing beacons displaying a flashing light display. Some are set in a sequence to flash together or individually as a marquee across the farm. Because most windmills are above 201 feet, the Federal Aviation Administration dictates they be marked as an aviation hazard. The hazard beacon can be red at nighttime, medium intensity white strobe lights used in daytime (sometimes at night), or a combination of both.
2. The metallic blades chop and reflect certain types of radio signals ruining the continuity of the communications circuit. This is the subject of this paper.

The attached drawing, WIND-01 Figure 1 shows the drawing of a typical windmill. They consist of a metal pole, a wind generator mounted atop the pole, and a 100 foot tri-blade. Because the installation is all-metal, radio signals passing through the windmill are reflected or blocked. Worse yet, the moving blades cause the signal to be chopped. Think of trying to shine a flashlight through an oscillating fan. The once steady light passing blades becomes pulsed on the wall behind the fan.

On television sets of homeowners in or near the wind farm, the viewer will see their TV picture as a high-speed flicker as the blades pass through the signals. This is especially bad where the homeowner is trying to pull TV signals from 30-60 miles away. This will worsen as the country switches to high definition television (HDTV) because that signal is a synchronized computer bit stream not the present and much more forgiving analog signal.

With microwave, similar fading takes place. Microwave is a digital computer bit stream synchronized (timed precisely) between both ends of the circuit. As the blade passes through the beam or its companion first Fresnel zone, it causes the microwave receiver at the other end to lose signal or synchronization with the other end. While the blade rotates, the microwave system struggles to resynchronize itself only to have the next blade chop the signal. In the end, the microwave never resynchronizes unless the blades stop turning.

Public safety microwave is built to telephone company standards and the signal is framed into blocks of channels. Communications must take place in a real time (no delays) state. On the other hand, microwave links used for computer networks are not necessarily real time. If a circuit fails due to an encounter with a windmill's blade, the computer system will simply retry repeatedly to pass the message. If a synchronized public safety signal fails, the ambulance or fire truck may not come to someone's door!

A reasonable analogy might be a motion picture of an airplane propeller or a car tire turning. There are times that the moving device appears to slow, stop, and then reverse itself in the film. It is the strobe light effect as the pulsing interval of the film begins to match the rotating speed of the propeller or wheel and then leaves synchronization. It is possible and depending on the speed of the windmill's blades for the microwave beam to come in synchronization with the moving blades.

A microwave beam or a TV signal for that matter is not like a laser beam. Per the attached drawing WIND-02 Figure 1, as the beam leaves the antenna at either end, it fattens just like if you point a flash light at a wall and walk backwards. The main power of the radio beam lies in the main beam or the red area in the drawing. The first Fresnel (pronounced Fra'-nel) zone lies in the blue area. In Figure 2 of WIND-02, the white zones are higher Fresnel zones and contain little power. <u>The main beam and the first Fresnel zone must pass through the wind farm and not be reflected or chopped by any metallic members of the wind farm.</u> Depending where the microwave terminal points are and the frequency of the microwave signal, the Fresnel zone can be <u>hundreds of feet wide</u>. A complex mathematical formula can calculate the size of the Fresnel zone for any frequency passing through the farm.

Some but not all of the problem can be alleviated by the windmill designer using non metallic blades. However, I have been told a metal blade is part of the lightning protection for the facility and thus there is a resistance to using non-metallic blades. Even if they did, you still have the metal pole and generator units to block and reflect radio waves,

The wind farms do not seem to bother regular two-way radio transmissions. As the mobile communications industry switches from analog signals to synchronized digital signals (APCO-25 Standard), problems could develop because of the same mechanisms exist as with microwave.

I would not want a user to build a critical communications tower in a wind farm unless the windmills were at least ½ mile away—better yet a mile. As the electrical energy is generated, signals from high electric fields and degrading generating equipment can radiate noise that will degrade two-way radio system receivers in the range of 25-200 Megahertz.

WHAT SHOULD BE DONE IF SOMEONE WANTS TO BUILD A WIND FARM?

All is not lost if an application for a wind farm is submitted to a zoning authority. If one is received:

1. The applicant should employ a microwave search firm such as Micronet in Plano, Texas or Comsearch in Ashburn, Virginia to identify which FCC licensed microwave paths will pass through the proposed wind farm.
2. The zoning authority should alert City and County public safety, utility, pipeline company, and your school district to provide their licensed and unlicensed microwave point to point routing to the applicant. The wind farm can especially effect:
    a. Point to point microwave.
    b. Wireless computer networks- 802.11 systems, WAN.
    c. Instructional TV for schools
    d. DTN Weather used by farmers and construction companies.
    e. Intercity wired telephone via microwave
    f. Cellular cell-site interconnection via microwave
    g. The real problem is the unlicensed data links. They are not in any database. You must seek out potential critical use owners.
3. The applicant should retain a Registered Professional Engineer with radio experience to be part of the design team for the wind farm to allow for microwaves to pass unaffected through the farm as shown in the attached drawing WIND-01 Figure 2. This may be as simple as leaving aisles open in the wind farm windmill-grid.
4. A wind farm advocate has suggested to me that some form of registration system of windmills and critical wireless communications circuits by the state might be reasonable to the work above.
    a. Critical communications circuits,
        i. Whether FCC licensed or not,
        ii. Planned or existing,
        iii. Can be registered in a GIS file along with the precise location of the planned and existing windmills
    b. Then, as new critical communications circuits are designed, engineers can consult the GIS system and be advised of the presence of a proposed or existing wind farm. They can register funded but not yet build circuits.
    c. The same is true with the planner of a wind farm.
    d. This sounds reasonable but the big issue would be keeping the data current and informing the planners and installers in both industries.

The Federal Communications Commission, when licensing a microwave system, offers no protection from new man-made objects obstructing a microwave system. Critical infrastructure communications systems are expensive and usually in planning for a long time. The very owners of most critical infrastructure systems are the approvers of wind farms. Therefore, the governmental entity should protect their interests otherwise, the fire department may be signaled by the 911 center and never show up at the fire. A signal may go out from a pipe line to shut the valves on a leaking line and the valve never close.

Leonard J. Koehnen, PE
Consulting Engineer-Wireless Telecommunications Systems and Facilities
Registered Professional Engineer (Electrical)
Saint Paul, MN

We have written many other White Papers that may be of interest to you. They are freely distributed to clients and other interested parties at no charge. Please write for a copy.

Spectrum Re-Farming	Tower Ordinances	Over Renting of Community Water Tanks
FCC Licensing Issues with Channels Adjacent to New Mutual Aid Channels	Installation of Minneapolis/Saint Paul Metro 800 control stations	Consulting Services Utility Data Systems

WIND-01

DELETE WINDMILLS IN GRID TO PROVIDE AN AISLE FOR THE MICROWAVE BEAM

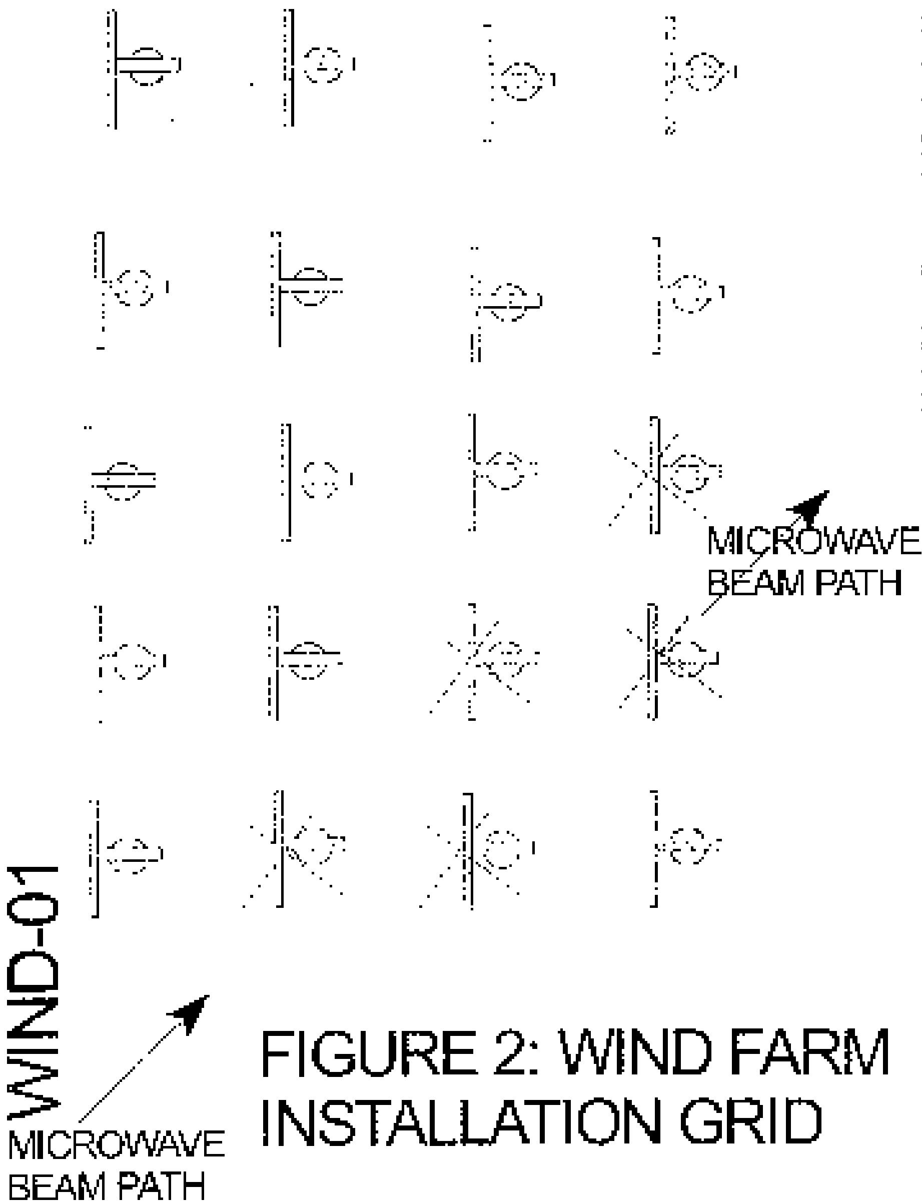


FIGURE 2: WIND FARM INSTALLATION GRID

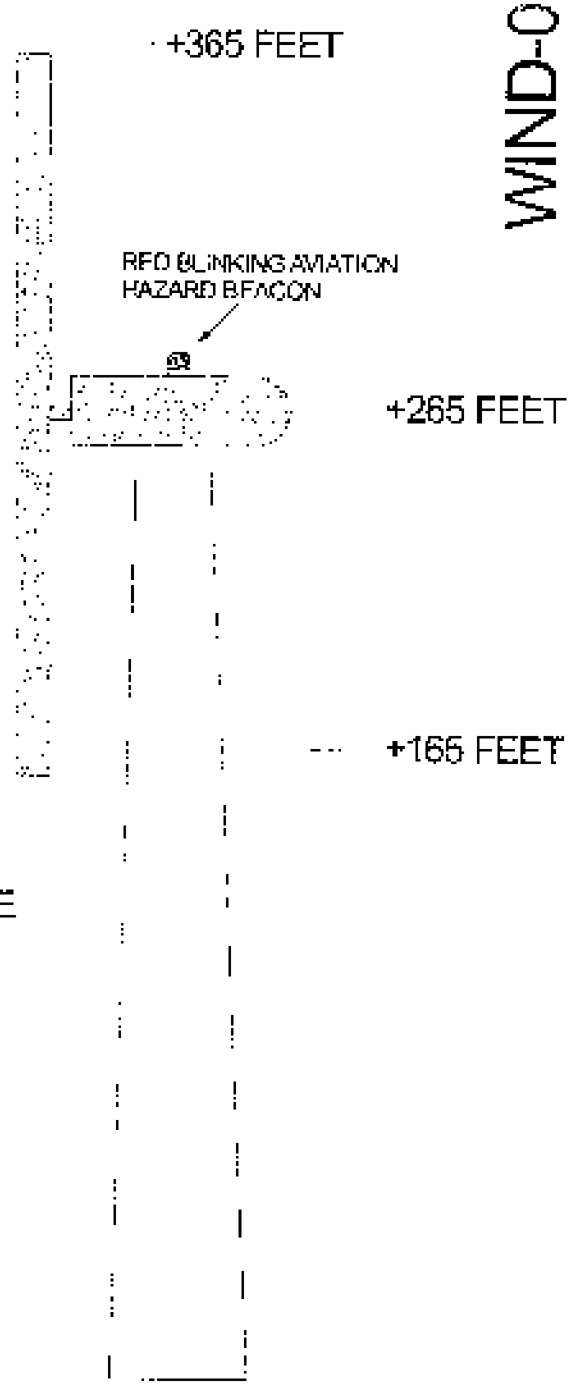


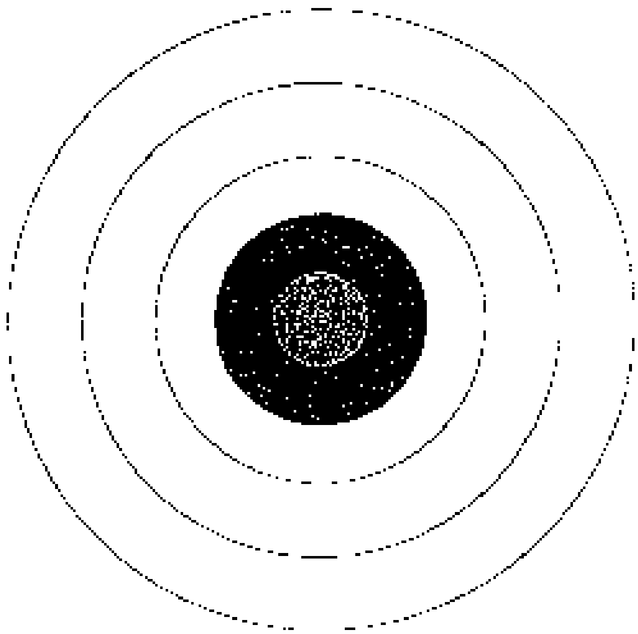
FIG 1: TYPICAL WINDMILL

WIND-01

REVISION HISTORY:	*THIS DRAWING WAS PREPARED BY ME AND THAT I AM A REGISTERED PROFESSIONAL ENGINEER IN MINNESOTA.*	WIND FARM EFFECTS ON MICROWAVE	
		STANDARD SPECIFICATIONS	
	LEONARD J. KOEHNEN, PE	*Leonard J. Koehnen, PE* *Consulting Engineer* *Leonard J. Koehnen & Assoc., Inc.* *3348 Jonathan Road* *Woodbury, MN 55125 651-739-1614*	DATE: 12-20-04
			REVISION: ORIG
	MINNESOTA | 9298		DWG. WIND-01

WIND-02

FIGURE 1: MICROWAVE BEAM
RED IS MAIN BEAM
BLUE IS FIRST FRESNEL ZONE



WIND-02

FIGURE 2: CROSS SECTION OF A MICROWAVE BEAM
RED IS THE PRIMARY BEAM
BLUE IS THE FIRST FRESNEL ZONE
WHITE ARE THE SECOND-THIRD ETC FRESNEL ZONES

REVISION HISTORY:

THIS DRAWING WAS PREPARED BY ME AND THAT I AM A REGISTERED PROFFESSIONAL ENGINEER IN MINNESOTA.

LEONARD J. KOEHNEN, PE

MINNESOTA 9298

MICROWAVE BEAM

STANDARD SPECIFICATIONS

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UWEX UNIVERSITY OF WISCONSIN EXTENSION • COOPERATIVE EXTENSION

LINCOLN TOWNSHIP WIND TURBINE SURVEY
This survey summary completed Thursday, May 16, 2001,
by David E. Kabes and Crystal Smith,

based on 233 completed surveys

Comments for the Lincoln Township Wind Turbine Survey
Completed May 15, 2001

1. Are any of the following wind turbine issues currently causing problems in your household?

b. TV reception

Question # 1b

1 Poor reception 11 and 14
2 Channel 14 flickers at the same rate as the turning of the turbine blade. Minimum of 50' antenna tower proposed but no guarantee that would be high enough. Such a tower is unacceptable.
3 WPS's TV consultant did not believe a 50' TV tower to be adequate for us. We now have a dish system from WPS with basic networks from east and west coast but do not receive Green Bay area stations.
4 Lately we have been having TV reception problems.
5 Our reception is bad since the turbines went up.
6 It is either high or low sound, also some stations are clear and some aren't.
7 Channels 38 and 26 are snowy and have static surges.
8 At times we get black and white TV. Two channels come in hazy!!

9 Only get 3 channels
Better
10 I don't know if it's the turbines causing the problem but it seems since they've been up. my TV's cut off in the middle of a program.
11 Certain days depending on wind direction Morse codes lines across TV screen.
12 Some days the picture is foggy and snowy.
13 It does at times affect reception and especially when the red lights blades.
14 Channels hazy or can see the flipping of the blades.
15 Poor reception for channels 11 and 14
16 There is this really loud noise that runs through the TV and reception gets real static.
17 This will last for about 2 minutes and them clears at least once a day. Already ruined one TV. Had to buy another.
18 Some stations are not good.
Not proven
Put a bigger TV antenna up
We have problems occasionally with channel 11 but I am not sure if it is because of the wind turbines.
Reception is poor on a majority of the channels and am not sure if it's the windmills or radio towers.
19 Channel 2 is not as good as before
No channels come in clearly at our home even though we do have an antenna. This may or may not be caused by the windmills.
At times even using antennas
Perhaps?
20 Poor reception since they were erected, real bad on some days.
21 I feel my channels 26,32,38, and 14 are poorer.
It did for a while but not anymore.
TV use to black right out at times. Got my TV repairman to fix it at my expense.
22 Sometimes
23 At night when red light blinks, we get that in our TV etc in Rynue with light one in a way we get a gap in TV!
24 Unable to receive some local stations.
Not sure if poor reception on local stations can be attributed to the wind turbines or not.
Channel 14 is snowy.
25 At times you can see shadowing on the TV that imitates the blades moving, also poor reception.
26 Have interference on channel 2.
27 On channel five and a windy day
Who cares though!
28 Have shadows on 2 channels
29 Affect TV reception
Was fixed by public service for now!
30 On some days we notice "snowy" reception because of our location, we had to install antenna (several years ago). We really didn't notice the reception problem again until the windmills.
31 Reception not the best.

Could not get any reception however the company has installed an outside antenna for us, which has solved the problem.

32 Some stations don't come in well.

I don't know because I moved here after they were installed.

33 We seem to have reception problems with some stations that other people living away from the turbines do not.

34 Ever since they went up our reception is bad.

35 Don't get reception that I use to get.

Not sure, I don't see any problem

Moved here after wind turbines were up, unsure if they're the reason for TV reception problems.

Fuzzy on some days.

Unsure, reception could be better.

36 When the turbines are running I have a very difficult time receiving all UHF to some VHF channels.

37 Channel 14 is bad, we don't want a tower. Once in a while we have interference with other channels

38 Some days, depending on the direction they're turned.

Sometimes but not often.

39 Channel interference

At times my TV reception is poor but I am not sure if the turbines are the cause but before they were put up I had no trouble.

40 One station has been affected.

41 At times there is a strobing effect across the screen which coincides with the turning of the blades.

Not in-line with the TV towers or it probably would.

Don't think so.

It did, WPS put in a 50' TV tower so we could get local TV reception.

Section title: Bird & bat deaths: Reports from the press

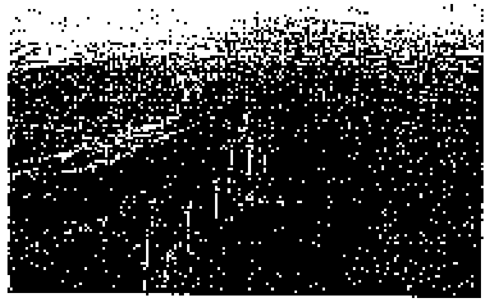
Windpower and Raptors: An Unsolved Issue

by David Brandes, Lafayette College

U.S. Energy Production and Windpower

All electric power generation methods have negative environmental impacts. For example:

- Fossil fuels (~80% of US energy): mining, drilling, mountain/watershed damage, acid rain, mercury, global warming
- Nuclear (~12% of US energy): what to do with rad waste, potential for catastrophic release
- Hydropower (~4% of US energy): damage to river ecosystems, loss of migratory fisheries, trapping of sediment and nutrients (percentages from the DoE Annual Energy Review 2004)

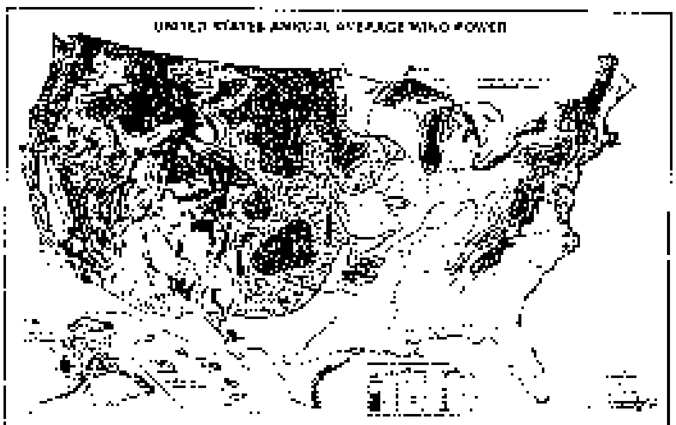


Aerial view of the Moosic Mountain windpower site near Scranton, PA.

Windpower is a promising renewable energy source with reportedly low environmental impact; however, it is very land-intensive, and proper siting is critical due to potential for bird and bat strikes and other wildlife impacts (e.g., forest fragmentation). DoE has a goal of making windpower at least 5% of our total generation capacity by 2020, and the PA goal is 8% by 2020. The recent rapid development of windpower sites in our region is largely due to subsidies and tax shelters provided by federal and state government to boost renewable energy production.

> "GAO recommends that FWS provide state and local regulatory agencies with information on the potential wildlife impacts from wind power and the resources available to help make *decisions about where wind power development should be approved.*"
>
> — USGAO Report to Congress *Wind Power: Impacts on Wildlife*, 2005

It will take tens of thousands of 1.5-MW turbines (each serving ~400 homes) to make a significant dent in our nation's dependence on fossil fuels for electric power. Due to the intermittent and seasonal nature of winds in our area, turbine power generation averages ~30% of rated capacity. The high plains of the midwest (see U.S. wind power graphic), where winds are much more reliable, is a logical place for industrial-scale windplant construction.



(from the *Wind Energy Resource Atlas of the United States*)

Wind resources of the U.S. Areas designated class 4 or greater (dark blues and grays) are generally considered suitable for wind turbines. Class 3 sites are marginal.

The viability of windpower is very sensitive to wind velocity (power output is proportional to v^3), so most existing and proposed windpower sites in the east are on high plateaus or ridgetops (see graphic). Some of these are the same locations where raptor migration is concentrated, since raptors seek updrafts along such topographic features (e.g., Hawk Mountain, PA is located on a ridgetop). Raptors serve an important ecological function and are protected.

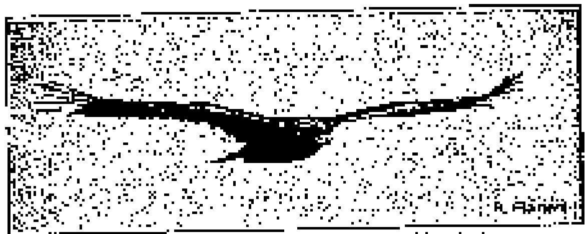
Windpower and Raptors

Mortality data from existing windpower sites is mixed. While many windplants are not on migratory routes and have had minimal impact on raptors, one site has major problems – the 5000-turbine Altamont Pass windplant in northern California kills about ~1000 raptors each year, ~100 of which are golden eagles. This early windplant was placed in a location with high densities of wintering raptors. Research shows that raptors have a problem with "motion smear" – although they have fantastic eyesight, they do not see fast-moving turbine blade tips and thus are vulnerable to strikes.

There is little regulatory oversight or uniformity regarding the siting of windplants – local land use ordinances and in some cases state regulations apply. USFWS has issued guidelines regarding siting (such as avoidance of migration routes), and pre- and post-construction monitoring, but has no legal authority until *after* protected species are impacted. A windplant is currently proposed for the Lake Erie shoreline in western NY where 20,000 raptors pass each spring. Although the USFWS and NYDEC oppose the project, they have no authority to prevent it.

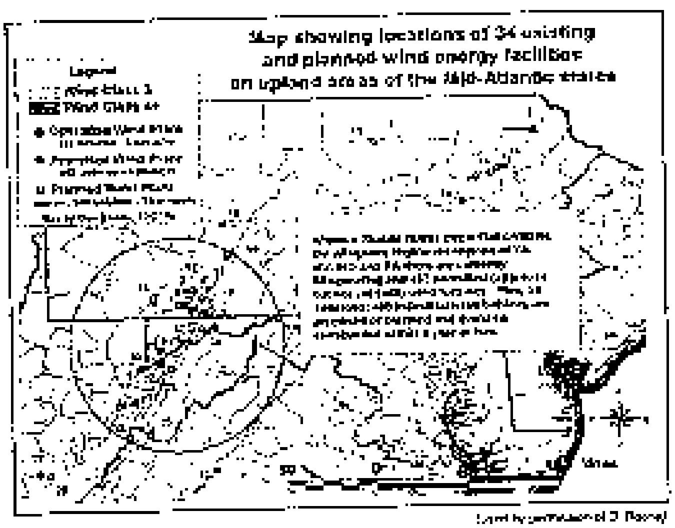
As shown on the graphic, many other new facilities are planned or already under construction in the Appalachian mountains where hundreds of thousands of raptors migrate and impacts are unknown. Pre- and post-construction monitoring in the region has not been rigorous enough to draw any conclusions about impacts (in some cases, even the pre-construction monitoring has been seriously flawed). So the fact is this: *we don't know the risk posed to migrating raptors!*

My suggestion: a combined effort by regulatory agencies, the wind power industry, and raptor migration experts to conduct a series of coordinated, peer-reviewed, multi year, multi-site pre- and post construction monitoring studies to quantify risk to migrating raptors and develop mitigation measures.



The golden eagle, very rare in eastern North America, migrates along the many ridgetops of Pennsylvania and neighboring states in late fall and very early spring

Golden eagle cut in half by wind turbine at Altamont Pass, California *(from Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area)*.



"At wind power-generating facilities in Appalachia and California, wind turbines have killed large numbers of migratory birds and bats."

"Only a few studies exist concerning ways in which to reduce wildlife fatalities at wind power facilities"

– USGAO Report to Congress *Wind Power Impacts on Wildlife*, 2005

1-44

Calvin Luther Martin

From: "Angela Kelly" <amk@clara.co.uk>
To: "Angela Kelly" <amk@clara.co.uk>
Sent: Saturday, March 05, 2005 7:46 AM
Attach: BIRDS legal challenge Altamont.dat, BIRDS legal challenge Altamont.doc
Subject: AK Re: BIRDS - Judge OKs wind-farm suit

9R

"The wind turbine owners are not moving forward, and don't recognize that the times have changed and what they've gotten away with over the past 20 years they can't continue to get away with for another 13 years," Wiebe said.

http://www.insidebayarea.com/searchresults/ci_2581683

Judge OKs wind-farm suit

By Matt Carter, STAFF WRITER

A judge has ruled that an environmental group that sued wind-farm operators over bird deaths in the Altamont Pass will have its day in court.

The Center for Biological Diversity filed suit Nov. 1 against companies operating about

5,200 electricity-producing wind turbines in the Altamont Pass.

The lawsuit alleges that wind turbines in the Altamont have killed thousands of eagles, hawks and owls and that the failure of wildlife regulators to enforce laws protecting the birds gave wind farm operators an unfair competitive advantage.

The suit was filed the day before the Nov. 2 election, when California voters passed Proposition 64, which limits the rights of private parties to file lawsuits on the public's behalf under California's Unfair Competition Law.

Wind farm operators,
including Florida-based FPL Energy LLC and Enxco Inc., argued that with the passage of Prop. 64, the Center for Biological Diversity had no standing to sue on behalf of the general public.

In a ruling issued Thursday to decide how Prop. 64 applies to the organization's lawsuit and 12 others, Alameda County Superior Court Judge Ronald Sabraw agreed. Sabraw said only the state attorney general or Alameda County's district attorney could file suit against wind farms on the public's behalf.

But Sabraw allowed the lawsuit to move forward, because "wildlife is part of the public trust, and the state holds the wildlife for the benefit of the people."

The California Supreme Court has held that any member of the general public has the right to raise a claim
of harm to the public trust, Sabraw said.

"The court has held that all of us Californians are being damaged and harmed by the destruction of this wildlife, and the judge recognized there should be a legal remedy for that harm," said Richard Wiebe, a lawyer representing the Center for Biological Diversity.

An attorney for Enxco, Seawest Windpower Inc., Altamont Winds Inc., and other wind farm operators declined comment.

Although the Center's lawsuit has survived one challenge, it could still be dismissed on other grounds at a March 24 hearing.

Wind farm operators are expected to argue that the Center has not incurred any actual damages. The lawsuit seeks restitution of "all money and property defendants have acquired" through unfair competition, and penalties
of up to $10,000 for each bird taken in violation of the Fish and Game code. The money would go to the state, not the Center, Wiebe said.

Also next month, the Alameda County Board of Supervisors will hear the Center's appeal of the county's decision to renew the permits of about 3,600 wind turbines in the Altamont.

The Board of Supervisors will take testimony on March 3, and could decide whether to impose new conditions on wind farm operators on April 7.

A California Energy Commission study released in January predicted that deaths of birds of prey in the Altamont — estimated at 881 to 1,300 each year — could be cut in half in three years.

The study recommended that wind farm operators shut down 43 percent to 100 percent of the wind turbines in the Altamont for five months in the winter and fall, and remove 294 to 653 of the machines that kill the greatest number of birds.

In their latest proposal to the county, wind farm operators said they are willing to attempt a 35 percent reduction of bird deaths in the next three years. The wind farm operators propose shutting down one-quarter of wind turbines during a four month period, and temporarily removing or relocating the 100 most lethal wind turbines.

The wind farm operators say they shouldn't be required to meet the 35 percent target if it proves to costly.

If "it becomes obvious that reducing fatalities by this magnitude will drive one or more companies or projects out of business, then the objective for that specific company or companies will need to be modified," wind farm operators said in their proposal to the county.

The conditions the county imposes could govern wind farm operations for the proposed 13-year life of the permits.

"The wind turbine owners are not moving forward, and don't recognize that the times have changed and what they've gotten away with over the past 20 years they can't continue to get away with for another 13 years," Wiebe said.

Testimony - Wind Power: Not Green but Red

Presented to the American Legislative Exchange Council Task Force on Energy, the Environment, Natural Resources and Agriculture Austin, TX

May 1, 2004

by H. Sterling Burnett, Ph.D.

Energy is and will remain an important factor in the U. S.'s economic growth. While for much the 20th Century, America has enjoyed excess energy capacity in the transportation and utility sectors, this is no longer the case. Sustained economic growth since 1980s combined with declining domestic fuel production, an aging energy delivery infrastructure, increasing numbers of power plants reaching the end of their licensed and/or productive lives and increased federal, state and local regulatory barriers to the construction of new power plants have produced rapidly rising energy prices. Estimates indicate that during the next 20 years, U.S. oil consumption will grow by one-third and electricity demand could increase by more than 45 percent. To meet these needs the Bush administration has estimated that the U.S. will need to bring between 1,300 and 1,900 new power plants on-line during the next 20 years. Leaving aside for the moment, how this energy will get from the power plant to our homes and businesses – the transmission problem – the question is what will be the source of energy for these power plants.

Fossil fuels are relatively abundant and are significantly less costly than renewable energy sources such as wind power, solar power, geothermal power and the burning of biomass. However, the price of renewable energy, particularly wind power, has fallen significantly in recent years and is quickly becoming, under certain conditions, cost competitive with conventional fossil fuel energy. Environmentalists also point out that burning fossil fuels causes air pollution and emits greenhouse gases which, many people argue, are causing potentially catastrophic global warming. In short, renewable energy promoters claim that wind power is both cheap and "green." Neither claim is true.

Wind Power on the Rise. The price of wind generated energy fell more steeply than any other energy source over the past 30 years. Indeed, the cost of wind power fell from approximately 25 cents per kilowatt hour (kwh) in the early 1980s to between 5 cents and 7 cents (adjusting for inflation) in prime wind farm areas a decade later. Wind advocates argue that a new generation of turbines will bring the cost down below 5 cents per kwh – which is competitive with conventional fossil fuel sources for electricity generation.

Wind power, currently less than 1 percent of the U.S. power supply, could double its share within 10 years. The American Wind Energy Association has optimistically projected that wind power could provide as much as 6 percent of the nation's energy by 2020.

Green Power Bleeds Red: Birds and Bats and Blood, Oh My! The most publicized environmental harm caused by wind power may be its effects on birds and bats. Wind farms must be located where the wind blows fairly constantly. Unfortunately, such locations are prime travel routes for migratory birds, including protected species like Bald Eagles and Golden Eagles. The Sierra Club labeled wind towers "the Cuisinarts of the air." Why?

- Scientists estimate as many as 44,000 birds have been killed over the past two decades by wind turbines in the Altamont Pass, east of San Francisco.

- The victims include kestrels and red-tailed hawks, and — since the area is home to the largest resident population of golden eagles in the lower 48 states — an average of 50 golden eagles each year.

- Exacerbating the problems, as one study explains, "Wind farms have been documented to act as both bait and executioner - rodents taking shelter at the base of turbines multiply with the protection from raptors, while in turn their greater numbers attract more raptors to the farm."

- Further, at least 400 migrating bats, including red bats, eastern pipistrelles, hoary bats, and possibly endangered Indiana bats, were killed at a 44-turbine wind farm in West Virginia in 2003.

This is also a problem in other countries. At Tarifa in Spain, the site of 269 wind turbines, thousands of birds from more than 13 protected species have been killed.

Lawsuits may prevent the expansion of wind farms in West Virginia and California, and the construction of wind farms off the New England coast. Indeed, the lead scientist for the Audubon Society called for a moratorium on new wind development in bird-sensitive areas — which includes most of the suitable sites for construction.

Wind Power Still in the Red: Growing, Growing, Gone. While the price of wind power has fallen, it still costs more than spot market electric power (3.5 to 4 cents kwh). The price gap between wind power and conventional power plants is actually greater, since wind power is directly subsidized by the federal government several state governments. Wind farms are being built in the U.S. primarily for 5 key reasons:

a) wind power is subsidized by the federal government through a production tax credit of 1.8 cents per kwh (this tax credit enables wind farm owners to avoid over $100 million in federal income taxes in 2002 – an amount which grows each year as the number of wind farms grow);

b) Wind power plants also get accelerated depreciation, allowing owners to write off their costs in five years rather than the usual 20 (this permits wind farm owners to shelter over $500 million in 2002 income from federal taxes);

c) state subsidies such as the $0.01 per kwh tax credit in New Mexico;

d) green energy mandates or renewable portfolio standards – 19 states require distribution utilities provide some energy from "green" or renewable energy producers, 25 states permit utilities to charge premium prices for renewable energy to customers who chose to take such energy (so far fewer than 2 percent of customers offered this opportunity vote with their dollars and take advantage of the service), since the amount charged doesn't reflect the true cost of getting green energy to market (green energy's share of new transmission lines is not captured when wind farms are proposed) those who don't choose green energy still pick up some of the costs;

e) Public relations – providing a portion of the utilities electricity from renewable sources to show environmental concern . These subsidies, and green power mandates account for most and perhaps all of the recent growth in wind power.

Indeed, evidence of how critical just one of these reasons is to the "success" of wind farms, when 1.8 cent kwh tax credit lapsed in 2003:

- California's Clipper Windpower abandoned already approved plans to build 67 windmills in Maryland.
- As of January 8, 2004, orders for wind towers from the builder Beaird Industries ground to a halt, costing the company 200 jobs.
- Vestas Wind Technologies shelved plans to build a manufacturing plant in Portland, Oregon.
- More than 1,000 megawatts of wind power that would have been added in 2004 with the tax in place The American Wind Energy Association estimates that the expiration of the tax credit cost the grid.

Green Power Equals Low Power Blight. Wind power's environmental benefits are usually overstated, while its significant environmental harms are often ignored.

Promised air pollution improvements have failed to materialize. Wind farms generate power only when the wind is blowing within a certain range of speed. When there is too little wind, wind towers don't generate power; but when the wind is too strong, they must be shut down for fear of being blown down. Even when they function properly, wind farms average output is less than 30 percent of their theoretical capacity compared to 85 to 95 percent for combined-cycle gas fired plants.

Because of intermittency problems, wind farms need conventional power plants to supplement the power they do supply. Bringing a conventional power plant on line to supply power is not as simple as turning on a switch; therefore most "redundant" fossil fuel power stations must run, even if at reduced levels, continuously. Accordingly, very little fossil-fired electricity will be displaced and few emissions will be avoided because fossil-fueled units (operating at less than their peak capacity and efficiency or operating in "spinning reserve" mode which means they are emitting more pollution per energy produced than if operating at peak efficiency, imagine a car idling near train tracks in case the power goes out) must be kept immediately available to supply electricity when the output from wind turbines drop because wind speed slows or falls below minimums required to power the turbines. Kilowatt-hours produced by wind turbines cannot be assumed displace the emissions associated with an equal number of kWh from fossil-fueled generating units. Combined with the pollutants emitted and CO2 released in the manufacture and maintenance of wind towers and their associated infrastructure, substituting wind power for fossil fuels does not improve air quality very much.

What about CO2? Recently researchers, Mark Jacobson and Gilbert Master's calculated that the U.S. could meet its Kyoto emission reduction goals by replacing 59 percent of coal's share of electricity production (Coal currently produces over 50 percent of the electricity generated in the U.S.) with 214,000 to 236,000, 1500 Kw windmills. They indicated that these windmills would require land space the size of South Dakota. This does not include the thousands of square miles of new transmission lines needed to deliver the energy to utilities. Because of intermittency and wind power's notorious low output when compared to theoretical capacity, Glenn Schleede has calculated that the actual number of windmills needed to replace 59 percent of coal-generated electricity would be approximately 294,500. This does not, however, look at the EIA's estimate of the new coal fired power plants that will come on-line by 2010. Replacing expected new coal generation would require an additional 71,000 1500 Kw windmills. As pointed out above, because of wind's intermittency, the coal plants would not actually be replaced or displaced, rather they would have to be maintained and idling. The "redundant" coal plants would continue to emit CO2. And having the backup system in place would be very expensive. Like a person having a second car (idling in the driveway) just in case the one he normally drives to work doesn't start.

What about the Cost? The cost data usually associated with proposed wind farms is misleading in the extreme because:

- Calculations of costs for wind energy are highly dependent on assumptions about facility lifetime. Calculations often assume 20 or 30 years when no one has experience with actual life of today's wind turbines or their O&M, repair and replacement costs over 20-30 year periods.
- Proponents assumes that the huge federal subsidies for wind facilities (which merely shift cost from "wind farm" owners to taxpayers and electric customers and hide them in tax bills and monthly electric bills) are not a part of the true costs.
- The cited costs for electricity from wind apparently do not take into account the cost of providing backup generation or the extra

costs of transmission and grid management.

Transmission capacity and costs. Lack of transmission capacity is a barrier to economic growth and electricity production in general but even more so for wind energy. Why? The intermittent and highly variable output from "wind farms" makes inefficient use of transmission capacity and cannot by itself justify the costs of adding new transmission capacity. When transmission capacity is added to serve "wind farms," the costs should be counted as part of the full cost of the wind-generated electricity. The wind industry is seeking to avoid these costs by getting regulators to roll them into base rates, thus shifting the costs from "wind farm" developers to all electric customers. (Such a case involving over $100 million is underway in Minnesota.)

Wind farms are also land-intensive and unsightly. In Europe, wind power is growing at even a faster rate than in the United States. *Wind Power Monthly*, the British magazine for the wind industry and enthusiasts, has reportedly recognized that the growing unpopularity of wind power is due to the industry's portrayal of wind farms as "parks" in order to trick their way into unspoiled countryside in "green" disguise. Wind farms are more like highways, industrial buildings, railways and factory farms. Often, the most favorable locations for wind farms also happen to be the current location of particularly spectacular views in relatively unspoiled areas. Wind farms that produce only a fraction of the energy of a conventional power plant require 100 times the acreage. For instance:

- Two of the biggest wind "farms" in Europe have 159 turbines and cover thousands of acres; but together they take a year to produce less than four days' output from a single 2,000 MW conventional power station — which takes up 100 times fewer acres.

- A proposed wind farm off the Massachusetts coast would produce only 450 MW of power but require 130 towers and more than 24 square miles of ocean.
- A wind farm occupying 192,000 acres – 300 square miles – would produce the same amount of energy as a 1000 MW nuclear plant (which has less than 1700 acres, or 2.65 square miles, within its security perimeter fence), or as a 1000 MW coal powered plant taking up 1950 acres, 3.05 square miles, for all of its associated infrastructure.

In addition, regular wind-tower maintenance increase requires miles of paved roads which causes increased runoff and decreased soil absorption of moisture. The impact on wildlife habitat is often greater than technologies associated with conventional fossil fuels.

Wind Power Promises: More tax revenue, more jobs, better farm economy. Wind power proponents often argue that new wind farms will improve the farm economy, increase tax revenues and produce jobs. Research indicates that the fiscal and employment benefits which occur will be less than promised and will come at a high cost -- indeed there will be a net cost.

For instance, wind advocates in:

- New Mexico wind power developer's have promised $450,000 in payments in lieu of taxes, $550,000 in land rental payments, and $500,000 in compensation for 12 employees who will operate the "wind farm" when completed.
  But, the annual total of $1.5 million is claimed

"economic benefits" is equal to about 12.6% of the $11.88 million in EXTRA costs loaded on electric customers each year if the full, true costs of the electricity from the "wind farm" were only $0.02 per kWh above the cost of electricity from other sources (i.e., 594,206,000 kWh x $0.02 per kWh = $11,884,120).

- In North and South Dakota, farmer's could reap as much as $2,400,000 (approximately $5,000 per MW of turbine capacity), which might employ 6 full time workers at, let us say, a generous $100,000 per worker an additional $600,000 per year and associated tax revenue. However, if wind power costs only $0.02 cents per kilowatt-hour (kWh) more than electricity produced from other energy sources – which is a low estimate of the additional costs – then the total *extra* annual cost of the electricity produced by the wind turbines at an average capacity factor of 30% $25,228,400. That amounts to a net cost to ND/SD residents of more than $ 23,000,000 per year.

- In Washington State, the Kittitas Valley Wind project when completed would add $14,892,000 per year to the annual cost of electricity to energy consumers, and due to the production tax credit cost U..S. taxpayers $13,402,800 per year. However it will only provide the State of Washington's farmers with an estimated $750,000 per year in rents, projected construction employment (for 6 months) of $3,120,000 and full time employment of about $332,000 per year (an estimated 8 permanent employees at $20.00 per hr).

- I have similar analysis on proposed wind projects in Virginia, West Virginia, New York and Illinois. In none of these cases do the net revenues exceed more than 1/5 of the net costs.

Comparing Wind Subsidies and Taxes to Conventional Fuels. Wind proponents often complain that it is unfair to single out tax credits and other forms of subsidies to their industry, or too renewable fuels in general, for attack, since, they argue, the fossil fuel industry receives subsidies as well. This is true as far as it goes, and, of course at the NCPA we argue for an end to subsidies for all forms of fuel -- allowing the market to decide energy winners and losers. Whatever one thinks of subsidies, however, the truth is that the fossil fuel industry receives far less in subsidies per BTU equivalent than renewable fuels, and far less overall than they pay in excise taxes, income taxes, royalties and other fees or taxes. At more than $101 billion, the oil and gas industry pays 40 times more in royalties and taxes than the subsidies that it receives (a total of about $2.4 billion – which includes $.8 billion for the Low Income Heating Energy Assistance Program).

While fossil fuels combined, leaving out LEHEAP, do receive slightly more in subsidies in absolute dollars than renewables (excluding hydropower) combined ($1.6 billion vs. $1.1 billion), per unit of energy produced renewables receive more than 3 times the amount of subsidies that fossil fuels receive ($308 million per quadrillion BTU vs. 92 million per QBTU). And, unlike fossil fuels, renewables do not produce more in tax or income revenues than the subsidies that they receive.

Conclusion. Wind power is expensive, doesn't deliver the environmental benefits it promises and imposes substantial environmental costs. Accordingly, it does not merit continued government promotion or funding. Wind power blows!

The author owes much to Glenn R. Schleede, of Energy

Market and Policy Analysis, Inc. Much of the cost data in this presentation comes from his pioneering work on the cost to various states of wind power projects.

H. Sterling Burnett, Ph.D.

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Anne 146

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Wednesday, June 08, 2005 2:01 PM
Subject: bat deaths from wind turbines ..

... this just in on bat deaths in W. Virginia & Pennsylvania from wind turbines: "as many as 2600 bats were killed ... during a 6-week period last year"! Yikes!

Calvin

West Virginia & Pennsylvania, USA

Study: Bats killed at wind turbine sites

(Mon, Jun/06/2005)

CHARLESTON, W.Va. - A study of two wind energy farms in West Virginia and Pennsylvania estimates as many as 2,600 bats were killed by the whirling blades during a six-week period last year.

Between Aug. 1 and Sept. 13, 2004, researchers with the Bats and Wind Energy Cooperative found 765 dead bats on the ground at the Mountaineer Wind Energy Center's 44 wind towers in Tucker County, a report summary released Sunday shows.

Researchers estimate that between 1,364 and 1,980 bats were actually killed in that period at Mountaineer, and many more before and after. An estimated 400 to 660 bats were killed at Meyersdale Wind Energy Center in Pennsylvania, which has about 20 wind towers, according to the study.

"Based on 2004 findings, BWEC scientists recommend comparisons of feathered versus normally operated turbines during periods of low wind, the condition under which most bat mortality occurred," researchers said in a statement.

Turbines produce electricity only when the blades are turning. Owners can lose money any time blades are feathered, either as a safety measure in very high winds or for the proposed tests. That could raise the average price of wind power. Feathered turbine blades are turned parallel to the wind direction to keep them from spinning.

"The goal is to measure exactly how much mortality can be prevented and at what cost to industry. To date, the BWEC has not been able to identify a project owner willing to host such experiments."

The cooperative was organized in late 2003 by FPL Energy, owners of the Tucker County wind farm, after an initial study at the Mountaineer site found the wind turbines killed an estimated 2,092 bats in the spring and late summer of 2003.

Merlin Tuttle, the director of the nonprofit research group Bat Conservation International, called that the largest known bat kill in the world.

Cooperative members include representatives of the U.S. Fish and Wildlife Service, the National Renewable Energy Laboratory, Bat Conservation International and the American Wind Energy Association, the chief industry trade group.

Tom Gray, an AWEA spokesman, said the number of bats killed at the Mountaineer and Meyersdale sites appears to be unusual because it is much higher than at sites in the West and Midwest where similar data has been collected.

"The industry is concerned about this problem and we are committed to finding a way to reduce bat kills based on thorough research, testing, cooperation and voluntary actions. We are working in collaboration with the U.S. government and the world's leading bat conservation organization to conduct research and identify solutions we can implement together," Gray said Sunday.

With public, private and industry funding, BWEC scientists planned three years of experiments to figure out why bats were colliding with wind turbines and to develop possible solutions.

But after just one year of comprehensive research at the Mountaineer and Meyersdale sites, the industry is apparently trying to focus research on solutions or deterrents.

Some sort of research will be done this summer, AWEA spokeswoman Laurie Jodziewicz said Sunday. She declined to name specific sites, saying they are under negotiation.

Gray said wind power is a clean energy source that can help wildlife since it does not pollute air or water and does not require mining or drilling.

"We need to find ways that wind and bats can coexist and we are committed to doing just that," he said.

Information from: The Charleston Gazette, http://www.wvgazette.com
<http://www.wvgazette.com/>
Article's URL:

http://www.phillyburbs.com/pb-dyn/news/103-06062005-498921.html

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Investigating a turbine tragedy

Bat deaths could threaten green image of wind power

By Jim Balow
Staff writer, Charleston Gazette

Bats and ridgetop wind turbines are a deadly combination, recent research at a Tucker County wind power sit confirms.

A second round of research this summer at the Mountaineer Wind Energy Center near Thomas shows that the wind turbines there killed at least as many bats as scientists found last year, said Merlin Tuttle, director of Bat Conservation International in Austin, Texas.

The 2003 study, aimed as much at birds as bats, unexpectedly found that the Mountaineer wind turbines on Backbone Mountain killed an estimated 2,092 bats.

Tuttle, not involved in that study, called the 2003 bat kill "by far the largest bat mortality event I know of worldv and, as far as I know, the biggest mortality event of any animal." The 2004 bat kill could be even worse.

Stunned by the 2003 findings, the wind energy industry joined hands with Tuttle's group and other scientists to conduct more comprehensive research for six weeks this summer, from Aug. 1 to Sept. 11.

Although they don't expect to finish analyzing all the data they collected until year's end, Tuttle and other resea Ed Arnett recently posted some preliminary findings on their Web site, www.batcon.org/wind/.

Tuttle is reluctant to discuss the research at length these days. He and others plan to present their findings to National Wind Coordinating Committee in Washington, D.C.

But he and Jessica Kerns, a biologist at the University of Maryland's Center for Environmental Science in Fros shared some thoughts a few days ago with the Sunday Gazette-Mail.

As she did last year, Kerns led a team who looked for dead bats beneath the wind towers. Researchers also lo for bat carcasses this year at a smaller wind farm in Meyersdale, Pa.

Both sites are owned by FPL Energy, sister of Florida Power & Light Co. The company would not let a reporte photographer on the Tucker County site during the study this summer, citing safety and other concerns.

Tuttle and Kerns declined to say exactly how many dead bats were found this year. "It's safe to say the mortal was no less and was probably higher than last year," Tuttle said.

"It was at least as high and it occurred at two locations and they are both forested ridgetops. We don't know a forested ridgetops with turbines in North America where we don't have a problem."

These findings suggest that any wind farm built on a forested ridgetop, such as two Grant County projects alre approved by the state Public Service Commission, would be likely to kill large numbers of bats.

Those projects — Mount Storm Wind Force's 166 towers and up to 200 towers by NedPower LLC — have bee the back burner since the end of 2003 after Congress failed to renew the lucrative tax credits that make wind p economically feasible.

The findings take on new urgency, though, because both the House and Senate approved a bill on Sept. 23 to extend the credits through Dec. 31, 2005. The bill is waiting for the signature of President Bush.

"If I were an investor and wanted to keep my green image intact, I would be deeply concerned about building turbines on forested ridgetops," Tuttle said.

"The bottom-line concern is, there's just no question if we keep putting turbines on ridgetops before the solutio are known, there will continue to be bat kills.

"We hope the data we collected will lead us to possible solutions. We appreciate the cooperation from industry think we'll have to do even greater research next year."

Updated 5/5/05

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Researchers use thermal imaging, ultrasound

In addition to simply counting dead bats this year, scientists brought an array of high-tech equipment to try to analyze why bats are flying into the giant windmills, whose blades reach up to 300 feet off the ground.

"We brought night imaging scopes, thermal imaging with infrared light and bat detectors. They detect the ultra of bats," Tuttle said. "We used a powerful light to spot bats. We used radar for the first time at various altitude: is also the first time trained retriever dogs were used to see how effective we were in finding [dead] bats."

The research was not inexpensive. "I think we spent $80,000 just to rent three thermal imaging devices." The turbines are so large researchers needed three thermal scopes to cover one turbine, he said.

An alliance of wind companies, including many of those that helped build the Mountaineer site, chipped in to fi the research.

Kerns and her team checked for dead bats every day this year; last year they searched once a week. "We sta sunrise," she said. "From Sunday to Friday we did half the turbines. On Saturdays we did all the turbines.

"It's very interesting. By being on the mountain every day, you could see how weather patterns interacted, hov the blades were turning. It's too early to see how the weather correlated with the bat kills.

"On some mornings when the blades weren't turning, we had higher numbers. You stand underneath and say Why now?' Maybe there were more insects."

To come up with an accurate estimate of dead bats, Kerns will develop a formula that accounts for bats her te couldn't find and those carried off by scavengers like crows and ravens. "We saw crows carrying off carcasse: said.

"There are areas up there it's just impossible — ravines impossible to climb into, grass that grows up to breast height. So some areas you just couldn't search."

Tuttle, Arnett and others are trying to compare the 750 gigabytes of data and other observations collected eac night with the morning counts of dead bats.

"For the first time we'll be able to correlate accurately with weather events and insect activity," Tuttle said. "Th the first time we were able to see bats strike the blades."

They've already reached a few conclusions. "We have identified key areas to focus on and are guardedly opti on finding solutions," he said.

"It appears at this point the largest kills may be quite predictable. There may be options that could be taken fo periods of time that might make a difference."

Peaks in bat kills seem to occur on calm, low-wind nights after the passage of storm fronts, for example.

On the other hand, "We find no evidence that bats are killed by stationary turbines," he said. In other words, it' spinning blades.

"We also have not given up on deterrents on adjusting the sounds put off by turbines," Tuttle said. "We have ju started looking at the thermal imaging tapes. The turbines put off a wide range of sounds that are audible and ultrasonic."

Industry's image, support base at risk

The wind energy industry is highly dependent on its clean, green image because wind-generated electricity cc more than other sources. People are willing to pay extra for wind power with the knowledge that it is a renewa non-polluting form of energy.

Some environmentalists argue that wind turbines are ugly, especially when built in sensitive areas. Others wo about hazards to birds, although the industry argues far more birds are killed in other ways.

Wildlife and industry people have learned only recently about the problems wind turbines pose to bats.

"It was definitely a surprise to us," said Tom Gray, deputy director of the American Wind Energy Association, t industry's main trade group. "It was upsetting."

The AWEA helped fund the research this summer and has gathered pledges from its members for three more of research, Gray said. "We're going to do a lot more research next year and try to determine how to minimize impacts."

Gray said this year's study is the most thorough research of bat-wind turbine interaction ever done. "This is th out. Out of this will come a lot of hypotheses. Maybe insects were being attracted because of certain weather conditions. Maybe there are certain sound factors.

"We'll just have to do more research"

"What we found this year just confirms what we know. We'll just have to do more research to determine what have to do about it."

Officials with the two pending West Virginia wind projects — NedPower and Mount Storm Wind Force — did n return calls from the Sunday Gazette-Mail.

Gray said project developers may be too busy dusting off blueprints now that extension of the federal tax cred seems imminent. To qualify for the credits, developers must have their turbines up and "spinning" by the end year.

"It's very good news for the industry," he said. "There's a pent-up frustration in the industry, a lot of projects in pipeline.

"We had to raise money for this research without a lot of revenue coming in. It's impacted us in a number of w There were a lot of layoffs."

Project developers are well aware of the bat research and the preliminary findings, Gray said. He said Tuttle a Arnett discussed them with developers in a conference call several days ago.

"Those are permitted projects," he said of the two in West Virginia. "Companies are probably going forward wi them. Those are decisions to be made by them [the developers].

"In terms of the long-term future of ridgeline turbines, I think it's too early to say. We need more research.... In of the green image, certainly there are those who can make that point.

"Our demand for electricity is growing. You have to get it from somewhere." Other energy sources have more environmental drawbacks than wind, he argued. "We do take this seriously," he added.

Tuttle said he's not an opponent of wind energy. "In fact, I love those big turbines. I'm fascinated, standing und them. But I'm concerned

"When it comes to the broad public, people who love green power also love wildlife, and I think that applies to Public support of wind energy could wane unless solutions are found, he said.

"I think they [people in the wind energy industry] should be concerned for their own support base," Tuttle said.

To contact staff writer Jim Balow, use e-mail or call 348-5102.

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Calvin Luther Martin

From: "Angela Kelly" <amk@clara.co.uk>
To: "Angela Kelly" <amk@clara.co.uk>
Sent: Tuesday, September 27, 2005 7:05 AM
Subject: AK Re: US: Windmills a fatal attraction for bats September 27,2005

RR

http://www.post-gazette.com/pg/05270/578361.stm

Windmills a fatal attraction for bats
Deaths at wind farms in Pa., W.Va. under study

Tuesday, September 27, 2005
By Paula Reed Ward, Pittsburgh Post-Gazette

They send out sound waves to bounce off objects around them so they can navigate through life.

It's a talent unique to only a handful of creatures, including the only flying mammals -- bats.

So why, then, are bats incapable of navigating around the fast-spinning blades of windmills?

The problem -- most notable at wind farm sites in West Virginia and Pennsylvania -- is so severe that the investigative arm of Congress, the Government Accountability Office, did a study of it.

The report, which looked at both bird and bat mortality at wind farms, was released last week. Its findings: Wind power does not kill a significant number of birds, but more research is needed on bats.

The United States has used wind energy, albeit sparingly, to produce electricity since the early 1980s. But the question of bat fatalities didn't come up until a large number of bats were found dead in 2003 at the 44-turbine Mountaineer Wind Energy Center on Backbone Mountain in Tucker County, W.Va.

A 2004 study estimated between 1,364 and 1,980 bats of six different species were killed there during a six-week period.

At the same time at a wind farm in Meyersdale, Somerset County, 400 to 660 bats of seven different species were killed.

With wind energy being touted as a clean, green, renewable energy source, industry leaders are worried the results could taint a product that produces no pollution, no waste and doesn't harm the land.

"Any sort of environmental impact that does come up, we need to take seriously and address," said Tom Gray, deputy executive director of the American Wind Energy Association, a trade organization.

The potential danger to birds has been known for more than a decade, when environmentalists discovered that thousands of raptors were being killed at a 5,400-turbine wind farm at Altamont Pass in California. The wind farm, which uses shorter, old-style windmills, was built along a migration route for birds of prey. A lawsuit filed against the wind farm by the Center for Biological Diversity is pending.

"This is not a perfect energy source," Gray acknowledged.

But, he continued, tens of thousands of birds killed annually by wind turbines is small when compared with the 1 billion birds that die annually in the United States after they crash into buildings, cars and power lines.

"I'm a numbers guy, and I keep saying, 'Gee, these numbers are really small,'" Gray said. "It's not a message with immediate appeal."

For bats, though, the problem could be worse. They are, for their size, the slowest reproducing mammal, having only one pup each year. Because their populations are not growing quickly, large hits at a wind farm could do real damage.

"Creatures like this can only sustain those types of kill rates for so long," said Ed Arnett, lead researcher for the Bats and Wind Energy Cooperative.

Besides being able to eat more than 1,000 mosquitoes in one night, bats also are helpful in pest control on farms and help pollinate many different types of plants and fruit trees.

Since wind farms began, only 12 sites across the country have done studies on bats, Arnett said.

Now, with the GAO report and other studies, research is beginning to pick up. Instead of just counting how many bats are dying at windmills, researchers are beginning to study bat populations and migrations at pre-construction sites.

That kind of work was done this summer at two sites in Pennsylvania -- one in Somerset County and another in Luzerne. Once the wind farms are built, researchers will do post-construction studies to try to correlate the data.

One key thing Arnett and his fellow researchers determined in their 2004 studies is that most of the bats were killed on low-wind nights, when power production was considered insubstantial. Even then, though, the turbine blades can spin at close to full speed, which is 17 revolutions per minute -- or between 140 and 160 mph.

Fewer fatalities occurred on higher-wind nights. Arnett said that could be explained a couple different ways. On extra windy nights, fewer insects -- the bats' food source -- are out. Also, bats themselves are less active on windy nights.

Arnett would like to do an experiment in which a wind farm shuts down turbines on low-wind, reduced-production nights to see if bat kills decline. Most companies have shied away from that idea, though.

"The research and the effort should be going into finding ways for turbines and bats to co-exist, rather than shutting them down," said Steve Stengel, spokesman for FPL Energy, which operates the Mountaineer and Meyersdale facilities. "If you shut them down, you're not generating the clean, renewable energy."

Another experiment that likely will happen in the next year is trying to use acoustic deterrents -- like white noise -- to keep bats away from windmills.

Other things that already have been tried include turning off the red strobe aviation lights at the tops of the turbines. That had no effect, Arnett said, probably because the lights don't attract insects.

Recent studies also have included the use of thermal imaging cameras and acoustic detectors that record the bats' ultrasound and allow it to be heard by researchers.

Bats are curious creatures, and they often try to investigate the blades of windmills. If the blades aren't spinning, Arnett said, some bats even try to land on them.

The effective range for bats' echolocation is only 3 to 5 meters.

"They're pretty close to the turbines before they can even pick them up," Arnett said. "The attraction might just be the structure itself. They may perceive them as potential roost sites."

Greg Turner, an endangered mammal specialist with the Pennsylvania Game Commission, is doing pre-construction studies at a planned 34-turbine wind farm on a forested plateau east of Wilkes-Barre.

The researchers there are trying to measure insect and bat activity relative to weather and temperature. By next year, once the wind farm is operating, they hope to experiment with deterrents, like white noise.

The research process, though, is long and arduous.

"We know next to nothing at this point," Turner said. "The research has a long way to go to catch up with the wind farms."

Stengel's company, FPL Energy, operates 45 wind farms in 15 states and is the largest generator of wind power in the United States. It has been an industry leader in encouraging research into bat fatalities.

"We are concerned about it, but we also believe that we need to work to better understand it, to try to work to find solutions," Stengel said. "What we're talking about are issues that have been identified at two of our 45 sites.

"All forms of power generation have impacts. Whether generating from coal, fuel oil, nuclear, wind, hydro, solar, they all have impacts on the environment. We think that wind stacks up very well and compares very favorably."

(Paula Reed Ward can be reached at pward@post-gazette.com or 412-263-1601.)

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Calvin Luther Martin

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Sunday, November 13, 2005 12:52 PM
Subject: Windmills prove deadly to bats

... wind turbines and bat deaths (see below).

Calvin

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http://www.statesman.com/news/content/auto/epaper/editions/saturday/news_34571acc50d2c1da004a.html

Windmills prove deadly to bats
Appalachian wind turbines are part of effort to develop clean source of energy, but they're killing thousands of bats.

By Larry Lipman

WASHINGTON BUREAU

Saturday, November 12, 2005

THOMAS, W.Va. -- Towering up to 228 feet above the Appalachian Mountain ridge, windmills are lined up like marching aliens from "War of the Worlds."

Up close, they emit a high-pitched electrical hum. >From a distance of a few hundred yards, their 115-foot blades make a steady whooshing sound as their tips cut through the air.

Owned by **FPL Energy,** a Florida-based company, they are part of the national effort to develop diverse and more environmentally friendly sources of energy.

The problem is, they're killing thousands of bats a year.

"I can appreciate that we need other energy sources," said Jane Burch, who lives in neighboring Grant County, W.Va., where a large wind farm has been proposed. "But I don't like the look of them, and I don't want them behind my property, and I don't like what they do with the bat kills."

The first wind turbines to generate electricity were erected about 25 years ago in California. But wind power capacity more than doubled from 2000 to 2004, and now **turbines are found in 31 states.**

Though wind still generates less than 1 percent of the nation's electricity, the Department of Energy has set a goal of raising that to at least **5 percent by 2020. To reach that goal, the American Wind Energy Association estimates, it will require an increase from about 16,000 turbines nationwide now to more than 78,000 turbines.**

About **600 of those turbines are planned for West Virginia and Pennsylvania.** If they are built, **more than 50,000 bats a year could be killed in these two states alone,** said Merlin Tuttle, founder and president of Austin-based Bat Conservation International Inc.

He said there are no good estimates of how many bats would be killed nationwide if the association's projection of 78,000 turbines were reached, but he estimated that it would be far higher than 50,000.

"They can't sustain that kind of kill rate," Tuttle said, noting that bats are among the slowest-reproducing mammals, generally having one pup each year.

"**Bats are just as important by night as birds are by day,**" he said. Indeed, bats play an important ecological role by eating mosquitoes and such crop-destroying insects as moths, locusts and grasshoppers.

Contrary to popular belief, bats have quite good vision. It's is enhanced by echolocation that helps them "see" in the dark and enables them to zero in on insects as small as a gnat.

A study conducted at **FPL's Mountaineer Wind Energy Center this year indicated that its 44 turbines might**

have caused between 1,300 and 2,000 bat deaths in a six-week period.

That study was led by Edward Arnett, a scientist with Bat Conservation International, and financed largely by the American Wind Energy Association and its 700 member companies.

During the study, one of the turbines at Mountaineer was out of service. It was the only turbine where no bat fatalities were recorded during the entire period.

That led bat enthusiasts to conclude that **bats are not colliding with stationary blades; they're being hit by moving blades, said Dan Boone**, a wildlife biologist from Bowie, Md., who has joined the fight against new windmill farms on forested mountaintops.

Experts don't know why the mortality rate might be so much higher at wind facilities in the Appalachian Mountains than elsewhere in the country.

A Government Accountability Office report in September showed that at wind farms outside the Appalachians, fewer than one to four bats were killed each year per turbine. But Arnett said **the GAO report summarized studies that might have focused on birds and underestimated bat kills.**

It's also unclear precisely why bats are killed by windmills. Among the theories: The windmills are located in the bats' migratory path; bats might be attracted by the turbines' humming sound, their flashing aircraft-warning lights or their tall masts suitable for roosting; the short range of the bats' echolocation does not give them time to avoid the blades.

The recent Mountaineer study has led to an impasse between bat conservationists and the wind power industry over what to do next.

Conservationists have called for further studies that would disengage some turbines on nights when the wind speed is low and bats and their prey are more likely to fly.

The wind power industry has rejected that suggestion. It has proposed studies of deterrent measures such as acoustics to **discourage bats from approaching the turbines.**

"We don't think it makes a whole lot of sense to be focusing on a solution that potentially could reduce the amount of power that is generated and potentially put stress on the machines," said Steve Stengel, an FPL Energy spokesman.

"We think there needs to be a great deal of effort put into finding ways for bats and wind turbines to coexist," he said.

The wind power industry echoes the views of FPL Energy, according to Tom Gray, deputy executive director of the American Wind Energy Association.

Because wind power companies have been trying to produce energy more cheaply, **any proposal that would reduce generating capacity and drive up costs would give the industry "heartburn," Gray said.**

Acoustical deterrent efforts currently are in the design stage and might be tested in the laboratory by early next year, Arnett said. If preliminary investigations show promise, field tests might take place next year. FPL Energy has offered to allow some of its facilities to be used for such tests.

But **Arnett and Boone noted that acoustic efforts to rid houses of bats rarely work and said they do not believe that sound deterrents would be effective in shielding turbines.**

Emotions are running high along the Appalachian ridge as more wind farms are being considered.

Opponents argue that the facilities not only kill bats and disturb other wildlife habitat but are an eyesore, create noise pollution, startle livestock with the flickering of sunlight through the blades, decrease property values and could harm tourism on scenic mountain ridges.

"I can't say I would forever be against wind power, but as far as windmills on mountaintops, there ought to be more study before they just put up these windmills willy-nilly," said Burch, who is retired from the construction industry. "What happens if, in 10 years, wind energy is not working? Who is going to pay to bring them down? It's going to be the counties and the landowners."

William Smith, executive director of the Convention and Visitors Bureau and the Tucker County Chamber of Commerce, said the Mountaineer facility in his county has created a few jobs and brought in more money to local government.

The wind facilities also produce electricity for thousands of homes "without effluent, smoke, nuclear waste, fly ash and other sorts of materials that are associated with alternative forms of electrical generation," Smith said.

As for tourism, though the wind farms do not attract tourists to the area, Smith said those who come for the spectacular fall foliage and the winter skiing also show an interest in seeing the windmills.

"They're not attracting people, but they're an attraction once people have arrived," he said.

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Section title: Birds & bats: Government studies & scientific reports

GAO

Accountability · Integrity · Reliability

Highlights

Highlights of GAO-05-906, a report to congressional requesters

September 2005

WIND POWER

Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife

Why GAO Did This Study

Wind power has recently experienced dramatic growth in the United States, with further growth expected. However, several wind power-generating facilities have killed migratory birds and bats, prompting concern from wildlife biologists and others about the species affected and the cumulative effects on species populations.

GAO assessed (1) what available studies and experts have reported about the impacts of wind power facilities on wildlife in the United States and what can be done to mitigate or prevent such impacts, (2) the roles and responsibilities of government agencies in regulating wind power facilities, and (3) the roles and responsibilities of government agencies in protecting wildlife. GAO reviewed a sample of six states with wind power development for this report.

What GAO Recommends

GAO recommends that FWS provide state and local regulatory agencies with information on the potential wildlife impacts from wind power and the resources available to help make decisions about where wind power development should be approved.

The Department of the Interior agreed with GAO's recommendation.

www.gao.gov/cgi-bin/getrpt?GAO-05-906.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Robin Nazzaro at (202) 512-3841 or nazzaror@gao.gov.

What GAO Found

The impact of wind power facilities on wildlife varies by region and by species. Specifically, studies show that wind power facilities in northern California and in Pennsylvania and West Virginia have killed large numbers of raptors and bats, respectively. Studies in other parts of the country show comparatively lower levels of mortality, although most facilities have killed at least some birds. However, many wind power facilities in the United States have not been studied, and, therefore, scientists cannot draw definitive conclusions about the threat that wind power poses to wildlife in general. Further, much is still unknown about migratory bird flyways and overall species population levels, making it difficult to determine the cumulative impact that the wind power industry has on wildlife species. Notably, only a few studies exist concerning ways in which to reduce wildlife fatalities at wind power facilities.

Regulating wind power facilities is largely the responsibility of state and local governments. In the six states GAO reviewed, wind power facilities are subject to local or state level processes, such as zoning ordinances to permit the construction and operation of wind power facilities. As part of this process, some agencies require environmental assessments before construction. However, regulatory agency officials do not always have experience or expertise to address environmental and wildlife impacts from wind power. The federal government plays a minimal role in approving wind power facilities, only regulating facilities that are on federal lands or have some form of federal involvement, such as receiving federal funds. In these cases, the wind power project must comply with federal laws, such as the National Environmental Policy Act, as well as any relevant state and local laws.

Federal and state laws afford generalized protections to wildlife from wind power as with any other activity. The U.S. Fish and Wildlife Service (FWS) is the primary agency tasked with implementing wildlife protections in the United States. Three federal laws—the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act—generally forbid harm to various species of wildlife. Although significant wildlife mortality events have occurred at wind power facilities, the federal government has not prosecuted any cases against wind power companies under these wildlife laws, preferring instead to encourage companies to take mitigation steps to avoid future harm. All of the six states GAO reviewed had statutes that can be used to protect some wildlife from wind power impacts; however, similar to FWS, no states have taken any prosecutorial actions against wind power facilities where wildlife mortalities have occurred.

Wind assessments found lacking

BY ANNE ADAMS • STAFF WRITER

WASHINGTON, D.C. — Researchers and biologists have insisted for years that thousands of wind turbines in the U.S., and the thousands more planned for construction, could do serious damage to wildlife, especially in Appalachia. They have cried for more environmental reviews that take into account the cumulative impact these 400-foot turbines could have if thousands are erected in this region.

This month, the federal government published an eight-month study that agrees with that conclusion. Its study found that, well, there needs to be more study.

And apparently, both the wind energy industry and its critics agree.

The Government Accountability Office, an investigative arm of Congress, looked at how commercial wind energy has developed nationwide, in a move prompted by two West Virginia congressmen — Nick Rahall II and Alan B. Mollohan.

GAO concentrated on wind plants' effect on migratory birds and bats, and what the government's responsible for doing about it. There's no doubt thousands of birds and bats have been killed by wind turbines, it found, but those kills vary widely by region.

GAO reviewed what studies and experts have reported so far, and the roles and responsibilities of government agencies in regulating wind plants. It sampled six states with commercial wind facilities, and concluded the U.S. Fish and Wildlife Service should provide state and local agencies with information on impacts and the resources to help make decisions about where wind power should be approved.

In northern California, Pennsylvania and West Virginia, GAO found, the industrial plants have killed large numbers of raptors and bats. In other parts of the country, the kills were comparatively lower, "although most facilities have killed at least some birds," it states. However, it cautions, many facilities have not been studied, and therefore, scientists "cannot draw definitive conclusions about the threat," especially since much is still unknown about bird flyways and species population levels.

As it stands, state and local governments carry the responsibility for regulating wind plants. Though many have ordinances which require environmental reviews, "regulatory agency officials do not always have experience or expertise to address ... impacts from wind power," it says.

The federal government plays a minimal role in approving wind developments, usually only when federal land is involved.

USFWS is charged with wildlife protection under three major federal laws — the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act — all of which generally "forbid harm" to various species. Though significant kills have occurred at wind plants, the federal government has not prosecuted any cases against wind power companies under these wildlife laws, "preferring instead to encourage companies to take mitigation steps to avoid future harm," the report states.

Though wind developers are not specifically required to take steps to avoid damage under these federal laws, the USFWS can hold them liable for harm if kills occur. In some cases, GAO found, developers voluntarily consulted with USFWS or another agency before construction.

In the congressmen's report introduction they said, "We are making a recommendation to USFWS to reach out to state and local regulatory agencies with information on the potential wildlife impacts ... and the resources available to help make decisions about the siting."

The report quotes one expert who said the number of bats currently being killed is "alarming" in the eastern U.S. "He explained that bats live longer and have lower reproductive rates than birds and therefore, bat populations may be more vulnerable to impacts. In addition, there are proposals for hundreds of new wind turbines along the Appalachian Mountains."

GAO cites a recent report from Bat Conservation International, which estimated if all ridge-top turbines are approved and the mortality rates continue at their current rate, turbines "might kill tens of thousands of bats in a single season."

Though none of the bats killed are endangered species, the USFWS has initiated a study with the U.S. Geological Survey to study bat migration and develop tools to identify the best locations for turbines and communication towers.

The report also notes some developments have lower levels of mortality, but there are also indirect impacts to wildlife. "For example," it states, "construction of wind power facilities may fragment habitat and disrupt feeding or breeding behaviors. According the USFWS, the loss of habitat quantity and quality is the primary cause of declines in most assessed bird populations and many other wildlife species."

GAO concluded it does not appear that wind power is responsible for a significant number of deaths compared to other threats to avian species. "While we do not know a lot about the relative impacts of bat mortality from wind power relative to other sources, significant bat mortality from wind power has occurred in Appalachia," it states. Furthermore, "much work remains before scientists have a clear understanding of the true impacts to wildlife from wind power."

Scientists are particularly concerned about the cumulative impacts on populations if the industry expands as expected, a point made by Virginia agency officials in a meeting with Highland New Wind Development recently. "Such concerns may be well-founded," GAO concludes, "because significant development is proposed in areas that contain large numbers of species or are believed to be migratory flyways."

Concerns are compounded by the fact that regulating wind power varies from location to location, GAO says, and some state and local regulatory agencies generally had little experience or expertise in addressing these impacts. Moreover, it said, "It appears that when new wind power facilities are permitted, no one is considering the impacts of wind power on a regional or 'ecosystem' scale — a scale that often spans governmental jurisdictions."

American Wind Energy Association executive director Randall Swisher said while his organization was pleased the GAO found wind turbines didn't kill as many birds as other kinds of threats, bats were another story.

"The report also shows that we need to learn more about wind-bat interactions, an issue about which the industry remains concerned even if further research eventually shows that the impact on bat populations is not significant," Swisher said in a written statement. "The industry believes that bats and wind turbines can and must coexist, and is working with stakeholder groups and experts to understand the issue and try to find ways to avoid or at least reduce collisions.

"The wind energy industry welcomes scrutiny of, and comparison with, all of the impacts of all sources of power generation," said Swisher. "We have nothing to hide. We hope that lawmakers and consumers concerned about impacts of energy use — as well they should be — will also call for detailed studies on the impacts of other operating or proposed power plants in the region."

AWEA spokesperson Christine Real de Azua said her organization agrees wildlife impacts need to be studied, but calls for equally rigorous studies on other energy industries as well. "The scope of the GAO study was really very narrow," she said, noting not much beyond the bird and bat findings were requested. "An even broader study is needed to have everything in context ... the birds are clearly having a hard time but more regulation is needed on other industries as well. Our industry is proud of its record. There is monitoring on various wind farms and more scrutiny is needed. A lot of other things need to be scrutinized as well."

Real de Azua says the impacts of wind projects are minor compared to other energy sources. "Our impact is not zero, but it's really microscopic by comparison," she said.

Most wind plants are installed in areas that are more than already fragmented, she added. She points to Tennessee ridges already stripped and mined, large agricultural fields in the midwest and upstate New York, and large, dry ranches in Oklahoma and Texas, all of which would be not be further disrupted by a wind project.

In cases like the site for Highland New Wind Development's project here on Allegheny Mountain, where there are pristine conditions and potentially negative impacts to endangered species, Real de Azua says, developers can work out a plan with USFWS to reconfigure the project and mitigate damage. She described a situation in the Pacific Northwest where a ground squirrel protected on the state level was identified. "They relocated the whole string of turbines and avoided disturbance of that particular habitat," she said. "There are some pristine places in Appalachia, but many are already disturbed." Some locations are better suited than others for wind projects, she added, but developers have additional factors to consider. "If you take a bird's eye view of the midwest, though, it's entirely compatible (with wind energy)," as are sections of Illinois, the Great Plains, and the heartlands of the U.S. "The Atlantic states are more modest (in wind potential)."

For various reasons, GAO says, the USFWS "generally spends a very small portion of their time assessing the impacts from wind power. Nonetheless, USFWS has taken some steps to reach out to the wind power industry by, among other things, issuing voluntary guidelines to encourage conservation and mitigation actions."

The USFWS interim guidelines were prepared in May 2003, and urge a precautionary approach to siting wind facilities. It encourages the industry to follow the guidelines and conduct scientific research on wildlife impacts (see sidebar).

Ultimately, the GAO recommended the Secretary of the Interior direct USFWS to develop consistent communication for state and local wind power regulators. The communication should alert regulators to the potential wildlife impacts, and various resources available to help make decisions about permitting facilities.

Also notable was that GAO found no instance in which a state or local agency regulating wind power had incorporated or adopted the guidelines developed by USFWS in their own requirements for approving wind plants, but it found two cases where states had used the guidelines to inform their regulations or how they monitor wildlife impacts.

Wind industry critics generally applauded the GAO findings, especially because they lent a strong voice of authority to recommendations the group had been making for so long. Lisa Linowes, a spokesperson for the newly formed "National Wind Watch" group, called GAO's report "very important."

"For the first time, the government has acknowledged that studies haven't been enough," she said this week. "We can't assume there's not an impact (from turbines), because there hasn't been any study."

The AWEA, she says, "grossly understates the impacts and over states the benefits" of wind energy. "They say we're misguided or misinformed, and we feel like the wind industry is misinforming." Linowes points to how fast wind projects have been proliferating in the East, and how much the industry saturates the public domain with its own assessments and spin. "It's been difficult to fight," she says. "When we raise issues, and speak of impacts, we're making statements contrary to other environmentalists, too. It's awkward."

The NWW group, currently applying for non-profit status, was formed this August after months of discussion among commercial wind industry critics, particularly those concerned about projects in their own hometowns. Linowes says NWW hopes to simply bring information to the public, and sustain a "watchdog" responsibility with a professional, factual approach.

NWW president David Roberson welcomed the GAO's findings. "The lack of scientific data on the potential damaging impacts to wildlife and our sensitive land areas must be addressed, especially when one considers how much of this industrial development is subsidized by state and federal tax dollars," he said in a written statement. Roberson said the AWEA chose to highlight only select sections of the investigative report that, taken out of context, diminished the findings. "National Wind Watch challenges the wind industry to do the right thing by openly acknowledging the potential risks of wind turbines on our ridge lines, shores and prairies."

For more information, see the American Wind Energy Association web site: www.awea.org, or the National Wind Watch site: www.windwatch.org.

The full GAO report can be found online at: www.gao.gov/new.items/d05906.pdf.

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Report to Congressional Requesters

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Wind power has recently experienced dramatic growth in the United States, with further growth expected. However, several wind power-generating facilities have killed migratory birds and bats, prompting concern from wildlife biologists and others about the species affected, and the cumulative effects on species populations.

GAO assessed (1) what available studies and experts have reported about the impacts of wind power facilities on wildlife in the United States and what can be done to mitigate or prevent such impacts; (2) the roles and responsibilities of government agencies in regulating wind power facilities, and (3) the roles and responsibilities of government agencies in protecting wildlife. GAO reviewed a sample of six states with wind power development for this report.

What GAO Recommends

GAO recommends that FWS provide state and local regulatory agencies with information on the potential wildlife impacts from wind power and the resources available to help make decisions about where wind power development should be approved.

The Department of the Interior agreed with GAO's recommendation.

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The impact of wind power facilities on wildlife varies by region and by species. Specifically, studies show that wind power facilities in northern California and in Pennsylvania and West Virginia have killed large numbers of raptors and bats, respectively. Studies in other parts of the country show comparatively lower levels of mortality, although most facilities have killed at least some birds. However, many wind power facilities in the United States have not been studied, and, therefore, scientists cannot draw definitive conclusions about the threat that wind power poses to wildlife in general. Further, much is still unknown about migratory bird flyways and overall species population levels, making it difficult to determine the cumulative impact that the wind power industry has on wildlife species. Notably, only a few studies exist concerning ways in which to reduce wildlife fatalities at wind power facilities.

Regulating wind power facilities is largely the responsibility of state and local governments. In the six states GAO reviewed, wind power facilities are subject to local- or state-level processes, such as zoning ordinances to permit the construction and operation of wind power facilities. As part of this process, some agencies require environmental assessments before construction. However, regulatory agency officials do not always have experience or expertise to address environmental and wildlife impacts from wind power. The federal government plays a minimal role in approving wind power facilities, only regulating facilities that are on federal lands or have some form of federal involvement, such as receiving federal funds. In these cases, the wind power project must comply with federal laws, such as the National Environmental Policy Act, as well as any relevant state and local laws.

Federal and state laws afford generalized protections to wildlife from wind power as with any other activity. The U.S. Fish and Wildlife Service (FWS) is the primary agency tasked with implementing wildlife protections in the United States. Three federal laws—the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act generally forbid harm to various species of wildlife. Although significant wildlife mortality events have occurred at wind power facilities, the federal government has not prosecuted any cases against wind power companies under these wildlife laws, preferring instead to encourage companies to take mitigation steps to avoid future harm. All of the six states GAO reviewed had statutes that can be used to protect some wildlife from wind power impacts; however, similar to FWS, no states have taken any prosecutorial actions against wind power facilities where wildlife mortalities have occurred.

Contents

Abbreviations

BLM	Bureau of Land Management
DOE	Department of Energy
FWS	U.S. Fish and Wildlife Service
MW	megawatts

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Accountability * Integrity * Reliability

United States Government Accountability Office
Washington, D.C. 20548

September 16, 2005

The Honorable Nick J. Rahall, II
Ranking Democratic Member, Committee on Resources
House of Representatives

The Honorable Alan B. Mollohan
Ranking Democratic Member, Subcommittee on Science,
the Departments of State, Justice, and Commerce
and Related Agencies
Committee on Appropriations
House of Representatives

The production of wind power, a renewable energy source, has recently experienced dramatic growth in the United States, although it still generates less than 1 percent of the electricity used in this country. Wind power-generating facilities were first built in California about 25 years ago. Now wind power facilities can be found in over 30 states, and the industry is expected to continue to grow rapidly. The vast majority of wind power facilities are located in just 10 western and midwestern states; most are on nonfederal land. Development has slowly made its way east and is currently being pursued along the ridge tops of the Appalachian Mountains in Maryland, Pennsylvania, Virginia, and West Virginia. Once thought to have practically no adverse environmental effects, it is now recognized that wind power facilities can have adverse impacts—particularly on wildlife, and most significantly on birds and bats.

Large numbers of birds and bats are believed to follow and cross through many parts of the United States, including along mountain ridges, during their seasonal migrations. Consequently, wind power projects located in these areas could potentially impact these species. At wind power-generating facilities in Appalachia and California, wind turbines have killed large numbers of migratory birds and bats. Wind power facilities may also have other impacts on wildlife through alterations of habitat. Habitat destruction and modification is a leading threat to the continued survival of wildlife species in the United States.

In this context, we assessed (1) what available studies and experts have reported about the impacts of wind power facilities on wildlife in the United States and what can be done to mitigate or prevent such impacts, (2) the roles and responsibilities of government agencies in regulating wind power facilities, and (3) the roles and responsibilities of government agencies in protecting wildlife.

To address these objectives, we reviewed major scientific studies and reports on direct impacts from wind power on avian species and other wildlife (we did not assess indirect impacts, such as habitat impacts). We interviewed experts from the Department of the Interior's U.S. Fish and Wildlife Service (FWS), state agencies, academia, industry, and conservation groups and obtained their views on these studies and reports. We also reviewed a nonprobability sample of six states with wind power development—California, Minnesota, New York, Oregon, Pennsylvania, and West Virginia.[1] We selected these states to reflect a range in installed wind generating capacity, regulatory processes, history of wind power development, and geographic distribution and to reflect our requesters' interests. We identified and reviewed relevant federal, state, and local laws and regulations. In addition, we interviewed federal, state, and local officials who were responsible for implementing related programs. More information about the objectives, scope, and methodology of our evaluation is presented in appendix I. We conducted our work between December 2004 and July 2005 in accordance with generally accepted government auditing standards, including an assessment of data reliability and internal controls.

Results in Brief

Recent studies and interviews with experts indicate that the impacts of wind power facilities on birds and other wildlife vary by region and by species. Wildlife mortalities in two locations in particular have elicited concerns from scientists, regulators, and the public. Specifically, a recent study shows that over 1,000 raptors are killed by wind power facilities in northern California each year. Many experts attribute this large number of fatalities to unique aspects of wind power development in northern California, such as the unusually large number of turbines (over 5,000), the type of turbines in the region, and the presence of abundant raptor prey in the area. On the other side of the country, a recent study estimated that over 2,000 bats were killed during a 1-year period at a wind power facility in the mountains of eastern West Virginia. Studies from these two locations stand in contrast to studies from other wind power facilities. These studies

[1] Results from nonprobability samples cannot be used to make inferences about a population because in a nonprobability sample, some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample.

show relatively lower bird and bat mortality. However, bat estimates are less precise because most of the studies were designed to estimate only bird mortality. These studies have not elicited the same degree of concern from biologists as the studies from West Virginia and California. However, significant gaps in the literature make it difficult for scientists to draw conclusions about wind power's impact on wildlife in general. For example, experts told us that there is a shortage of information on migratory bird routes and bat behavior as well as the ways in which topography, weather, and turbine type affect mortality. In addition, studies conducted at one location can rarely be used to extrapolate potential impacts or mitigation effectiveness at other locations because of differences in site-specific conditions, such as topography, the types and densities of species present, and the type of wind turbines installed. Finally, while some authors have recommended mitigation strategies for reducing bird and bat kills, there are relatively few comprehensive studies testing the effectiveness of these strategies.

Regulating wind power facilities on nonfederal land is largely the responsibility of state and local governments. In the six states we reviewed, the permitting of wind power development consisted of local-level processes, state-level processes, or a combination of the two. In California, New York, and Pennsylvania, local governments regulate the development of wind power. Local governments in these states generally require wind developers to adhere to local zoning ordinances and obtain special use permits before construction. In addition, California and New York have state environmental laws that require various studies and analyses to be conducted before a permit can be issued. West Virginia uses a state-level process, whereby its Public Service Commission is responsible for, among other things, regulating the activities of all public utilities operating in the state, including wind power. The commission has the authority to include certain conditions in wind power certificates, such as requiring wildlife studies before and after construction. In Minnesota and Oregon, local and state agencies regulate wind power development. In these two states, local agencies, such as county planning commissions or zoning boards, permit the development of wind power unless a project exceeds a certain level of electric-generating capacity; larger facilities are regulated by a state agency. While some state and local regulatory agencies require environmental assessments before construction, some state and local regulatory agency officials told us that they have little experience or expertise in addressing environmental and wildlife impacts from wind power. For example, officials in one state told us that they did not have the expertise to evaluate wildlife impacts and review studies prior to construction. The federal government generally only has a regulatory role in wind power development when development occurs on federal land or involves some form of federal participation, such as providing funding for projects. In these cases, the development and operation of a wind power facility must comply with any state and local laws as well as federal laws, such as the National Environmental Policy Act and the Endangered Species Act—which often require preconstruction studies or analyses and possibly modifications to proposed projects to avoid adverse environmental effects.

As with any activity, federal and state laws afford protections to wildlife from wind power facilities. Three laws—the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act—are the federal laws most relevant to protecting wildlife from wind power facilities, and these laws generally forbid harm to various species of wildlife. FWS is the federal agency that has primary responsibility for implementing and enforcing these three laws. Although none of the three laws expressly require wind power developers and operators to take specific steps to ensure that wildlife will not be harmed during either the construction or operation of their facilities, wind power developers or operators are liable for any harm to protected species that may occur. In some cases, developers voluntarily consult with FWS—or a state natural resources agency—before they construct a project or they do so as a requirement of a state or local wind power regulatory agency, to identify potential impacts to wildlife. In other cases, federal involvement may consist of FWS law enforcement officials investigating instances of wildlife fatalities at a wind power facility. While significant mortality events have occurred at some wind power facilities—and, in some cases, are recurring—the federal government has not prosecuted any cases against wind power companies for violations of federal wildlife laws. In some cases, FWS has not taken action because the species killed are not federally protected, such as the bat species killed in West Virginia. In cases where violations of federal law have occurred, FWS law enforcement officials told us that before FWS pursues civil or criminal penalties, the agency prefers to work with companies to encourage them to take mitigation steps to avoid future harm. According to FWS officials, they have been reasonably successful in resolving impacts to wildlife by following this approach with the electric power industry. FWS has also referred cases against wind power developers to either the Interior's Office of the Solicitor San Francisco field office or the Department of Justice for killing raptors, but Justice was unable to comment on the specifics of its ongoing investigation. FWS has been working with the wind industry to help identify solutions and ensure that wildlife mortality at wind power facilities is minimized. For example, FWS has participated in industry-sponsored workshops and conferences, issued voluntary guidelines for industry to use in developing new projects, and served as a member in a wildlife working group with industry. Regarding state wildlife protections, all of the six states we reviewed have statutes that can be used to protect some wildlife from wind power impacts. However, similar to FWS, no states have taken any prosecutorial actions against wind power facilities where wildlife mortalities have occurred.

To encourage potential wildlife impacts to be considered when wind power facilities are permitted, we are making a recommendation to FWS to reach out to state and local regulatory agencies with information on the potential wildlife impacts due to wind power and on the resources available to help make decisions about the siting of wind power facilities.

We received written comments on a draft of this report. The Department of the Interior stated that they generally agree with our findings and our recommendation in the report. Written comments from the department are included in appendix III.

Background

The energy used to generate our nation's electricity comes from many different sources. Currently, most electricity in the United States is generated with fossil fuel and nuclear technologies—coal (52 percent), nuclear (20 percent), natural gas (16 percent), and oil (3 percent). Fossil fuels are considered nonrenewable because they are finite and will eventually dwindle or become too expensive or environmentally damaging to retrieve. Wind, however, is one of several sources of energy known as renewable energy. Other forms of renewable energy sources include sunlight (photovoltaics), heat from the sun (solar thermal), naturally occurring underground steam and heat (geothermal), plant and animal waste (biomass), and water (hydropower).

To reduce our dependence on nonrenewable energy sources, the United States has promoted the development of renewable resources, such as wind. A key federal program supporting the development of such sources is the federal production tax credit established by the Energy Policy Act of 1992.[2] This law provides a tax credit for electricity generated by renewable

[2] 26 U.S.C. § 45. Section 1301 of the Energy Policy Act of 2005, Pub. L. No. 109-58, extended the tax credit through January 1, 2008.

energy sources, such as wind turbines. The Economic Recovery Tax Act of 1981 provides an additional incentive for wind power growth.[3] In some cases, this law allows a 5-year depreciation schedule for renewable energy systems. In conjunction with the tax credit, this accelerated depreciation allows an even greater tax break for renewable energy projects, such as wind projects, that have high initial capital costs.[4]

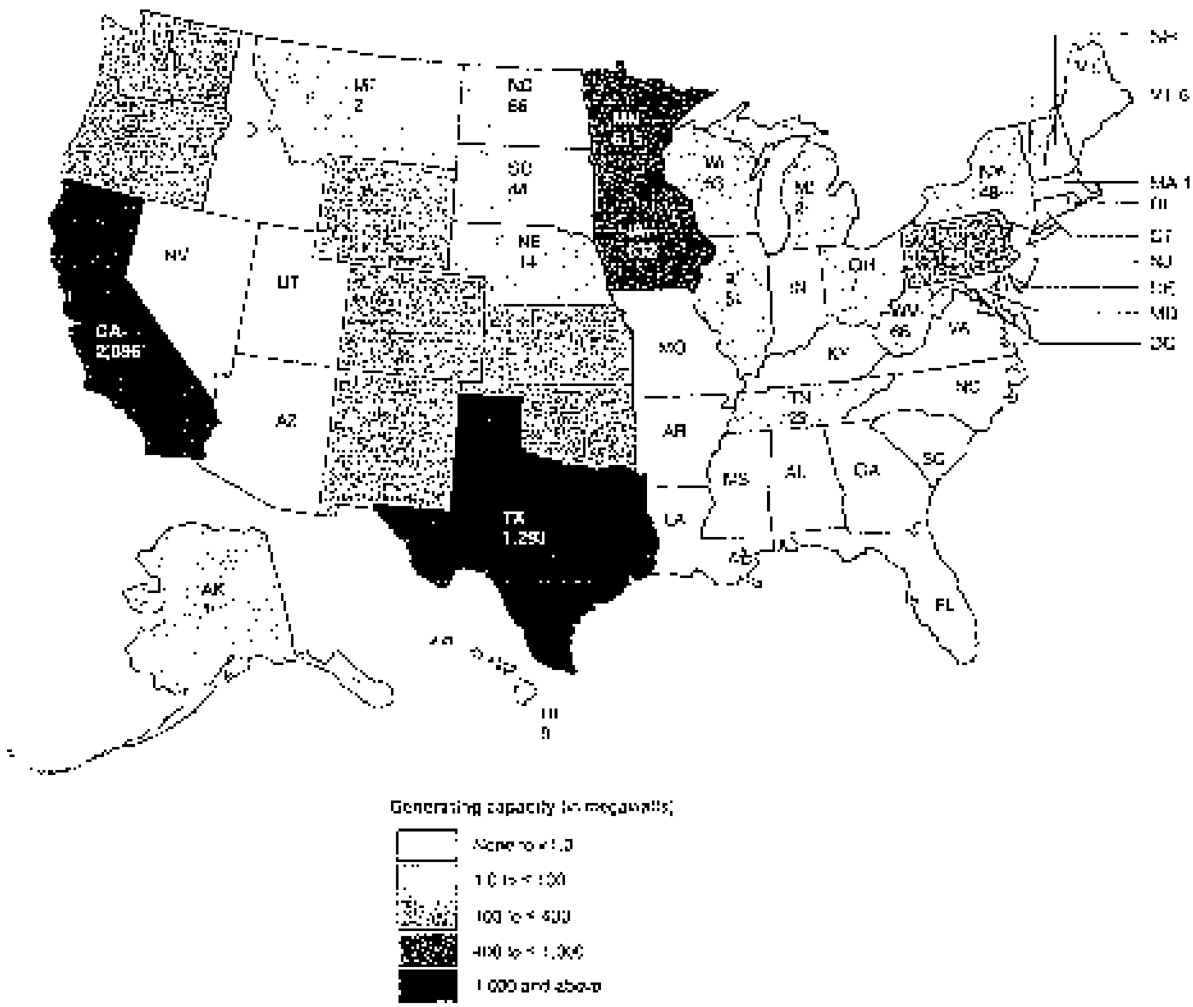
Some states also provide incentives for wind power development. One of the strongest drivers is a renewable portfolio standard. Generally, a renewable portfolio standard requires utilities operating in a state to acquire a minimum amount of their electricity supply from renewable energy sources. As of June 2005, 18 states had some form of renewable power requirements capable of being met by wind power. Other common types of incentives for renewable energy development provided by several state and local governments are income tax incentives and property and sales tax exemptions. Many states provide more than one type of incentive. In addition, 25 states have statewide wind working groups that are funded (at least partially) through grants from the Department of Energy (DOE). The purpose of these working groups is to promote more widespread development of wind power.

These federal and state programs have helped spur significant wind power development in the last 5 years. At the end of 2004, the total installed capacity from wind power in the United States was 6,740 megawatts (MW), or enough capacity to meet the electricity demand of between 1.5 and 2.0 million average American households (see fig. 1).

[3] 26 U.S.C. § 168(e)(3)(B)(vi).

[4] See GAO, *Renewable Energy: Wind Power's Contribution to Electric Power Generation and Impact on Farms and Rural Communities*, GAO-04-756 (Washington, D.C.: Sept. 3, 2004) for prior work related to this issue.

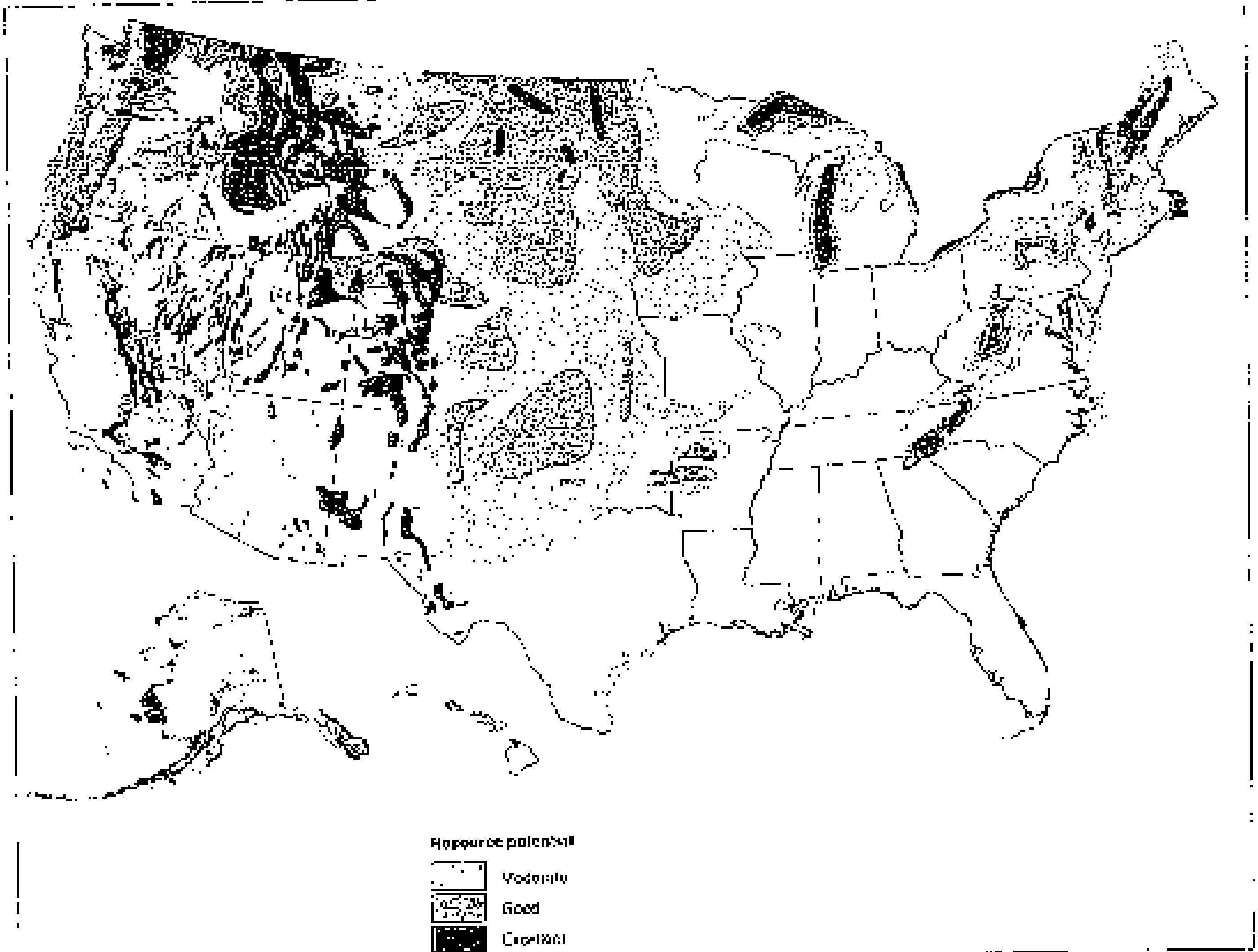
Figure 1: Installed Wind Power-Generating Capacity in Megawatts, by State, as of January 24, 2005



Source: American Wind Energy Association

Between January 2000 and December 2004, installed electric-generating capacity more than doubled, adding over 4,200 MW of capacity. Although wind power generates less than 1 percent of the nation's electricity, with an average annual growth rate of over 24 percent, it is the fastest growing source of electricity generation on a percentage basis. Because wind energy is a function of wind speed, the best locations for turbines are areas that have frequent strong winds to turn the blades of the power-generating turbines. See figure 2 for areas of the United States with high wind potential.

Figure 2: Areas of the United States with High Wind Potential



Source: Department of Energy, National Renewable Energy Laboratory.

According to DOE, 36 of the 48 continental states have wind resources that would support utility-scale wind power projects (i.e., projects that generate at least 1 MW of electric power from 1 or more turbines annually for sale to a local utility). A DOE goal for wind power is to generate 5 percent of the electricity generated in the United States by 2020; the American Wind Energy Association has a similar goal.[5] To reach this goal, the association estimates that about 100,000 MW of installed capacity will be needed—approximately 15 times the current installed capacity. On the basis of the average MW size of wind turbines commonly being installed today (1.5 MW), more than 62,000 additional turbines will need to be added to the existing 16,000 turbines already constructed in the United States to meet such a goal.

Most of the wind power development in the United States has occurred in 10 western and midwestern states—California, Colorado, Iowa, Minnesota, New Mexico, Oklahoma, Oregon, Texas, Washington, and Wyoming. In fact, these 10 states have over 90 percent of the total installed wind power capacity nationwide. Only recently have developers begun to build wind energy facilities in the eastern United States. As shown in figure 2, wind power potential in this geographic area is best along mountain ridges, primarily the Appalachian Mountains, and along the coast of the northeastern United States.

Wind power is considered a "green" technology because, unlike fossil fuel power plants, it does not produce harmful emissions, such as carbon dioxide, nitrogen oxides, sulfur dioxide, mercury, and particulate matter, which can pose human health and environmental risks such as acid rain. However, it is now recognized that wind power facilities can adversely affect the environment in other ways, specifically in impacting wildlife such as birds and bats. Wind power facilities located in migratory pathways or important habitats may harm the wildlife living or passing through the area by killing or injuring them or by disrupting feeding or breeding behaviors. But wind power is not alone in its impacts on wildlife. Millions, or perhaps billions, of wildlife are killed every year in the United States through a myriad of human activities. While sources of bat mortality are not as well known, FWS estimates that some of the leading sources of bird mortality, per year, are collisions with building windows—97 million to 976

[5]The American Wind Energy Association is a national trade association that represents wind power plant developers, wind turbine manufacturers, utilities, consultants, insurers, financiers, researchers, and others involved in the wind industry.

million bird deaths, collisions with communication towers— 4 million to 50 million bird deaths, poisoning from pesticides—at least 72 million birds, and attacks by domestic and feral cats —hundreds of millions of bird deaths. Human activities also result in the destruction or modification of wildlife habitat; habitat loss and fragmentation are leading threats to the continued survival of many species.

Studies Show Wind Power Facility Impacts on Wildlife Vary, Although Notable Gaps in the Literature Remain and Few Studies Address Mitigation

Recent studies and interviews with experts reveal that the impacts of wind power facilities on birds and other wildlife vary by region and by species. Specifically, studies showing raptor mortality in California and bat mortality in Appalachia have elicited concerns from scientists, environmental groups, and regulators because of the large number of kills in these areas and the potential cumulative impact on some species. Thus far, documented bird and bat mortality from wind power in other parts of the country has not occurred in numbers high enough to raise concerns. However, gaps in the literature make it difficult to develop definitive conclusions about the impacts of wind power on birds and other wildlife. Notably, only a few studies have been conducted on strategies to address the potential risks wind power facilities pose to wildlife.

Wildlife Mortality Varies by Region and by Species

Our review of the literature and discussions with experts revealed that, thus far, concerns over direct impacts to wildlife from wind power facilities have been concentrated in two geographic areas—northern California and Appalachia.[6] (For a discussion on how we selected these studies, see app. I.) While bird and bat kills have been documented in many locations, biologists are primarily concerned about mortality in these two regions because of the numbers of wildlife killed and the species affected.

Studies Have Found Large Numbers of Raptors Killed by Wind Turbines in California

Wind power facilities in northern California, specifically in the Altamont Pass Wind Resource Area about 50 miles east of San Francisco, have been responsible for the deaths of numerous raptors, or birds of prey, such as hawks and golden eagles, and, as a result, these deaths have elicited concern from wildlife protection groups, biologists, and regulators. Studies conducted in the last two decades have documented large numbers of raptor deaths in this area. One study in our review found estimates as high

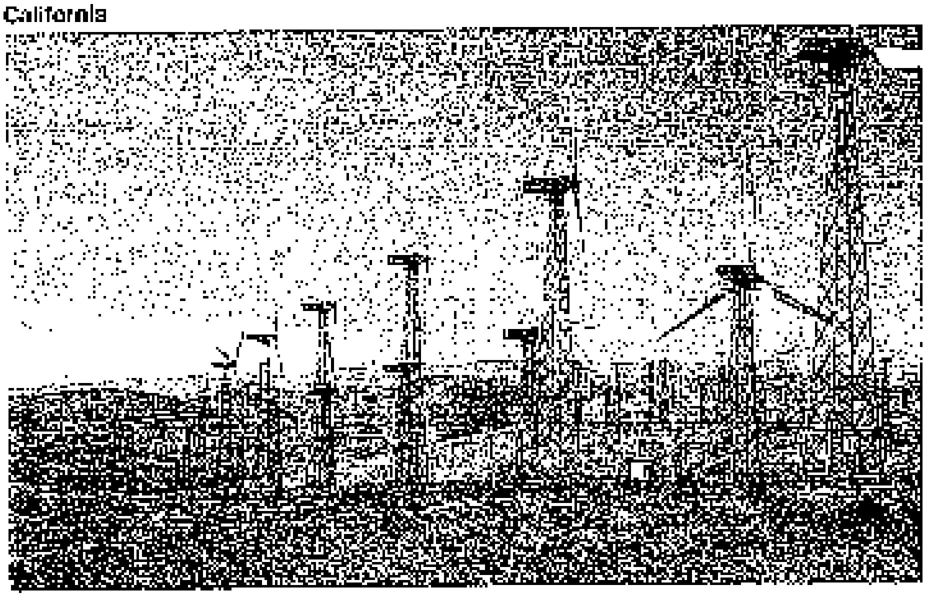
[6] Many of these studies were conducted by consultants for wind power companies and were not scientifically peer-reviewed. In addition, protocols used in these studies may vary.

as over 1,000 raptor deaths per year. Such large numbers of raptor kills due to wind power are not seen elsewhere in the United States. A 2001 summary that examined raptor mortality rates from studies in 10 states estimated that over 90 percent of the raptors killed annually in the United States by wind power turbines occurred in California.[7]

Several unique features of the wind resource area at Altamont Pass contribute to the high number of raptor deaths. First, California was the first area to develop wind power in significant numbers and thus has some of the oldest turbines still in operation in the United States. Older turbines produce less power per turbine, so it took many turbines to produce a certain level of energy; today, newer facilities producing the same amount of energy would have much fewer turbines. For example, Altamont Pass has over 5,000 wind turbines—many of which are older models—whereas, newer facilities generally have significantly fewer turbines (see figs. 3 and 4). Some experts told us that the sheer number of turbines in Altamont Pass has been a major reason for the high number of fatalities in the area.

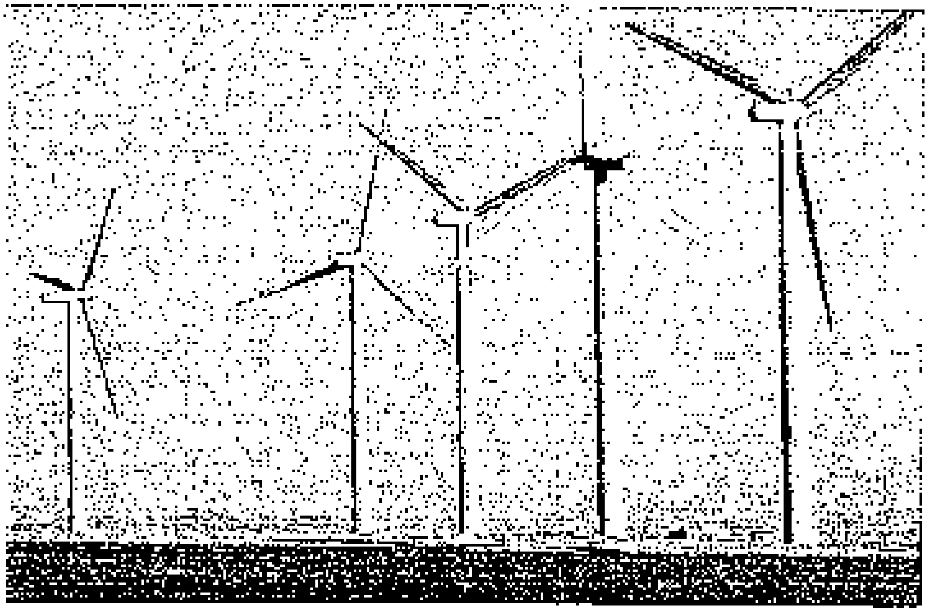
[7] Erickson, Wallace P., Gregory D. Johnson, M. Dale Strickland, David P. Young Jr., Karyn J. Sernka, and Rhett E. Good. *Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States.* A National Wind Coordinating Committee Resource Document. August 2001. Because summaries of studies generally do not present detailed information about the methodologies of the studies they include, these results should be considered with caution.

Figure 3: Example of Older Generation Wind Turbines in Altamont Pass, Northern California



Source: California Energy Commission.

Figure 4: Example of a Newer Generation Wind Power Facility



Source: Department of Energy, National Renewable Energy Laboratory

Secondly, some scientists believe that the design of older generation turbines, like those found in Altamont Pass, are more fatal to raptors. Specifically, early turbines were mounted on towers 60 feet to 80 feet in height, while today's turbines are mounted on towers 200 feet to 260 feet in height. Experts told us that the older turbines at Altamont Pass have blades that reach lower to the ground, and thus can be more hazardous to raptors as they swoop down to catch prey. Experts also reasoned that the relative absence of raptor kills at newer facilities with generally taller turbines supports the notion that these turbines are less lethal to raptors. Third, the location of the wind turbine facilities at Altamont Pass may have contributed to the high number of raptor deaths. Studies show that there are a high number of raptors that pass through the area, as well as an abundance of raptor prey at the base of the turbines. In addition, the location of wind turbines on ridge tops and canyons may increase the likelihood that raptors will collide with turbines. Some experts note that one reason why other parts of the country may not be experiencing high levels of raptor mortality is partly because wind developers have used information from Altamont Pass to site new turbines in hopes of avoiding similar situations.

Studies Have Found Large Numbers of Bats Killed by Wind Turbines in Appalachia

Recent studies conducted in the eastern United States in the Appalachian Mountains have found large numbers of bats killed by wind power turbines. A 2004 study conducted in West Virginia estimated that slightly over 2,000 bats were killed during a 7-month study at a location with 44 turbines. More recently, a 2005 report that examined wind resource areas both in West Virginia and Pennsylvania estimated that about 2,000 bats were killed during a much shorter 6-week study period at 64 turbines. Lastly, a study conducted of a small 3-turbine wind facility in Tennessee estimated that bat mortality was about 21 bats per turbine, per year, raising concerns about the potential impact on bats if more turbines are built in this area.

Various species of bats have been killed at these wind power facilities and experts are concerned about impacts to bat populations if large numbers of deaths continue. For example, one expert noted that "it is alarming to see the number of bats currently being killed coupled with the proposed number of wind power developments" in these areas. He explained that bats live longer and have lower reproductive rates than birds, and, therefore, bat populations may be more vulnerable to impacts. In addition, there are proposals for hundreds of new wind turbines along the Appalachian Mountains. A recent report from Bat Conservation International estimated that if all ridge-top turbines are approved and the mortality rates continue at their current rate, these turbines might kill tens of thousands of bats in a single season. Although none of the bats killed by wind power to date have been listed as endangered species, FWS—recognizing the seriousness of the problem—has initiated a study with the U.S. Geological Survey to study bat migration and to develop decision tools to provide assistance in identifying locations for wind turbines and communication towers.

Studies Show That Bird and Bat Mortality from Wind Power in Other Parts of the Country Is Comparatively Lower Than in California and Appalachia

Results from studies on bird and bat mortality from wind power conducted in areas other than northern California and Appalachia have not caused the same degree of concern as in these two locations. Our review of studies conducted in areas other than the Appalachian Mountains showed bat fatality rates ranging from 0 to 4.3 bats per turbine, per year—compared with rates as high as 38 bats per turbine, per a 6-week study period, in the Appalachian Mountains (see app. II). Raptor fatalities outside Altamont Pass ranged from 0 to 0.07 raptors per turbine, per year, whereas, rates in Altamont Pass ranged from 0.05 to 0.24. Our review of studies found that overall bird fatalities from wind power ranged from 0 to 7.28 birds per turbine, per year. In addition, a 2004 National Wind Coordinating Committee fact sheet shows that an average of 2.3 birds per turbine, per year are killed at facilities outside of California.[9] However, it is important to also look at the number of turbines and the vulnerability of the species affected when interpreting these rates. For example, the high rate of 7.28 overall bird fatalities per turbine was found at a facility of only 3 wind turbines. Therefore, if no additional turbines are built in this area, the overall impact to the bird populations may be minimal; whereas, a lower fatality rate may cause impacts if there are many turbines in that particular area. In addition, comparing study findings can be difficult because researchers may use differing metrics and many areas of the country remain unstudied with regard to avian and bat impacts from wind power. While interpreting these statistics can be complicated, the experts we spoke with agreed that outside of California and Appalachia at the current level of wind power development, the research to date has not shown bird or bat kills in alarming numbers.

While the studies we reviewed showed relatively low levels of mortality in many locations, there are also indirect impacts to wildlife from wind power facilities. For example, construction of wind power facilities may fragment habitat and disrupt feeding or breeding behaviors. According to FWS, the loss of habitat quantity and quality is the primary cause of declines in most assessed bird populations and many other wildlife species. However, this review focuses on the direct impacts of avian and bat mortality.

Several Gaps Exist in Research on Wind Power Facility Impacts on Wildlife

While experts told us that the impact of wind power facilities on wildlife is more studied than other comparable infrastructure, such as communication towers, important gaps in the research remain. First, relatively few postconstruction monitoring studies have been conducted and made publicly available. It appears that many wind power facilities and geographic areas in the United States have not been studied at all. For example, a bird advocacy group expressed concern at a recent National Wind Coordinating Committee meeting that most of the wind projects that have been monitored for bird impacts are in the west. The American Wind Energy Association reports that there are hundreds of wind power facilities currently operating elsewhere in the country. However, we were able to

[9] National Wind Coordinating Committee, *Wind Turbine Interactions with Birds and Bats: A Summary of Research Results and Remaining Questions*, Fact sheet: Second Edition November 2004. Because summaries of studies generally do not present detailed information about the methodologies of the studies that they include, these results should be considered with caution.

locate only 19 postconstruction studies that were conducted to assess direct impacts to birds or bats in 11 states.[9] Texas, for example, is second only to California in installed wind power capacity, but we were unable to find a single, publicly available study investigating bird or bat mortality in that state.

Lack of comprehensive data on bird and bat fatalities from wind turbines makes it difficult to make national assessments of the impact of wind turbines on wildlife. A 2001 analysis of studies estimated that wind turbines in the United States cause roughly 33,000 avian deaths per year.[10] However, the authors noted that making projections of the potential magnitude of wind power-related avian fatalities is problematic, in part, because of the lack of long-term data. The authors further noted that the data collected at older sites may not be representative of newer facilities with more modern turbine technology. In addition, FWS considers this estimate to be a "minimum" to "conservative" estimate due to problems of data collection and uneven regional representation. In addition to limiting assessments of national impacts, a lack of data on actual mortality impacts siting decisions for new facilities. Specifically, the conclusions of postconstruction studies are often used when making preconstruction predictions about the degree of harm to wildlife that is likely expected from proposed facilities. If there are no local postconstruction studies available, predictions of future mortality at a proposed site must be based on information from studies conducted in areas that may have different wildlife species, topography, weather conditions, climate, soil types, and vegetative cover.

A second important research gap is in understanding what factors increase the chances that turbines will be hazardous to wildlife. For example, it can be difficult to discern, among other things, how the number, location, and type of turbine; the number and type of species in an area; species behavior; topography; and weather affect mortality and why. Drawing conclusions about the degree of risk posed by certain factors—such as terrain, weather, or type of turbine—is difficult because sites differ in their combination of factors. For example, according to experts, data are inadequate about what turbine types are most hazardous and to what species. This is partly because most wind power facilities use only one

[9]See appendix I for the criteria we used for including studies in our review.

[10]Erickson, Wallace P., Gregory D. Johnson, M. Dale Strickland, David P. Young Jr., Karyn J. Sernka, and Rhett E. *Avian Collisions with Wind Turbines.*

turbine type. Therefore, even if one facility proved more hazardous than another, it would be difficult to attribute the difference to turbine type alone because other variables, such as topography or migratory patterns, are also likely to vary among the sites. Additionally, comparisons between studies are difficult because researchers may use different study methodologies. Therefore, even if two sites had similar bird populations, topography, and weather characteristics but different turbines, it would be difficult to isolate the effect of the turbine if the scientists collecting the information used differing methodologies.

Altamont Pass, however, has the potential to allow researchers to determine which turbines are more hazardous because it contains many different types of turbines in one place. However, even this analysis has been complicated by confounding variables. For example, according to experts, at one time it was commonly thought that turbines with lattice towers killed more birds than turbines with tubular towers in Altamont Pass; however, some studies have reached the opposite conclusion. One study noted that although the authors found higher mortality associated with lattice towers, this relationship might be explained by factors such as the fact that lattice towers were found to be in operation more frequently than were other towers, including tubular towers, rather than the difference in the design of the towers. Complicating matters still, some factors may be more hazardous for some species than others. One study found that red-tailed hawk fatalities occurred more frequently than expected at turbines located on ridgelines than on hillsides. The authors found the reverse to be true for golden eagles, demonstrating the difficulty of understanding interactions between turbines and bird mortality from bird mortality estimates alone.

A third research gap is the lack of complete and definitive information on the interaction of bats with wind turbines. As previously noted, bats have collided with wind turbines in significant numbers in some parts of the United States, but scientists do not have a complete understanding regarding why these collisions occur. Bats are known to have the ability to echolocate to avoid collision with objects, and they have been able to avoid colliding with comparable structures such as meteorological towers.[31] Therefore, their collision with wind turbines remains a mystery. The few studies that have been conducted show that most of the kills have taken

[31] Meteorological towers are used to assess weather conditions, including wind speed and direction.

place during the migratory season (July through September), and this suggests that migrating bats are involved in most of the fatalities. In addition, one study showed that lower wind speeds were associated with higher fatality rates. However, experts admit that much remains unknown about why bats are attracted to and killed by turbines and about what conditions increase the chances that bats will be killed. One expert noted that there is still very little known about bat migration in general and about the way in which bat interactions with turbines are affected by weather patterns. This expert further noted that there still has not been a full season of monitoring bat mortality from which patterns can be identified.

Although scientists still do not know why bats are being killed in large numbers by wind power turbines in some areas, several hypotheses have been offered. One hypothesis states that the lighting on turbines attracts insects, which in turn attracts bats, but studies have not demonstrated differences in fatalities between lit turbines and unlit turbines. Other hypotheses include the notions that bats may be investigating wind turbines as potential roosting sites, that open spaces around turbines create favorable foraging habitats, and that migrating bats do not echolocate and thus are less able to avoid collision. One thing bat experts agree on is the need for more research.

In addition to these research gaps regarding bird and bat interactions with turbines, very little is known about bird and bat populations in general, such as their size and migratory pathways. An FWS official told us that data are available regarding the migration routes and habitat needs of only about one-third of the more than 800 bird species that live in or pass through the United States each year. In addition, bat researchers stressed to us that very little is known about the pathways and behavior of migratory bats. This lack of information, among other factors, makes it difficult to assess the cumulative impacts from wind power on species populations. One expert noted that many bird populations are in decline in general and additional losses due to wind power may exacerbate this trend. However, it is very difficult to attribute a decline in bird populations to wind power specifically or to get good data on overall populations that span international borders. Our literature search was only able to find one study in the United States that examined the impact of fatalities from wind power on a particular species population—golden eagles—and those results have been described as relatively inconclusive, or mixed, by other scientists. Without this kind of information, it can be difficult to determine the appropriate public policy responses to wildlife impacts due to wind power.

Although there are currently several gaps in the study of wind power's direct impacts on birds and bats, FWS and the U.S. Geological Survey have recently initiated a study of bird and bat migration behaviors to address some of these data gaps. This study will use radar technology to characterize daily and seasonal movements and habitat and landform associations of migrating birds and bats, and will seek to develop decision support tools to provide assistance in identifying locations for wind turbines and communication towers. In addition, Congress has appropriated funds for a National Academy of Sciences study on the environmental impacts of wind power development in the Mid-Atlantic Highlands that will include developing criteria for the siting of wind turbines in this area. Finally, the Bats and Wind Energy Cooperative, a partnership of Bat Conservation International, the American Wind Energy Association, FWS, and the National Renewable Energy Laboratory, continues to sponsor research on bats and wind turbines focusing on acoustic deterrence methods and pre- and postconstruction risk assessment at a planned wind farm in the Appalachian region.

Few Studies Have Been Conducted on Mitigation Measures

Overall, there is much to be learned about mitigation strategies for reducing impacts from wind power facilities on birds and bats, and some strategies that once looked promising are now proving ineffective. Specifically, we found that relatively few studies have examined strategies for reducing the potential impacts of wind power on birds and bats. Some of these studies were based on information collected from birds in a laboratory setting, and, therefore, their conclusions still need to be verified by conducting studies at actual wind power facilities. One study examined the idea of addressing motion smear—the inability of birds to see moving blades—by painting turbine blades to make them more visible. This study indicated that color contrast was a critical variable in helping birds to see objects like moving turbine blades and recommended painting stripes on blades as a way to test whether this could be an effective deterrent. Some developers adopted this strategy; however, a recent study found that turbines with painted blades were ineffective in reducing bird kills. Another laboratory-based study tested bird reactions to noise and sound pressure and suggested that whistles could make blades more audible to birds, while making no measurable contribution to overall noise levels. However, the authors of this study made no predictions about changes in bird flight in response to hearing the noise and noted that field tests would be required to test this hypothesis.

Although there have been relatively few laboratory-based experiments on mitigation strategies, some strategies have already been attempted in Altamont Pass. A recent 4-year study conducted by the California Energy Commission in Altamont Pass tested some of these mitigation efforts attempted by industry and suggested possible future mitigation strategies. This study found that some of the strategies adopted by industry, such as perch guards on turbines and rodent control programs that reduce prey availability, were ineffective in reducing kills. Another study compared the differences between turbines painted with ultraviolet reflectant or nonultraviolet reflectant to see whether one would act as a visual deterrent, but the study found no evidence of a difference in mortality between the two treatments.

While there is less than adequate information on the effectiveness of mitigation strategies from existing scientific research, the experts with whom we spoke were hopeful about several strategies on the basis of their experience in the field. Some of these experts noted that because birds have been found to collide with electrical wires, wind facilities should bury their transmission lines under ground and avoid using guywires on their meteorological towers; such fixes have generally been adopted. Although some studies have shown that there are no differences in mortality rates for lit turbines versus unlit turbines, some experts argue that, regardless, it is best to use low lighting to avoid attracting birds that migrate at night. In addition, researchers recommended that sodium vapor lights should never be used at or near wind power facilities because they have commonly been shown to attract birds to other structures. They noted that the largest number of birds killed at one time near wind turbines was found adjacent to sodium lights after a night of dense fog. No fatalities have been discovered near these turbines since the lights were subsequently turned off. Some researchers have observed that many bird and bat kills occur during the time of year that has the lowest wind production. For example, most bats are killed during the fall migration season on low wind nights. Consequently, researchers suggested turning off some turbines during these times in order to reduce kills. Perhaps most importantly, many experts have noted that using preconstruction studies on wildlife and their habitats can help identify locations for wind turbines that are less likely to have adverse impacts.

Regulating Wind Power Facilities on Nonfederal Land Is Largely the Responsibility of State and Local Governments

Since most wind power development has occurred on nonfederal land, regulating wind power facilities is largely a state and local government responsibility. In the six states we reviewed, wind power development is subject to local-level processes, state-level processes, or a combination of the two. For example, in three of the six states, local governments regulate the development of wind power and generally require wind developers to adhere to local zoning ordinances and to obtain special use permits before construction. The federal role in regulating wind power development is limited to projects occurring on federal lands or those that have some form of federal involvement, such as projects that receive federal funding; to date, there have been relatively few wind power projects on federal land. In these cases, wind power projects must comply with federal laws as well as any relevant state and local laws.

State and/or Local Governments Regulate Wind Power on Nonfederal Lands

State and/or local governments regulate the development and operation of wind power facilities on nonfederal lands. The primary permitting jurisdiction for wind power facilities in many states is a local planning commission, zoning board, city council, or county board of supervisors or commissioners. Typically, these local jurisdictional entities regulate wind projects under zoning ordinances and building codes. In some states, one or more state agencies play a role in regulating wind power development, such as natural resource and environmental protection agencies, state historic preservation offices, industrial development and regulation agencies, public utility commissions, or siting boards. In addition, some states have environmental laws that impose requirements on many types of construction and development, including wind power, that state and local agencies must follow. The regulatory scheme for wind power in the six states we reviewed included all of these scenarios (see table 1).

Table 1: Type of Regulatory Process and Responsible Agency in Select States

State	State/Local processes	Regulatory agency/authority
California	Local-only	Local governments (are subject to the state's environmental quality act, which requires assessment of environmental impacts of proposed actions)
Minnesota	State and local	Local governments regulate facilities under 5 megawatts. Minnesota Public Utility Commission regulates facilities 5 megawatts or larger
New York	Local-only	Local governments (are subject to the state's environmental quality review act, which requires assessment of environmental impacts of proposed actions)
Oregon	State and local	Local governments regulate facilities under 105 megawatts (peak capacity). Oregon Energy Facility Siting Council regulates facilities 105 megawatts or larger
Pennsylvania	Local only	Local governments
West Virginia	State-only	Public Service Commission (though local authorities could have some regulatory impact through zoning and subsidies)

Source: GAO analysis of state and local data.

In the six states we reviewed, we found that approval for the construction and operation of a wind power facility is typically provided in permits that are often referred to as site, special use, or conditional use permits or certificates. Such permits often include various requirements, such as "setback" provisions—which stipulate how far wind power turbines must be from other structures, such as roads and residences—and decommissioning requirements that are intended to ensure that once a wind power facility ceases operation, its structures are removed and the landscape is restored according to a specific standard. State and local regulations may require postconstruction monitoring studies to assess a facility's impact on the environment. In one state we reviewed, facilities are required to submit periodic reports on issues related to its operation and impact on the surrounding area.

In most of the six states we reviewed, state and local regulations related to wind power are evolving as the industry has developed in the states because government agencies realized that their existing authorities were not applicable to wind power. For example, when wind power began to emerge in Minnesota, an advisory task force held public meetings to determine how to proceed in permitting development. In part based on concerns raised from counties during these meetings, responsibility for permitting larger facilities was given to the state. In addition, West Virginia finalized new regulations for electric-generating facilities in May 2005 that include provisions specific to wind power facilities. Prior to this, the state made decisions on a case-by-case basis. Similarly, the Pennsylvania Game

Commission is developing a policy for wind power development on its lands in response to private interest in promoting renewable energy sources on state property. Officials with the state's Department of Environmental Protection also told us that they are examining a number of options, including developing statewide rules and model ordinances that could be adopted by local authorities.

Some state and local regulatory agencies we reviewed generally had little experience or expertise in addressing environmental and wildlife impacts from wind power. For example, officials in West Virginia told us that they did not have the expertise to evaluate wildlife impacts and review studies prior to construction, although such studies are required. Instead, they said they rely on the public comment period while permits are pending for concerns to be identified by others, such as FWS and the state Division of Natural Resources. In addition, Alameda County officials in California told us that they did not have the expertise to assess the impacts of wind facility construction but rely on technical consultants during the permitting stage, and that they are planning to form a technical advisory committee for assistance with postapproval monitoring. In some of the states we reviewed, state agencies were conducting outreach efforts with local governments since wind power development is still a relatively new industry for regulators. These efforts typically focus on educating local regulators about the issues that are often encountered during wind power development and about how permitting can be handled. These efforts may also include providing sample zoning ordinances and permits.

California

California had the most installed wind power in the country, with 2,096 MW of generating capacity as of April 2005 and an additional planned capacity of 365 MW. California was the first state in which large wind farms were developed, beginning in the early 1980s. It is also one of the few states with significant wind power development on federal land, with over 250 MW on land owned by the Bureau of Land Management (BLM). Aside from the facilities on BLM land, the state relies on local governments to regulate wind power. In addition to the local permitting process, the California Environmental Quality Act requires all state and local government agencies to assess the environmental impacts of proposed actions they undertake or permit.[12] This law requires agencies to identify significant environmental effects of a proposed action and either avoid or mitigate significant environmental effects, where feasible.

[12] California Environmental Quality Act, Cal. Pub. Res. Code § 21100.

We met with officials from Alameda County and Contra Costa County, which are home to the Altamont Pass Wind Resource Area—at one time the largest wind energy facility in the world. In both counties, local land use ordinances allow wind power development on agricultural lands. These counties originally issued conditional or land use permits to various wind power developers in the 1980s that contained approval conditions, including requirements for setbacks from property lines and noise limits. As previously discussed, the Altamont Pass Wind Resource Area was subsequently found to be responsible for the deaths of numerous raptor species. The counties are currently renewing or amending some of the permits for facilities in this area and will add permit conditions in an attempt to reduce avian mortality. Alameda County officials were working with various federal and state agencies, environmental groups, and wind energy companies to agree on specific permit conditions. At the time of this report, Alameda County has recently approved a plan that is aimed at reducing bird deaths at Altamont Pass by removing some existing turbines, turning off selected turbines at certain times, implementing other habitat modification and compensations measures, and gradually replacing existing turbines with newer turbines. In addition, Contra Costa County had completed the permitting for a wind power facility that included a number of conditions to reduce avian mortality.

Minnesota

Minnesota had 615 MW of installed wind generating capacity as of April 2005 and an additional planned capacity of 213 MW. Wind power development in Minnesota is subject to either local or state permitting procedures, depending on the size of the project. Local governments generally issue conditional use permits or building permits to wind power developers for facilities under 5 MW. We spoke with officials in Pipestone County, which was the first in the state to adopt a wind power ordinance. This ordinance focuses mainly on setbacks and decommissioning requirements. In southwestern Minnesota—which includes Pipestone County and most of the wind power development in the state—a 14-county renewable energy board is working to adopt a "model" wind power permitting ordinance that would provide uniformity for regulating development in the region. Two factors that officials cited in pursuing such guidance is the recognition that development is likely to occur under the 5 MW threshold for state permitting, and that wind power developers would benefit from uniform regulations.

Between 1995 and the first half of 2005, the Minnesota Environmental Quality Board—comprised of 1 representative from the governor's office, 5 citizens, and the heads of 10 state agencies—was responsible for regulating large wind energy systems that are 5 MW or larger, studying environmental issues, and ensuring state agency compliance with state environmental policy.[13] Effective July 1, 2005, authority for permitting these large wind energy systems was transferred to the Minnesota Public Utilities Commission. The commission requires, among other things, an analysis of the proposed facility's potential environmental and wildlife impacts, proposed mitigative measures, and any adverse environmental effects that cannot be avoided. Instead of requiring individual wind developers to conduct their own assessments of impacts to wildlife, Minnesota took a different approach. Since much of the wind power development is concentrated in the southwestern part of the state, the state determined that it would be more efficient to conduct one large-scale study, rather than requiring each developer to conduct individual studies. Thus, the state required wind developers to participate in a 4-year avian impact study at a cost of about $800,000 as well as a subsequent 2-year bat study. The studies concluded that the impacts to birds and bats from wind power are minimal. Therefore, on the basis of the results of the state-required studies, state and local agencies in Minnesota are not requiring postconstruction studies for wind power development in this portion of the state. The costs for these studies were charged back to individual wind developers on the basis of the number of megawatts built or permitted within a specified time frame.

New York

New York had three operating wind power facilities, with 49 MW of installed wind generating capacity as of April 2005. An additional 350 MW of wind power capacity is planned for the state. According to state officials, local governments permit the development of wind power in the state using their zoning authorities. In addition to this local permitting, the state has an environmental quality review act that requires all state and local government agencies to assess the environmental impacts of proposed actions, including issuing permits to wind power facilities.[14] This law requires that an environmental impact statement be conducted if a proposed action is determined to have a potentially significant adverse environmental impact. Because wind power is still new to the state and there are a significant number of proposed facilities, a state agency focused on promoting energy development is beginning a program for educating local communities about regulating wind power. This program includes examples of zoning ordinances that have been used in other counties.

[13] Minn. Stat. §§ 116C.691 - 116C.697.

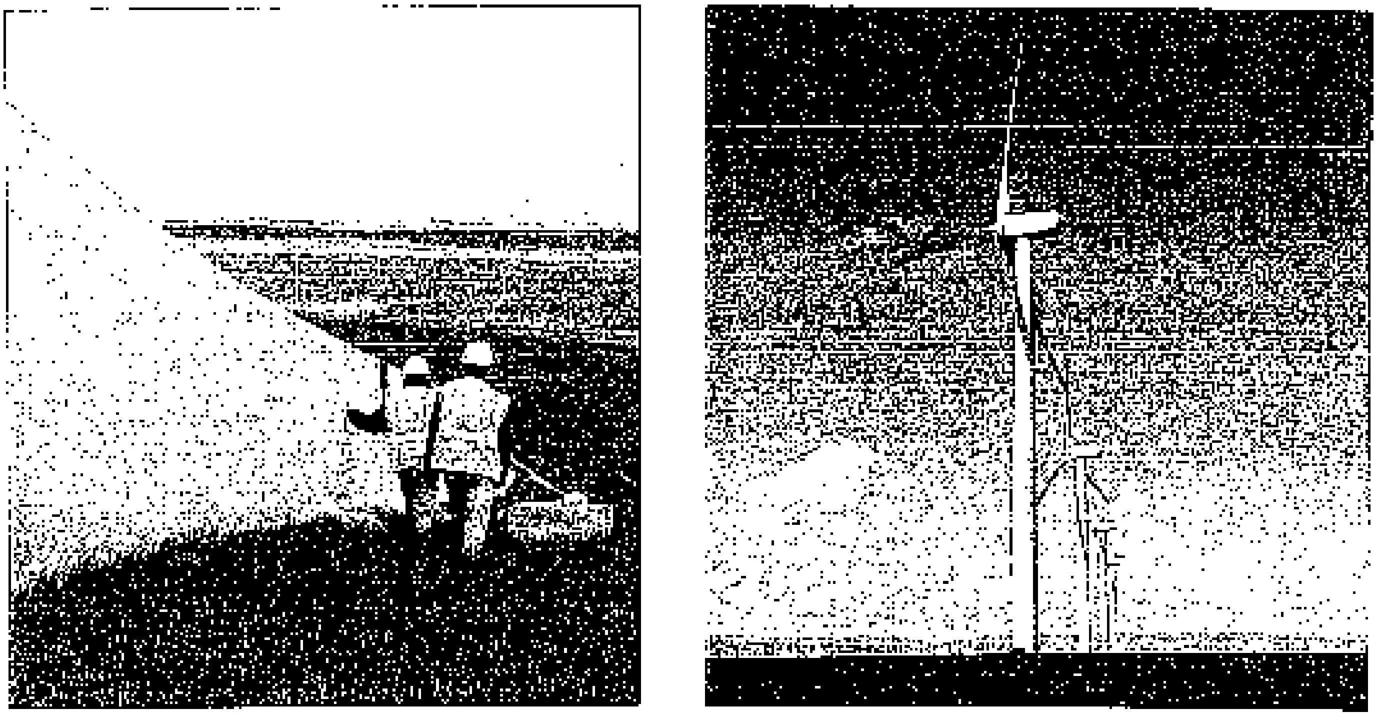
[14] State Environmental Quality Review Act, N.Y. Envtl. Conserv. Law § 8-0109.

We met with officials from the Town of Fenner—in north-central New York—which has the largest wind power facility in the state. On the basis of complaints about noise from the first facility permitted by the town, the local planning board now requires that turbines be located a certain distance from residences. In order to comply with the state's environmental law, the town conducted an environmental assessment to determine the potential impacts of the proposed facility and determined that the project would not have any significant adverse environmental impacts or pose a significant risk to birds. However, elsewhere in New York, approval of one wind power project is under review given concerns expressed by environmental groups and the state environmental and conservation agency about potential impacts to migratory birds.

Oregon

Oregon had five large wind projects, with a total of 263 MW of installed wind power generating capacity as of April 2005 (see fig. 5).

Figure 5: Wind Power Facility in Sherman County, Oregon



Source: GAO.

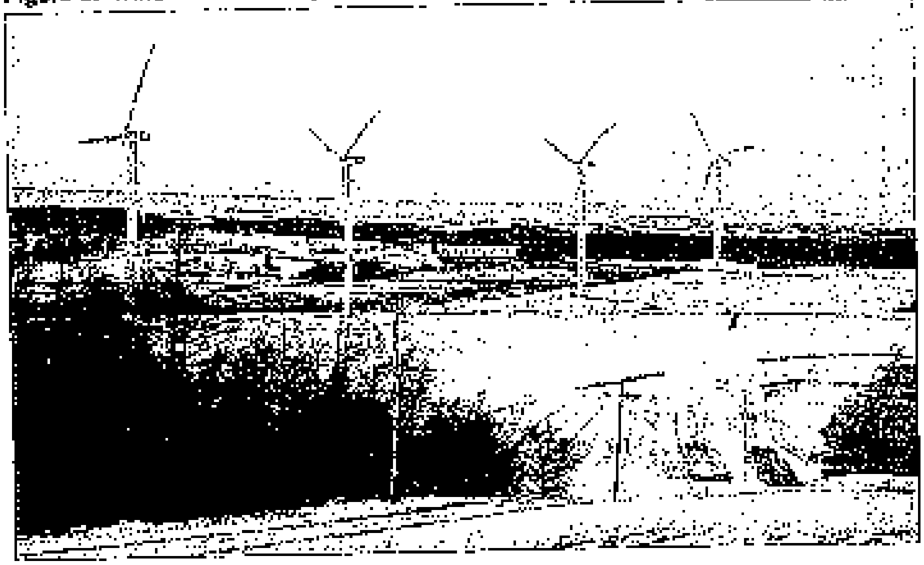
Wind turbine blade prior to being installed at expansion of the facility in Sherman County (left) and the wind power facility in Sherman County (right).

Several new wind projects and expansions are under way or being planned that would take total capacity in Oregon to more than 700 MW. Similar to Minnesota, wind power regulation in Oregon is subject to either local or state permitting procedures, depending on the size of the project. Local governments issue conditional use permits for facilities capable of generating up to 105 MW peak capacity. For example, in Sherman County, the planning commission approved a 24 MW wind power project near Klondike in north-central Oregon. Under its zoning authority, the county attached various conditions to the project's permit, including an avian postconstruction study, and decommissioning and removal requirements. If projects exceed 105 MW peak capacity, they are permitted by the Oregon Energy Facility Siting Council, which makes decisions about issuing site certificates for energy facilities. The siting council is a seven-member citizen commission that is appointed by the governor. Wind power projects that are subject to the council's jurisdiction must comply with the council's standards and applicable statutes. Some of the standards are specific to wind power, such as design and construction requirements to reduce visual and environmental impacts.[15] The council also ensures that wind power facilities are constructed and operated in a manner consistent with state rules, such as state fish and wildlife habitat mitigation goals and standards, and local agency ordinances. In addition, regulations protect against impacts on the surrounding community by requiring that minimal lighting be used to reduce visual impacts, and protect some bird species by requiring that developers avoid creating artificial habitat for raptors or raptor prey. Also in Oregon, energy development—including wind power—must not adversely impact scenic and aesthetic values and is prohibited in certain areas, such as state parks.

Pennsylvania

Pennsylvania had 129 MW of installed wind generating capacity as of April 2005 and applications for an additional 145 MW to be developed (see fig. 6).

Figure 6: Wind Power Facility in Somerset County, Pennsylvania



Source: GAO.

[15]Oregon Revised Statutes (ORS) § 469.300 et seq.; Oregon Administrative Rules (OAR) Chapter 345, Divisions 1, 15, 20-23, 26, 27, and 29.

In Pennsylvania, wind power is regulated by local governments; no state agency has the authority to specifically regulate wind power development. For example, in Somerset County, which is home to the first wind power facility in the state, the county's planning commission regulates wind power development through an ordinance that allows for subdividing existing land. This ordinance contains requirements for setbacks and decommissioning. Some county and state officials have suggested that the state should provide a consistent framework for wind power development. The state, through its Pennsylvania Wind Working Group, is currently discussing whether there should be uniform state-level siting guidelines or regulations for wind power development. Pennsylvania was the only state of the six we reviewed that did not have state-level requirements for environmental assessments. However, one state official told us that many developers have done some environmental studies—generally including wildlife, noise, and protection of scenic vistas (i.e., viewshed)—in an attempt to head off criticism or opposition to a proposed project.

West Virginia

West Virginia had one operating wind power facility, with 66 MW of installed wind power generating capacity and a planned additional capacity of 300 MW for the state (see fig. 7). The state's Public Service Commission has been the only agency involved in regulating wind power to date, although state officials noted that local governments could get involved through their zoning authorities. Prior to 2005, West Virginia permitted construction and operation of wind power facilities under laws and regulations designed to regulate utilities providing electrical service directly to its citizens. Wind power facilities are wholesale generators and do not provide service to consumers, and according to commission officials, several provisions of these regulations were not relevant to wind power facilities. As a result, in 2003, the state amended the legislation to specifically address the permitting of wholesale electric generators, such as wind power.

Figure 7: Wind Power Facility in Tucker County, West Virginia

Source: GAO

West Virginia followed the regulations in place before the legislation was amended to approve construction of the two wind power facilities in the state; one of these facilities has yet to be constructed. During the public comment periods for these facilities, concerns were raised regarding potential impacts to wildlife. As a result, certain conditions were required of the developers, such as prohibiting turbines in certain locations and requiring postconstruction wildlife studies.[16] In May 2005, the state finalized new regulations for wholesale electric-generating facilities that include provisions specific to wind power facilities.[17] For permitting wind power facilities, West Virginia regulations now require spring and fall avian migration studies, avian and bat risk assessments, and avian and bat lighting studies.

Federal Government's Role in Regulating Wind Power Is Generally Limited to Facilities on Federal Land

The federal government's role in regulating wind power development is limited to projects occurring on federal lands or projects that have some form of federal involvement. While the Federal Energy Regulatory Commission regulates the interstate transmission of electricity, natural gas, and oil, it does not approve the physical construction of electric generation, transmission, or distribution facilities; such approval is left for state and local governments. Certain standards issued by the Federal Aviation Administration apply to wind power facilities and other tall structures, on all lands. These standards are intended to protect aircraft and specify the type of lighting that should be used for structures of a certain height.

Since the majority of wind development to date has been on nonfederal land or has not required federal funding or permits, the federal government has had a limited role in regulating wind power facilities. In those cases where federal agencies do regulate wind power, projects must comply both with state and local requirements and with any applicable federal law. At a minimum, these laws will include the National Environmental Policy Act and the Endangered Species Act.[18] These laws often require preconstruction studies or analyses of proposed projects, and possibly project modifications to avoid adverse environmental effects. For example, if the development of a proposed wind power project on federal land could impact wildlife habitat and/or species protected under the Endangered Species Act, permitting of the project would involve coordination and consultation with FWS and/or the National Marine Fisheries Service to

[16] Developers of these two facilities voluntarily conducted some preconstruction wildlife studies.

[17] The West Virginia Public Service Commission adopted *Rules Governing Siting Certificates for Exempt Wholesale Generators* (WV 150 C.S.R. 30) on May 25, 2005, effective July 25, 2005.

[18] Other federal laws may apply to wind power development on federal land, such as the Federal Land Policy and Management Act, which provides BLM with a framework for managing its land.

determine the potential harm to species and the steps that may be necessary to avoid or offset the harm.

To date, BLM has been the only federal agency with wind energy production, with about 500 MW of installed wind power capacity.[19] This wind energy development is located in Southern California in the San Gorgonio Pass and Tehachapi Pass areas, and in the Foote Creek Rim and Simpson Ridge areas of Wyoming.[20] According to BLM officials, as of June 2005, they had authorized 88 applications for wind energy development on their land and had 66 pending applications—most of which are in California and Nevada. Energy development on BLM-administered lands is regulated through its process for granting private parties access to federal lands, which is referred to as granting a "right-of-way authorization." BLM's Interim Wind Energy Development Policy establishes the requirements for granting these authorizations to wind energy facilities. This policy requires that all proposed facilities conduct the necessary assessments and analyses required by the National Environmental Policy Act, the Endangered Species Act, and other appropriate laws. In one case, some changes have been made to the location of some wind power turbines because of potential impacts to avian species that were identified during these preconstruction studies.

Because of an increased focus on developing energy sources on public lands, BLM has proposed revising their interim policy by developing a wind energy development program that would establish comprehensive policies and best management practices for addressing wind energy development. As a part of this effort, BLM issued a programmatic environmental impact statement in June 2005 that assesses the social, environmental, and economic impacts of wind power development on BLM land. This document also identifies best management practices for ensuring that the impacts of wind energy development on BLM lands are kept to a minimum. While subsequent proposed wind power facilities will still need to conduct some environmental assessments, they can rely on BLM's programmatic assessment for much of the needed analyses. BLM hopes that the availability of this assessment will enable wind power development to

[19]At the time of this report, a developer had submitted an application to build what would be the first wind power project on U.S. Forest Service land.

[20]Postconstruction wildlife studies in these areas of California and Wyoming found low avian mortality. The California study in Tehachapi Pass was not included in appendix II because estimating fatality rates was not a primary goal of that study.

proceed more quickly on its lands, assuming that such development complies with needed requirements.

Federal and State Laws Protect Wildlife

As with any other activity, federal and state laws afford protections to wildlife from wind power. Three federal laws—the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act—generally forbid harm to various species of wildlife. While each of the laws allows some exceptions to this, only the Endangered Species Act includes provisions that would permit a wind power facility to kill a protected species under certain circumstances. While wildlife mortality events have occurred at wind power facilities, the federal government has not prosecuted any cases against wind power companies under these wildlife laws, preferring instead to encourage companies to take mitigation steps to avoid future harm. Regarding state wildlife protections, all of the six states we reviewed had statutes that can be used to protect some wildlife from wind power impacts. However, similar to FWS, no states have taken any prosecutorial actions against wind power facilities where mortalities have occurred.

Various Wildlife Protections Are Provided by Three Federal Laws

The primary federal regulatory framework for protecting wildlife from impacts from wind power includes three laws—the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act. (See table 2.)

Table 2: Federal Wildlife Protection Laws

Federal wildlife law	Protections	Permits	Penalties for violations
Migratory Bird Treaty Act	Prohibits the taking, killing, possession, transportation, and importation of over 860 migratory birds, their eggs, parts, and nests, except when specifically authorized by FWS	Authorizes permits for some activities, including but not limited to, scientific collecting, depredation, propagation, and falconry No permit provisions for "incidental take"	Only criminal penalties are possible, with violators subject to fine and/or imprisonment
Bald and Golden Eagle Protection Act	Prohibits the taking and sale of bald and golden eagles and their eggs, parts, and nests, except when specifically authorized by FWS	Authorizes permits for scientific or exhibition purposes, or religious purposes by Indian tribes; and for other purposes No permit provisions for "incidental take"	Civil and criminal penalties are possible, with violators subject to civil penalties, fines, and/or imprisonment
Endangered Species Act	Protects about 1,265 species that have been determined to be at risk for extinction, referred to as threatened or endangered species; prohibits the taking of protected animal species, including actions that "harm" or "harass"; federal actions may not jeopardize listed species or adversely modify habitat designated as critical	Authorizes permits for the "taking" of protected species if the permitted activity is for scientific purposes, is to establish experimental populations, or is incidental to an otherwise legal activity, such as construction of wind turbines	Civil and criminal penalties are possible, with violators subject to civil penalties, fines, and/or imprisonment

Source: GAO analysis of federal laws.

FWS is primarily responsible for ensuring the implementation and enforcement of these laws.[31] In general, these laws prohibit various actions that are deemed harmful to certain species. For example, each law prohibits killing or "taking" a protected species, unless done under circumstances that are expressly allowed by statute and authorized via issuance of a federal permit. The Endangered Species Act may also prohibit actions that harm a protected species' habitat. In addition, each federal agency that takes actions that have or are likely to have negative impacts on migratory bird populations are directed by Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds," to work with FWS to develop memorandums of understanding to conserve those species. While the executive order was signed on January 10, 2001, no memorandums have yet been signed. Wildlife species that fall outside the

[31] FWS shares responsibility for enforcing the Endangered Species Act with the National Marine Fisheries Service, which is responsible for protecting ocean-dwelling species and anadromous species, such as salmon.

scope of these three laws, such as many species of bats, are generally not protected under federal law. However, FWS is not only responsible for ensuring the survival of species protected by specific laws, but also for conserving and protecting all wildlife.

All three of the federal wildlife protection laws prohibit most instances of "take," although each law provides for some exceptions, such as scientific purposes. The Endangered Species Act is the least restrictive of these laws in that it authorizes FWS to permit some activities that take a protected species as long as the take meets several requirements, including a requirement that the take be incidental to an otherwise legal activity. Wind power facilities may seek an incidental take permit under this act for facilities sited on private land or where no federal funding is used or federal permit is required. The Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act also allow permits for take, but incidental take of migratory birds is not allowed. Under all three statutes, unauthorized takings may be penalized, even if the offender had no intent to harm a protected species.[22]

Although not required by these federal laws, in some cases, state or local entities that regulate wind power, or wind power developers themselves, will consult with FWS for information on protected species or advice on how to ensure that wind power facilities will not harm wildlife. For example, in the Altamont Pass Wind Resource Area, Alameda County officials and the companies operating wind facilities there have asked FWS for technical assistance related to renewing permits for existing wind power facilities. FWS officials told us that their technical assistance in Altamont Pass is aimed at avoiding or minimizing potential impacts to threatened or endangered species under the Endangered Species Act. In addition, FWS officials from the New York field office told us that they are asked to provide input on wind power proposals during the state's environmental review process. These officials noted that they will likely not be able to review all of the wind power development proposals in the state due to staffing constraints. Similarly, FWS officials in five of the six states we reviewed told us that they have not conducted outreach to state or local regulators to inform them of the potential for wildlife impacts from wind power primarily because of workload constraints. If state and local regulators do not consult with FWS during the regulatory process, it can be

[22] FWS identifies violations of federal wildlife laws in several ways, including by receiving citizen complaints and self-reporting by industry or individuals.

difficult for FWS to encourage actions that might reduce wildlife deaths before wind turbines are sited.

Federal Government Uses Prosecutorial Discretion in Dealing with Wildlife Mortality

Although FWS investigates all "take" of federal trust species, the government has elected not to prosecute wind energy companies for violations of wildlife laws at this time. In most of the states we reviewed, there were relatively few law enforcement officials, and they told us that they often had higher priority violations of federal wildlife laws than mortality events due to wind power, particularly given the relatively low levels of mortality that have occurred in most wind power locations. In West Virginia, the agent-in-charge told us that most of his time is spent on the commercialization of wildlife, such as the illegal import and export and interstate commerce of protected species; illegal hunting is also a major problem, particularly for bears and eagles. FWS law enforcement officials in all of the six states we reviewed told us that in cases of violations, they prefer to work cooperatively with the owners of wind power facilities to try to get them to take voluntary actions to address impacts on wildlife, rather than pursuing prosecution; however, other cases of wildlife violations, such as illegal trade in protected species, are pursued via prosecution.

FWS has been investigating and monitoring avian mortality at Altamont Pass for nearly 20 years, including the mortality of many protected species, such as golden eagles and other raptors.[23] Since that time, FWS has opened investigations and tried to work with the owners of wind power facilities to reduce the level of mortality. In the earlier years, some avian mortality was due to electrocutions along power lines. FWS had been working with electrical utility companies to resolve this problem elsewhere, and several relatively easy "fixes" were known to reduce electrocutions. As a result of official correspondence and conversations between FWS and company officials, many companies implemented these fixes, and avian mortality due to electrocutions has been reduced. However, large numbers of birds, particularly raptors, were still being killed due to actual collisions with wind turbines. On several occasions, FWS expressed concern about these mortalities to wind power companies and Alameda County—the county government with the most wind power development in California. In response, Alameda County and some wind power companies have conducted avian monitoring studies and tested several mitigation

[23] Of all the species that have been killed, only two endangered species kills have been documented—a peregrine falcon in 1996 and a brown pelican in 2002.

measures, including painting turbine blades, installing perch guards on lattice-work towers, and conducting rodent control. However, these actions appear to have no significant impact on reducing avian mortality. Since January 2004, the wind power companies have worked together to develop an adaptive management plan for reducing avian mortality at Altamont Pass. The plan contains various mitigation measures, such as (1) removing old turbines and replacing them with fewer, new turbines and (2) implementing a partial seasonal shutdown of turbines.

Over the past 6 years, FWS has referred about 50 instances of golden eagles killed by 30 different companies in Altamont Pass either to the Interior Solicitor's office for civil prosecution or to the Department of Justice for criminal prosecution. Officials noted that, in general, prosecutions by both the Departments of the Interior and Justice focus on companies that kill birds with disregard for their actions and the law, especially when conservation measures are available but have not been implemented. Despite the recurring nature of the avian mortality in Altamont Pass and concerns from federal, state, and local officials, no prosecutions pursuant to federal wildlife laws have been taken against any wind power companies. Justice has not pursued prosecution in these cases, although they currently have an open investigation on avian mortality in Altamont Pass. As a matter of policy, Justice does not discuss the reasons behind specific case declinations, nor does it typically confirm or deny the existence of potential or actual investigations. However, Justice officials told us that, in general, when deciding to prosecute a case criminally, they consider a number of factors, including the history of civil or administrative enforcement, the evidence of criminal intent, and what steps have been taken to avoid future violations. Regarding the matters that FWS referred for civil enforcement, Interior's regional solicitor has also not pursued prosecution in any of these cases. Interior's Office of the Solicitor San Francisco field office declined to pursue the most recent civil referrals because Justice agreed to review turbine mortalities for possible criminal prosecution. Some citizen groups remain concerned about the lack of enforcement of federal and state wildlife protections. For example, in November 2004, the Center for Biological Diversity filed a lawsuit against the wind power companies in Altamont Pass to seek restitution for the killing of raptors.[24]

[24] *Center for Biological Diversity v. FPL Group*, No. RG04183113 (Calif. Super. Ct., Alameda County, filed Nov. 1, 2004).

In addition to the avian mortalities at Altamont Pass, significant wildlife mortality has also occurred at wind power locations in the Appalachian Mountains in West Virginia and Pennsylvania in 2003 and 2004. FWS has reviewed high numbers of bat kills; however, these bat species are not protected under federal law. Several studies have been completed or are under way in these regions to better determine the potential causes of the mortality events and how future events might be mitigated. The FWS law enforcement agent-in-charge in West Virginia told us that he has contacted wind power developers of some of the proposed facilities in the state about potential violations of federal wildlife laws should an endangered bat or other protected species be killed. The agent said that he prefers to have early involvement with wind power facilities, rather than wait for violations to occur.

FWS law enforcement officials told us that the way they have handled avian mortalities at wind power facilities is similar to how they deal with wildlife mortality caused by other industries. These officials explained that FWS recognizes that man-made structures will generally result in some level of unavoidable incidental take of wildlife and, as a result, FWS reserves a level of "enforcement discretion" in determining whether to pursue a violation of federal wildlife law. Law enforcement officials told us that before FWS pursues civil or criminal penalties, the agency prefers to work with a company to encourage them to take mitigation and conservation steps to avoid future harm. If a company shows a good-faith effort to reduce impacts, FWS will likely not refer such a case for prosecution. If, however, a company repeatedly refuses to take steps suggested by FWS, officials said they are likely to refer it for prosecution.

Work that FWS has done with the electric power industry illustrates this approach to resolving impacts to wildlife. FWS began working with the electric power industry in the early 1980s to reduce significant avian mortality due to collisions with and electrocutions at power lines, particularly mortality events involving eagles and other large birds. Pursuant to investigations of avian mortality at power lines and conversations with individual companies, solutions were identified that reduced mortality events. Because these solutions were relatively inexpensive and generally easy to install based on scientific testing—and were known to work—FWS law enforcement officials expected other electric line companies to install them. According to law enforcement officials, the threat of a potential conviction under the Migratory Bird Treaty Act or the Bald and Golden Eagle Protection Act was generally enough to get companies to voluntarily install the fixes without FWS prosecuting them. However, by the late 1980s, some electric companies were aware of mortalities due to electrocutions but were not taking actions to resolve the causes. The federal government in 1998 charged an electric utility cooperative—the Moon Lake Electric Association in Colorado and Utah—with criminal violations of these two laws. This is the first and only instance of a federal criminal prosecution of an electric power line company under any of the three federal wildlife protection laws. Civil cases have been filed and out-of-court agreements have been reached with other electric utilities for similar cases of wildlife mortalities.

FWS Has Taken Some Proactive Steps to Help Minimize the Impacts of Wind Power on Wildlife

Even though FWS does generally not have a direct role in determining whether and how wind power facilities are permitted, FWS has been involved for about 20 years with the wind power industry to help avoid and minimize impacts to wildlife from wind power development. FWS's work has been in the following three main areas—participating on a national wind working group and in technical workshops, and issuing guidance.

Working Group

An FWS senior management official has been a member of the National Wind Coordinating Committee since 1997. The wildlife workgroup serves as an advisory group for national research on wind-avian issues and a forum for defining, discussing, and addressing wind power-wildlife interaction issues. The workgroup has facilitated five national avian-wind power planning workshops to define needed research and explore current issues. The most recent workshop also included discussions of bat-wind turbine interactions. In addition, the working group released a report in December 1999, *Studying Wind Energy/Bird Interaction: A Guidance Document*, that includes metrics and methods for determining or monitoring potential impacts on birds at existing and proposed wind energy sites.

Workshops

FWS officials have participated in industry sponsored workshops and conferences. For example, a senior FWS official presented information on cumulative impacts on wildlife from wind power at a 2004 workshop cosponsored by the American Wind Energy Association and the American Bird Conservancy. Another FWS official presented information on the agency's experience and expectations for regional wildlife issues at a national workshop on wind power siting sponsored by the wind association. FWS also helped to sponsor and organize, and participated in, a 2004 bats and wind power technical workshop attended by both wind industry representatives and researchers. As a result, FWS was instrumental in establishing the Bats and Wind Energy Cooperative discussed elsewhere in the report.

Guidance

In July 2003, in an effort to inform wind power developers about the potential impacts to wildlife and encourage them to take mitigating actions before construction, FWS issued interim voluntary guidelines for industry to use in developing new projects. FWS developed the interim guidelines in response to the Department of the Interior's push to expand renewable energy development on public lands. The wind power interim guidelines are intended to assist FWS staff in providing technical assistance to the wind energy industry to avoid or minimize impacts to wildlife and their habitats through (1) proper evaluation of potential wind energy development sites, (2) proper location and design of turbines, and (3) pre- and postconstruction research and monitoring to identify and assess impacts to wildlife. The voluntary guidelines were open for public comment for a 2-year period that ended on July 10, 2005. At the time of this report, FWS had received numerous comments from the wind industry on the guidelines. In general, industry representatives thought that the guidelines were overly restrictive—to a degree not supported by the relative risk that wind power development poses to wildlife compared with other sources of mortality. FWS also had received comments from other groups—such as the Ripley Hawk Watch, the Clean Energy States Alliance, the Humane Society of the United States, the Massachusetts and Pennsylvania Audubon, the American Bird Conservancy, Defenders of Wildlife, and Chautauqua County Environmental Management Council—that were generally in support of the guidance or recommended that it be put into regulation. BLM also provided comments and expressed some concerns over the review process outlined in the guidelines. FWS will be reviewing and incorporating the public, industry, and agency comments received on the interim guidelines as appropriate in order to revise and improve them, and will solicit additional public input before disseminating a final version.

In addition, FWS recently began developing a template for a letter to be sent to wind power project applicants to alert them to federal wildlife protection laws, FWS's interim guidance, and FWS's role in protecting wildlife. FWS officials told us that they hope the letter will assist developers in making informed decisions regarding site selection, project design, and compliance with applicable laws. The availability of a ready-to-use template is important because most field officials told us that working with the wind power industry is just one of many responsibilities in FWS offices that often do not have enough staff, given their workloads.

Field officials also noted that if wind power developers, their consultants, or state or local regulatory agencies do not contact them, they may not know about wind power projects until there is a problem with an operating facility.

All Six States We Reviewed Have Wildlife Protections

Although federal jurisdiction for migratory birds has not been delegated to the states and primary responsibility for the protection of these birds resides with Interior, all states we reviewed had additional wildlife protections. Responsibility for protecting species and implementing wildlife laws and regulations is typically found in a state's natural resource protection agency. In some states, however, responsibility is assigned according to the type of species addressed. For example, in some states, agriculture departments address plant issues, while in other states, fish and boat commissions address fish, amphibian, and reptile issues; in these cases, wildlife agencies typically address the remaining species.

In all six states, the most common laws related to wildlife protection—and likely the most utilized wildlife laws—are those that govern hunting and fishing. These laws and regulations may include limits on the type and number of species that can be killed and the manner in which they can be taken. In addition to identifying the species that can be hunted or fished, the six states we reviewed identify as threatened or endangered specific species that are at risk for extinction or extirpation in their state. These states also identify "species of concern" or rare species. Such species are identified as a way to provide an early warning signal for species that are not yet endangered or threatened, but could become so in the future.

All of the six states we reviewed have laws that provide at least some degree of protection for species that are at risk of extinction or extirpation in their state. These protections generally go beyond what the federal Endangered Species Act provides by protecting more species than are protected under the federal law, although the protections may not be as extensive. In the five states that have specific protections, protection is provided through prohibitions on taking a protected species. In some cases, these protections are only applicable under certain circumstances. For example, in Oregon, protections apply only to state actions or on state-owned or -managed lands. All of the state laws or regulations that include take prohibitions, also include exceptions for when permits can be issued in order to allow the take to occur. Such permits are issued according to prescribed conditions or on a case-by-case basis. Two of the six states also provide protections for habitat. In West Virginia, the primary protection for wildlife, aside from hunting and fishing regulations, is a prohibition on the commercial sale of wildlife and specific protection for bald and golden eagles.

Most of the states' wildlife protection laws for threatened and endangered species include enforcement provisions. In some cases, these laws identify violations as misdemeanor crimes. Similar to FWS law enforcement's approach to wind power, we found that state agencies had not taken any prosecutorial actions in response to wildlife mortalities at wind power facilities. Instead, many state officials told us that they prefer—like FWS—to work with developers to try to identify solutions to the causes of mortality. For example, in Minnesota, after impacts to native prairie grass caused by a wind power facility were discovered, the state natural resource agency required the facility to purchase additional habitat elsewhere to compensate for the loss. In California, Alameda County has worked with wind power facilities and others, and recently approved a plan that is aimed at reducing bird deaths at Altamont Pass by having wind power companies turn off selected turbines at certain times and replace some turbines with newer turbines.

State natural heritage programs serve as key sources of information on wildlife for federal and state wildlife protection agencies. All six of the states we reviewed have natural heritage programs that manage information on natural resources, including threatened and endangered species (all 50 states have such programs). These programs are part of an international effort to gather and share information on biological resources. This effort has slightly different designations and criteria for identifying imperiled species and habitat than the federal Endangered Species Act. In five of the states we reviewed, the natural heritage program is run by the states' natural resource agencies; in the sixth state, Oregon, it is run by a university. Although West Virginia does not have a state endangered species law and protects only bald and golden eagles, it does identify other imperiled species through its natural heritage program.

State natural resource agencies—which typically house the natural heritage programs—are sometimes consulted by a state or local wind power regulator or a wind power developer during the permitting process for help in identifying potentially sensitive species or concerns about possible impacts to wildlife in general. For example, staff from West Virginia's natural resources agency were involved in reviewing wildlife monitoring studies conducted by the first wind power facility in the state. During the consultation process on another proposed facility in the state, agency staff requested that certain studies be conducted because of concerns about impacts on bat populations. Similarly, in Minnesota, natural resource agency staff requested changes in the location, construction, and operation of certain proposed wind power turbines through the state's environmental review process. However, in some cases, the process for regulators or wind power developers to consult with natural resource agency staff on wildlife is often an informal one and is not necessarily required by states' species protections or laws and regulations used to permit wind power.

Conclusions

In the context of other sources of avian mortalities, it does not appear that wind power is responsible for a significant number of bird deaths. While we do not know a lot about the relative impacts of bat mortality from wind power relative to other sources, significant bat mortality from wind power has occurred in Appalachia. However, much work remains before scientists have a clear understanding of the true impacts to wildlife from wind power. Scientists, in particular, are concerned about the potential cumulative impacts of wind power on species populations if the industry expands as expected. Such concerns may be well founded because significant development is proposed in areas that contain large numbers of species or are believed to be migratory flyways. Concerns are compounded by the fact that the regulation of wind power varies from location-to-location and some state and local regulatory agencies we reviewed generally had little experience or expertise in addressing the environmental and wildlife impacts from wind power. In addition, given the relatively narrow regulatory scope of state and local agencies, it appears that when new wind power facilities are permitted, no one is considering the impacts of wind power on a regional or "ecosystem" scale—a scale that often spans governmental jurisdictions. FWS, in its responsibility for protecting wildlife, is the appropriate agency for such a task and in fact does monitor the status of species populations, to the extent possible. However, because wildlife, federally protected birds in particular, face a multitude of threats, many of which are better understood than wind power, FWS officials told us that they generally spend a very small portion of their time assessing the impacts from wind power. Nonetheless, FWS has taken some steps to reach out to the wind power industry by, among other things, issuing voluntary guidelines to encourage conservation and mitigation actions at new wind power facilities. In addition, FWS and the U.S. Geological Survey are initiating some studies to capture data on migratory flyways to help determine where the most potential harm from wind power might occur and to gather data for use in assessing wind power's cumulative impacts on species. Although these are valuable steps in educating industry and improving science, FWS has conducted only limited outreach to state and local regulators about minimizing impacts from wind power on wildlife and informing them about species that may be particularly vulnerable to impacts from wind power. Such outreach is important because these are the entities closest to the day-to-day decisions regarding where wind power will be allowed on nonfederal land.

Recommendations for Executive Action

Given the potential for future cumulative impacts to wildlife species due to wind power and the limited expertise or experience that local and state regulators may have in this area, we recommend that the Secretary of the Interior direct the Director of the FWS to develop consistent communication for state and local wind power regulators. This communication should alert regulators to (1) the potential wildlife impacts that can result from wind power development; (2) the various resources that are available to help them make decisions about permitting such facilities, including FWS state offices, states' natural resource agencies, and FWS's voluntary interim guidelines--and any subsequent revisions—on avoiding and minimizing wildlife impacts from wind turbines; and (3) any additional information that FWS deems appropriate.

Agency Comments and Our Evaluation

We provided copies of our draft report to the Department of the Interior and received written comments. (See app. III for the full text of the comments received and our responses.) Interior officials stated that they generally agree with our findings and our recommendation in the report. We also sent portions of the report to state and local regulators and state wildlife protection agencies. Many of these entities provided technical comments, which we incorporated as appropriate. Interior also provided technical comments, which we incorporated where appropriate.

Interior officials agreed in most part with our recommendation to develop consistent communication to deliver to state and local wind power regulators. However, they stated that because the comment period on the FWS voluntary interim guidelines has closed and final guidelines have yet to be developed, it would be inappropriate to include these in such communication. However, because FWS is currently disseminating the voluntary interim guidelines on wind power to its field offices to share with regulators and developers, we believe that it is appropriate to include reference to this document in communications to local and state regulators. As Interior noted, these voluntary guidelines are currently undergoing review and revision. Therefore, it would be appropriate to draw attention to this fact in any such communication and to provide information about how the most current version might be accessed.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies of this report to the Secretary of the Interior, as well as to appropriate congressional committees and other interested Members of Congress. We also will make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staffs have questions about this report, please contact me at (202) 512-3841. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix IV.

Robin M. Nazzaro

Robin M. Nazzaro
Director, Natural Resources
and Environment

Objectives, Scope, and Methodology

On the basis of a June 22, 2004, request from the Ranking Democratic Members—House Resources Committee and the House Appropriations Subcommittee on Science, the Departments of State, Justice, and Commerce and Related Agencies—and of subsequent discussions with their staffs, we reviewed wind energy development and impacts on wildlife. Specifically, we assessed (1) what available studies and experts have reported about the impacts of wind power facilities on wildlife in the United States and what can be done to mitigate or prevent such impacts, (2) the roles and responsibilities of government agencies in regulating wind power facilities, and (3) the roles and responsibilities of government agencies in protecting wildlife from the risks posed by wind power facilities.

To determine what available studies and experts have reported about the direct impacts of wind power facilities on wildlife, we reviewed scientific studies and reports on the subject that were conducted by government agencies, industry, and academics. Our review focused on wildlife mortality as opposed to indirect impacts, which include habitat modification and disruption of feeding or breeding behaviors due to wind power facilities. We used several criteria to select studies for review. We chose studies that included original data analyses (rather than summaries of existing literature) conducted in the United States since 1990, and we primarily focused on the impact of wind power on birds and bats and/or ways in which to mitigate those impacts. We did not include preconstruction assessments of wildlife impacts in our review. We excluded studies that had preliminary findings when there was a more recent version available. We located studies using a database search with keywords of "wind power" and "birds," "bats," or "wildlife" in the following databases: AGRICOLA, DOE Information Bridge, National Environmental Publications Information, Energy Citations Database, Energy Research Abstracts, Environmental Sciences and Pollution Management, and JSTOR. In addition, we located studies using bibliographies of other studies and through publicly available lists of studies from the National Wind Coordinating Committee, the California Energy Commission, the National Renewable Energy Laboratory, and Bat Conservation International. We shared our list of studies with experts and asked them to identify any studies missing from our list. When studies were not publicly available, we contacted the authors and attempted to obtain copies. Using these methods and criteria, we obtained 31 studies. We reviewed the studies' methodology, assumptions, limitations, and conclusions for the purposes of excluding studies that did not ensure a minimal level of methodological rigor.[2] We excluded 1 study, leaving 30 studies that are used in this work. In addition to these studies, we also reviewed two summaries of studies produced by the National Wind Coordinating Committee. Generally, we did not directly use these two summary studies, we did use them as a check for our conclusions and findings in relation to the studies we reviewed.[3] We also interviewed experts and study authors from the Department of the Interior's U.S. Fish and Wildlife Service (FWS), state government agencies, academia, wind industry, and conservation groups and obtained their views on the risks of wind power facilities to migratory birds and other wildlife and on ways in which to minimize these risks.

To determine the roles and responsibilities of government agencies in regulating wind power facilities, we identified and evaluated relevant federal laws and regulations for wind power development. We reviewed a nonprobability sample of six states with wind power development: California, Minnesota, New York, Oregon, Pennsylvania, and West Virginia. We selected these states to reflect a range in installed capacity, different regulatory processes, a history of wind power development, and geographic distribution and to reflect our requesters' interests. For these states, we identified and evaluated relevant state and local laws and regulations for wind power development. We interviewed federal officials from FWS, Bureau of Land Management, and Interior's Office of the Solicitor as well as officials from the Department of Justice. We interviewed officials from FWS headquarters and from field office locations in the six states that we selected. We also interviewed officials from various state agencies, such as the Oregon State Siting Council and the West Virginia Public Service Commission, and from local and county governments that were responsible for issuing permits or certificates for the development of wind power facilities in their states. Finally, we visited wind power facilities in California, New York, Oregon, Pennsylvania, and West Virginia and interviewed wind industry company officials.

To determine the roles and responsibilities of government agencies in protecting wildlife from the risks posed by wind power facilities, we identified and evaluated relevant federal, environmental, and wildlife

[2]Many of these studies have not been scientifically peer-reviewed, and the protocols in each study may vary.

[3]We referenced one of these studies in two places in this report. In each of these places, a source and associated caveat are presented in a footnote.

protection laws and regulations. We interviewed FWS law enforcement officials from headquarters and the six states that we reviewed. For the six states that we selected, we identified and evaluated relevant state and local environmental and wildlife protection laws. We also interviewed officials from state environmental and wildlife agencies in California, Minnesota, New York, Oregon, Pennsylvania, and West Virginia.

We conducted our work between December 2004 and July 2005 in accordance with generally accepted government auditing standards, including an assessment of data reliability and internal controls.

Studies of Bird, Bat, and Raptor Fatality Rates, by Region

Table 3 includes only studies where calculating bird or bat mortality was a primary goal. Some studies may contain more than one study location.

Table 3: Studies of Bird, Bat, and Raptor Fatality Rates, by Region

Region	Location and year	Number of turbines	Fatalities per turbine, per year: Birds	Bats	Raptors
Pacific NW	Stateline, OR - 2003	181	1.93	1.12	0.06
	Nine Canyon, OR - 2003	37	3.59	3.21	0.07
	Klondike, OR - Phase I - 2003	16	1.16[a]	1.16	0
	Vansycle, OR - 2000	38	0.63	0.74	0
West	Foote Creek Rim, WY - 2003	69	1.5	1.34	0.03
	National Wind Tech Center, CO - 2003	Varies	0	0	0
California	Altamont Pass, CA - (Thelander et al) - 2003	5,400	0.19[c]	***	***
	Altamont Pass, CA - (CEC) - 2004	5,400	0.87	0.004	0.24
	Altamont Pass and Solano County, CA - 1992	7,340	***	***	0.058 (1989) 0.025 (1990)
	Altamont Pass, CA - 1991	3,000	***	***	0.047[b]
	Montezuma Hills, CA - 1992	600	0.074[b]	***	0.047[b]
Midwest	Buffalo Ridge, MN - P1 - 2000	73	0.98	0.26	***
	Buffalo Ridge, MN - P2 - 2000	143	2.27	1.78	***
	Buffalo Ridge, MN - P3 - 2000	138	4.45	2.04	***
	Buffalo Ridge, MN - (Osborn et al) - 2000	73	0.33-0.66	***	***
	Buffalo Ridge, MN - (Bols) - 2004	281	***	2.02 (2001) 1.3 (2002)	***
	Northeastern, WI - 2002	31	1.29	4.26	0
	Top of Iowa - 2004	69	0.12[c]	1.88[f]	***
Northeast	Searsburg, VT - 2002	11	0	***	0
Appalachian Mt. Region	Mountaineer, WV - 2004	44	4.04[e]	47.53[d]	***
	Tennessee - 2005	3	7.28	20.8	***
	Mountaineer, WV - 2005	44	***	38.0[e]	***
	Meyersdale, PA - 2005	20	***	23.0[e]	***

Source: GAO analysis of various scientific studies and reports.

Notes:

*** indicates that the study authors did not calculate a mortality rate for that category.

Some of the studies that presented a bird/turbine/year mortality rate also included raptors in that calculation. With the exception of the studies conducted in the Appalachian region, most of the studies listed were designed and timed to focus on bird mortality. Bats were found only incidentally in the study objectives; therefore, rates of bat mortality reported from those studies may not represent a reliable measure.

Fatality rate applies to small birds only.

Fatality rate not adjusted for both searcher efficiency and scavenging rate.

Fatality rate represents number of birds and bats killed per turbine per 8-month study period.

Fatality rate represents number of bats killed per turbine per 7-month study period.

Fatality rate represents number of birds and bats killed per turbine per 6-week study period; however, bat mortality has been shown to be concentrated in the season during which these study periods took place.

Comments from the Department of the Interior

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

United States Department of the Interior

OFFICE OF THE ASSISTANT SECRETARY
POLICY, MANAGEMENT AND BUDGET
Washington, DC 20240

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SEP - 2 2005

Ms. Robin Nazzaro
Director, Natural Resources and the Environment
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Ms. Nazzaro:

Thank you for providing the Department of the Interior (Department) the opportunity to review and comment on the draft U.S. Government Accountability Office (GAO) report entitled, "Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife," GAO-05-906, dated July 28, 2005. In general, we agree with the findings and concur in part with the recommendation in the report.

See comment 1.

A number of the studies used by GAO in the report, investigating direct mortality impacts on migratory birds and bats, were conducted by consultants for companies developing the wind energy facilities being studied. These studies have not been scientifically peer-reviewed, and the protocols used have varied and are in some cases unknown. We believe that use of literature that has not been peer-reviewed should be noted in the report.

See comment 2.

We believe that the report accurately describes the Office of Law Enforcement (OLE) U.S. Fish and Wildlife Service (FWS), approach to addressing the impact of wind power facilities on protected wildlife. We would stress, however, that OLE has investigated and continues to investigate "take" of Federal trust species by wind turbines. Companies that violate the Migratory Bird Treaty Act (MBTA) by killing birds face fines of up to $15,000.00 and/or imprisonment for up to six months. Higher penalties can be involved if the birds killed are bald or golden eagles or a species protected under the Endangered Species Act (ESA). Prosecutions by OLE and the Department Justice (DOJ) focus on companies that kill birds with disregard for their actions and the law, especially when conservation measures are available but have not been implemented. At this time, there have been no prosecutions of any wind energy development company for violations involving "take" of these species. The OLE protects migratory birds not only through investigating violations of the MBTA, but also by fostering relationships with individuals, companies, and industries that seek to eliminate impacts on these species. The OLE recognizes that some birds may be killed even if all reasonable measures to prevent such deaths are taken; however, it is important that industries continue to work toward eliminating these losses of migratory birds. While it is not possible under the MBTA to absolve individuals, companies, or agencies from liability if they follow recommended conservation practices, the

Ms. Robin Nazzaro 2

OLE and DOJ have used enforcement and prosecutorial discretion in the past toward those who have made good faith efforts to avoid the take of migratory birds. These efforts are exemplified by the 25 years of work in collaboration with the electric power industry to identify ways to prevent bird electrocutions and power line collisions.

The FWS's effort to assist in proper location and design of wind energy facilities through the voluntary Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines, released for public review and comment in July 2003, is adequately described in the report. The FWS stressed that the guidelines were interim in nature pending public review and comment, were voluntary, flexible, and were not intended to be used as a set of rigid requirements that should be applied in every situation. There has been some concern that local and State regulatory agencies were using the voluntary guidelines as regulatory requirements in their local permitting processes, creating unreasonable demands on developers. Several interested parties have requested that the Interim Guidelines be rescinded for this reason. GAO informed the FWS during the review that it had investigated these allegations during the development of the current report, and found no evidence of any local or State regulatory entity using the Interim Guidelines as regulation. We recommend that this finding be included in the report. We believe this would help to dispel the perception that inappropriate use of the voluntary Interim Guidelines has had a negative effect on the wind industry.

See comment 3.

The State-by-State-review of laws and regulations regarding wind power development is fairly complete for the States visited by GAO. However, we believe the report could better synthesize how well the various local controls provide for consistent treatment and protection of individual animals and species that are interjurisdictional in their life cycles and are protected under Federal law. The report would also benefit from a discussion of the difficulties deriving from inconsistencies in regulatory requirements and frameworks that now exist among States. We believe the report should address that the responsibility for the protection of migratory birds continues to reside with the Federal Government (DOI), even though State and local laws and regulations have also been established for the protection of migratory birds. It should also be clarified that Federal jurisdiction for migratory birds has not been delegated to the States.

See comment 4.

We concur with the recommendation that the FWS should develop consistent communication to deliver to State and local wind power regulators alerting them to potential wildlife impacts and to the resources that are available to assist them in decision-making. However, it would be inappropriate to include the FWS voluntary Interim Guidelines in such communication, as the comment period on the interim guidelines has closed and final guidelines have not yet been developed. The FWS will be reviewing and considering the public, industry, and agency comments received on the interim guidelines, and will solicit additional public input before making a decision on whether or how to finalize them.

Ms. Robin Nazzaro 3

The enclosure provides comments from the U.S. Fish and Wildlife Service and Bureau of Land Management. We hope these comments will assist you in preparing the final report.

Sincerely,

P. Lynn Scarlett
Assistant Secretary
Policy, Management and Budget

Enclosure

The following are GAO's comments on the Department of the Interior's letter dated September 2, 2005.

GAO Comments

The Department of the Interior raised one issue with our recommendation that we have addressed in the Agency Comment and Our Evaluation section in the report. We address below the four other points the department raised in its letter. In addition, the department provided technical comments that we have incorporated into the report, as appropriate.

1. We agree that it is important to point out that many of these studies were not scientifically peer-reviewed and have added a footnote to this effect in the body of the report. However, we disagree that in some cases protocols used in the studies were unknown. As we explain in appendix I, we only included studies that were determined to have reasonably sound methodologies. We did not include any study for which we were unable to assess the protocols or methodology.

2. We believe the section on law enforcement reflects continued investigation of "take" of federal trust species by wind turbines and FWS's and the Department of Justice's enforcement and prosecutorial discretion, although we have added some clarification on these points.

3. We did not find any instances where state or local agencies that regulate wind power included in our review had incorporated or adopted the interim guidelines into their own jurisdictional requirements for approving wind power facilities. We did, however, find agencies in two states that had used the guidelines to inform either their development of regulations or their monitoring of the wildlife impacts at operating wind power facilities.

4. We did not assess how various local controls provide for protection of individual animals that are interjurisdictional in their life cycles. The section of the report that pertains to state wildlife laws is descriptive in nature and serves to highlight the fact that state laws sometimes provide additional protections to species, beyond federal laws, that may be affected by wind power. We added language to highlight that federal jurisdiction for migratory birds has not been delegated to the states, and that primary responsibility for the protection of these birds resides with the federal government (Interior).

GAO Contact and Staff Acknowledgments

GAO Contact

Robin Nazzaro (202) 512-3841

Staff Acknowledgments

In addition to the individual named above, Patricia McClure, Assistant Director; José Alfredo Gómez; Kimberly Siegal; and William Roach made key contributions to this report. Important contributions were also made by Judy Pagano, John Delicath, and Omari Norman.

Bibliography

Anderson, R., N. Neumann, J. Tom, W. P. Erickson, M. D. Strickland, M. Bourassa, K. J. Bay, and K. J. Sernka. *Avian Monitoring and Risk Assessment at the Tehachapi Pass Wind Resource Area, Period of Performance: October 2, 1996 – May 27, 1998*. NREL/SR-500-36416. September 2004.

Arnett, E. B., technical editor. *Relationships Between Bats and Wind Turbines in Pennsylvania and West Virginia: An Assessment of Bat Fatality Search Protocols, Patterns of Fatality, and Behavioral Interactions with Wind Turbines*. A Final Report Submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA. 2005.

Dooling, R. *Avian Hearing and the Avoidance of Wind Turbines*. NREL/TP-500-30844. June 2002.

Erickson, W. P., B. Gritski, and K. Kronner. *Nine Canyon Wind Power Project Avian and Bat Monitoring Report, September 2002 – August 2003*. Technical report submitted to Energy Northwest and the Nine Canyon Technical Advisory Committee. October 2003.

Erickson, W. P., J. Jeffrey, K. Kronner, and K. Bay. *Stateline Wind Project Wildlife Monitoring Final Report, July 2001 – December 2003*. Technical report peer-reviewed by and submitted to FPL Energy, the Oregon Energy Facility Siting Council, and the Stateline Technical Advisory Committee. December 2004.

Erickson, W. P., G. D. Johnson, M. D. Strickland, and K. Kronner. *Avian and Bat Mortality Associated with the Vansycle Wind Project, Umatilla County, Oregon 1999 Study Year: Final Report*. Prepared for Umatilla County Department of Resource Services and Development. February 7, 2000.

Hodos, W. *Minimization of Motion Smear: Reducing Avian Collisions with Wind Turbines Period of Performance: July 12, 1999 – August 31, 2002*. NREL/SR-500-33249. August 2003.

Hoover, S. *The Response of Red-Tailed Hawks and Golden Eagles to Topographical Features, Weather, and Abundance of a Dominant Prey Species at the Altamont Pass Wind Resource Area, California: April 1999 – December 2000*. NREL/SR-500-30868. June 2002.

Howe, R. W., W. Evans, and A. T. Wolf. *Effects of Wind Turbines on Birds and Bats in Northeastern Wisconsin.* Report submitted to Wisconsin Public Service Corporation and Madison Gas and Electric Company. November 21, 2002.

Howell, J. A., and J. DiDonato. *Assessment of Avian Use and Mortality Related to Wind Turbine Operations Altamont Pass, Alameda and Contra Costa Counties, California; September 1988 Through August 1989: Final Report.* November 7, 1991.

Howell, J. A., and J. Noone. *Examination of Avian Use and Mortality at a U.S. Windpower, Wind Energy Development Site Montezuma Hills, Solano County, California: Final Report.* September 10, 1992.

Howell. J. A. *Bird Mortality at Rotor Swept Area Equivalents, Altamont Pass and Montezuma Hills California.* Transactions of the Western Section of the Wildlife Society. 33: 24-29. 1997.

Hunt, W. G., R. E. Jackman, T. L. Hunt, D.E. Driscoll, and L. Culp. *A Population Study of Golden Eagles in the Altamont Pass Wind Resource Area: Population and Trend Analysis 1997.* Report to the National Renewable Energy Laboratory, Subcontract XAT-6-16459-01. Predatory Research Group, University of California, Santa Cruz. 1998.

Johnson, G., W. Erickson, J. White, and R. McKinney. *Avian and Bat Mortality During the First Year of Operation at the Klondike Phase I Wind Project, Sherman County, Oregon.* Prepared for Northwestern Wind Power. March 2003.

Johnson, G. D., W. P. Erickson, M. D. Strickland, M. F. Shepherd, and D.A. Shepherd. *Avian Monitoring Studies at the Buffalo Ridge, Minnesota Wind Resource Area: Results of a 4-Year Study.* Prepared for Northern States Power Company. September 22, 2000.

Johnson, G. D., M. K. Perlik, W. P. Erickson, and M. D. Strickland. *Bat Activity, Composition, and Collision Mortality at a Large Wind Plant in Minnesota.* Wildlife Society Bulletin 32(4):1278-1288. 2004.

Kerlinger, P. *An Assessment of the Impacts of Green Mountain Power Corporation's Wind Power Facility on Breeding and Migratory Birds in Searsburg, Vermont July 1996 – July 1998.* Prepared for the Vermont Department of Public Service. March 2002.

Kerns, J., and P. Kerlinger. *A Study of Bird and Bat Collision Fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003*. Prepared for FPL Energy and Wind Energy Center Technical Review Committee. February 14, 2004.

Koford, R., A. Jain, G. Zenner, and A. Hancock. *Avian Mortality Associated with the Top of Iowa Wind Farm: Progress Report Calendar Year 2003*. February 28, 2004.

National Wind Coordinating Committee. *Wind Turbine Interactions with Birds and Bats: A Summary of Research Results and Remaining Questions*. Fact Sheet: Second Edition. November 2004.

Nicholson, C. P., R. D. Tankersley, Jr., J. K. Fiedler, and N. S. Nicholas. *Assessment and Prediction of Bird and Bat Mortality at Wind Energy Facilities in the Southeastern United States*. Prepared for the Tennessee Valley Authority. 2005.

Orloff, S., and A. Flannery. *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas 1989-1991: Final Report*. Prepared for Planning Departments of Alameda, Contra Costa, and Solano Counties and the California Energy Commission Grant #990-89-003. March 1992.

Orloff, S., and A. Flannery. *A Continued Examination of Avian Mortality in the Altamont Pass Wind Resource Area*. Prepared for the California Energy Commission. January 1996.

Osborn, R. G., K. F. Higgins, C. D. Dieter, and R. E. Usgaard. *Bat Collisions with Wind Turbines in Southwestern Minnesota*. Bat Research News. Vol. 37, No. 4. Winter 1996.

Osborn, R. G., K. F. Higgins, R. E. Usgaard, C. D. Dieter, and R. D. Neiger. *Bird Mortality Associated with Wind Turbines at the Buffalo Ridge Wind Resource Area, Minnesota*. The American Midland Naturalist. 143:41-52.

Schmidt, E., A. J. Piaggio, C. E. Bock, and D. M. Armstrong. *National Wind Technology Center Site Environmental Assessment: Bird and Bat Use and Fatalities – Final Report, Period of Performance: April 23, 2001 – December 31, 2002*. NREL/SR-500-32981. January 2003.

Smallwood, K. S. and Thelander, C.G. *Developing Methods to Reduce Bird Mortality in the Altamont Pass Wind Resource Area.* Final Report by BioResource Consultants to the California Energy Commission, Public Interest Energy Research – Environmental Area. Contract No. 500-01 019; L. Spiegel, Program Manager. August 2004.

Smallwood, K. S., and L. Neher. *Repowering the APWRA: Forecasting and Minimizing Avian Mortality Without Significant Loss of Power Generation.* The California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-005. December 2004.

Thelander, C. G., K. S. Smallwood, and L. Rugge. *Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area, Period of Performance: March 1998 – December 2000.* NREL/SR-500 33829. December 2003.

Young Jr., D. P., W. P. Erickson, R. W. Good, M. D. Strickland, and G. D. Johnson. *Avian and Bat Mortality Associated with the Initial Phase of the Foote Creek Rim Windpower Project, Carbon County, Wyoming, November 1998 – June 2002.* Prepared for Pacificorp, Inc., SeaWest Windpower, Inc., and the Bureau of Land Management. January 10, 2003.

Young, Jr, D. P., W. P. Erickson, M. D. Strickland, R. E. Good, and K. J. Sernka. *Comparison of Avian Responses to UV Light-Reflective Paint on Wind Turbines: Subcontract Report July 1999-December 2000.* NREL/SR-500-32840. January 2003.

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Anne 153

From: "Calvin Luther Martin" <rushton@westelcom.com>
To: "Anne Britton" <WOW@westelcom.com>
Sent: Monday, December 12, 2005 11:35 AM
Subject: US Fish & Wildlife criticizes Chautauqua County ARA (Avian Risk Analysis)

... this might be worth adding to our Article 78 petitions, as evidence to the court.

Calvin

... see http://kirbymtn.blogspot.com/2005/12/chautauqua-wind-threat-to-birds-no.html
Eric Rosenbloom

Thursday, December 08, 2005

Chautauqua wind: threat to birds, no benefits

The New York Field Office of the U.S. Fish and Wildlife Service reviewed the avian risk assessment (ARA) produced for a wind project in Chautauqua County. It is withering in its criticism of the ARA's assumptions, methods, and conclusions. A PDF (13 MB) of the document is available at Chautauqua Wind Power. It also takes issue with the claimed benefits.

> While electricity derived from "green" energy sources other than fossil fuels will reduce harmful emissions, the placement of wind turbines within an avian flyway certainly would not have greater environmental benefits to wildlife. ... The ARA authors argue that producing electricity from nonrenewable sources will have greater social, environmental, and economic impacts. However, there is no indication that the [Chautauqua Wind Project] will replace any other electricity source .... (pages 35-36)
>
> We agree that there are serious consequences associated with burning fossil fuels to generate electricity, and we support energy policies which promote renewable sources, such as wind and solar, to provide alternate forms of electricity. However, construction of wind energy facilities will not reduce air pollution emissions at existing power generation facilities. Coal, oil, and nuclear generating facilities must be kept in operation and online to provide the main source of electricity, especially when the wind resources are not turning the turbine blades. The intermittency of wind, coupled with the fact that the times of peak availability of wind resources in a given location may not coincide with the times of peak demand for electricity, makes wind energy less suitable from an energy standpoint. ... Due to the intermittent nature of wind-generated electricity, none of the existing coal, oil, or nuclear powered generation facilities will be shut down or run as reserve units. (page 36)
>
> New York State has pushed for reducing air pollution emissions at existing power plants ... Operating changes in these power plants will be more effective at reducing emissions than constructing thousands of wind turbines across the landscape. (page 37)

In other words, discussion of the shortcomings of other sources is irrelevant, as those sources will not be reduced by the construction of wind turbines. Only the shortcomings of wind power itself need be discussed. Because their contribution will be minimal (if measurable at all) any negative impact is reason to reject construction.

(Another analysis of the Chautauqua ARA was done by Mark Duchamp.)

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Migration Patterns & Routes of the Greater Snow Goose

Note: Clinton, Franklin and St. Lawrence counties are a significant part of this migration route

Compiled by

Gerald Duffy

Nina Pierpont, MD, PhD

Calvin Luther Martin, PhD

Habitat and habits

During its breeding season, from early June to early September, the Greater Snow Goose lives in the high arctic tundra near the coast or inland on rolling terrain or in low-lying wet meadows with many grasses and sedges. During the winter along the United States Atlantic coast, it frequents marine inlets and bays, marshes, coastal prairies, and cultivated fields

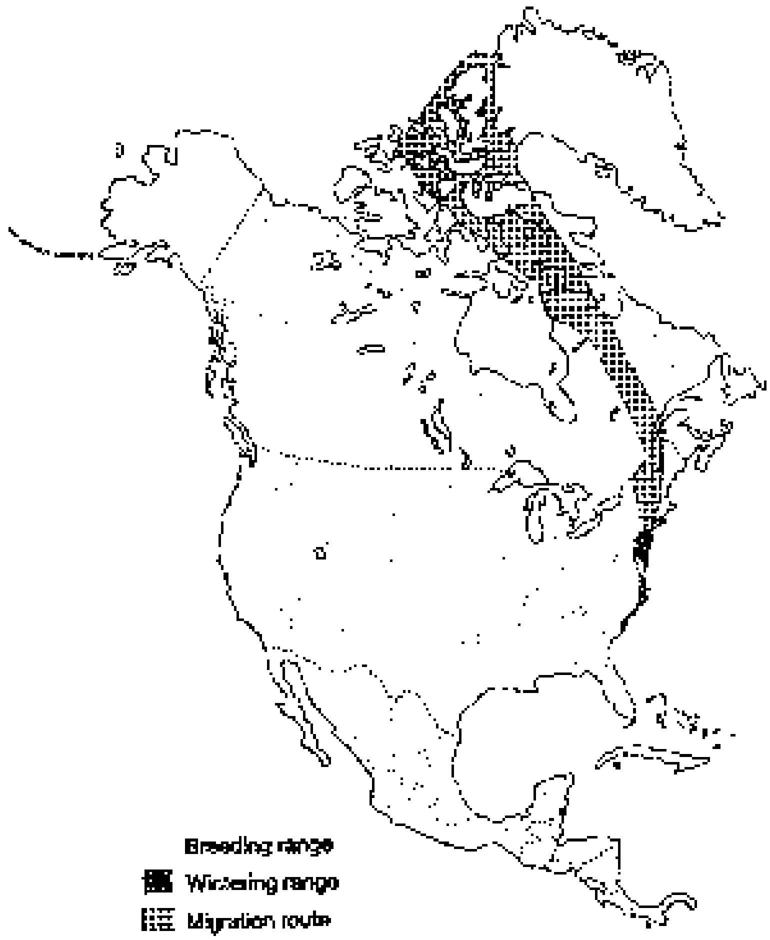
The Greater Snow Goose moves very well on land, on the water, and in the air. It is a good walker. On Bylot Island, Nunavut, the world's largest Greater Snow Goose breeding colony, the distance between the birds' nesting and breeding sites is more than 30 km. Within a day of hatching, many young geese set off on this trek with their families, reaching their destination within four days. As an adult, a Greater Snow Goose can outrun most predators when it is moulting and cannot fly. It swims well, and while it does not dive for food, it will dive short distances if it is threatened. As for flying, this goose usually travels at about 55 km/h, is capable of reaching speeds of up to 95 km/h, and can make long nonstop flights of up to 1 000 km.

Unique characteristics

The Greater Snow Goose is dimorphic, meaning that it appears in two forms. Most Greater Snow Geese are called light morphs: they are white. Some are called dark morphs, or blue, geese: most of their feathers are blue grey. The blue morph, which is quite common in Lesser Snow Geese, is rare in Greater Snow Geese: fewer than 4 percent of Greater Snow Geese are of this blue phase. Blue morph geese tend to mate with blues, and whites with whites.

❑ Back to top

Range



Distribution of the Greater Snow Goose

Only one population of Greater Snow Geese exists in the world. It is almost entirely confined to the Atlantic flyway of North America. Greater Snow Geese breed in the Canadian High Arctic, from the Foxe Basin to Alert on northern Ellesmere Island. Some breeding colonies can also be found on the western coast of Greenland. This makes the Greater Snow Goose one of the most northerly breeding geese in the world. It winters along the United States Atlantic coast, from New Jersey to South Carolina, with major concentrations around Delaware and Chesapeake bays.

Greater Snow Geese undertake longer migrations than most other North American geese: they usually travel more than 4 000 km. In spring and fall, they fly in flocks of families and individuals, travelling day and night. The spring flocks are smaller than the autumn ones: between 35 and 400 birds fly together in the spring, whereas more than 1 000 can travel together in the fall.

In Canada, the Greater Snow Goose migration follows a corridor between the eastern seaboard and the eastern Arctic. The spring migration begins in March, and the first geese arrive in the St. Lawrence River area by the first week of April; the last leave on the final stage of their northward journey by May 25. The entire population of 700 000 to 800 000 birds stages, or gathers, in a few localized areas, making their migration a most spectacular event. Striking concentrations of more than 500 000 Greater Snow Geese can be seen in early April at Baie-du-Febvre, on the south shore of Lac-Saint-Pierre, between Montréal and Trois-Rivières. Large groups of geese also gather at Cap Tourmente, Quebec, about 60 km east of Quebec City, from about April 25 to May 20.

In the fall, the birds leave the Arctic breeding grounds in early September, when the soil and freshwater ponds begin to freeze, journeying more than 1 000 km during the first segment of their odyssey. This takes them rapidly southward across Baffin Island to the central portion of the Ungava Peninsula in northern Quebec. There, they stage for several days, moving between many sites.

The second major part of the migration occurs when the birds are close to the tree line. Once again, they fly more than 1 000 km, following the boreal forest to the St. Lawrence River, where they arrive during the first half of October. About 80 percent of the geese stay there an average of 19 days—with the greatest concentrations from October 5 to 20—to replenish the energy reserves they need to continue their migration in early November to their wintering grounds in the United States

The geese that do not stop here fly directly to the United States Atlantic coast.

Since the 1970s, an important change has occurred in the way the Greater Snow Geese use the St. Lawrence staging area. The geese used to stage almost exclusively in the bulrush marshes near Quebec City before heading north in the spring, and flying non-stop to their wintering grounds in the fall. Now, in the spring, they gather at the Lac-Saint-Pierre and other sites, moving west to east along the St. Lawrence River, before they head north. In the fall, the birds disperse from the Quebec City area in late October and move a short distance southwest towards Lac-Saint-Pierre or northern Lake Champlain, where they feed in corn fields and where some remain well into November and December. Wildlife biologists have also noticed greater use of the more northerly Lac Saint-Jean area in Quebec since 1995

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Anne

From: "Calvin Luther Martin" <rushton@westelcom.com>
Sent: Sunday, November 27, 2005 6:22 PM
Attach: Greater Snow Geese 10-31-05 c.pdf
Subject: Migrating geese force energy firm to scrap plans for wind farm

... worthwhile article, below, from the United Kingdom on wind company scuttling plans for windfarm because of goose flyway -- which is exactly what we have here in the North Country, with Canada and Greater Snow Geese (see attached map).

Calvin
Calvin Luther Martin

---

http://news.scotsman.com/scotland.cfm?id=2300292005

Migrating geese force energy firm to scrap plans for wind farm

JOHN ROSS

A POWER company has dropped plans for a wind farm because of fears that geese could be killed by the turbines.

Perth-based Scottish & Southern Energy (SSE) wanted to build the 56-turbine, 116 megawatt development at Broubster Leans in Caithness, a site of European nature conservation importance.

However, a two-year bird study showed that the wind-farm site would be under the flight route of migrating Greenland white-fronted geese and greylag geese which roost in the area. SSE decided that a wind farm would pose a significant risk of collision for the birds and dropped the proposals.

Dr Brian Smith, SSE's head of projects, said: "The development of more wind farms in Scotland is vital if we are to maintain secure supplies of power and tackle the huge risks to our country posed by climate change. But each potential site must be considered on its merits and be the subject of detailed scrutiny.

"Our work has shown that a wind farm at Broubster would not be sufficiently compatible with other environmental concerns, and so we have decided not to progress this further."

Anne McCall, head of planning and development for the Royal Society for the Protection of Birds, said: "The development of sensibly located renewable energy developments is one important means of tackling climate change.

"That SSE has resolved not to develop on this environmentally sensitive site is enormously welcome and is an approach we commend to all those involved with the renewables industry."

About 14,000 Greenland white-fronted geese visit the UK each year with about 25 pairs stopping in Caithness.

A Scottish Natural Heritage report this week showed that geese are returning to winter in Scotland in some of the highest numbers recorded since their populations crashed in the early 20th century.

The report found that numbers of pink-footed geese, Greenland white-fronted geese, greylag geese and two types of barnacle goose have recovered significantly in recent decades.

Numbers of Greenland white-fronted geese in Scotland reached a peak of 21,164 in 1998-9 and, after a period of stability, is now showing signs of a decline to 17,500.

The population of Icelandic greylag geese peaked at 115,000 in 1990, followed by a decline to about 73,000 in 2002.

The report said goose populations remain extremely vulnerable to changing circumstances in their Arctic breeding grounds and their migration stopovers.

Related topic

- Alternative energy sources
  http://news.scotsman.com/topics.cfm?tid=605

This article: http://news.scotsman.com/scotland.cfm?id=2300292005

Last updated: 25-Nov-05 10:25 GMT

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Ecological Services
6669 Short Lane
Gloucester, VA 23061

September 28, 2005

Highland New Wind Development, LLC
c/o Henry T. McBride, Jr.
1583 Ridgedale Road
Harrisonburg, Virginia 22801

Re: Highland New Wind Development, LLC, Highland County, Virginia

Dear Mr. McBride:

As you are aware, the U.S. Fish and Wildlife Service (Service) provided comments to the United States Department of Agriculture (USDA) on the referenced project in letters dated October 14, 2003 and March 31, 2004. In our letter to you dated December 9, 2003 regarding timber cutting activities on your property in Highland County, the Service advised Highland New Wind Development , LLC (HNWD) of their responsibilities under Section 9 of the Endangered Species Act. The Service also participated in a site visit on January 22, 2004. According to the recently approved Highland County conditional use permit, HNWD is currently proposing to build a substation and up to 22 wind turbines to produce up to 39 megawatts of electricity. The turbines will not exceed 400 feet in height (including the blade) and will be placed on Tamarack Ridge and Red Oak Knob on Allegheny Mountain. It is our understanding that the HNWD is no longer pursuing funding through the USDA's Rural Energy Systems and Energy Efficiency Improvements Grant Program. The purpose of this letter is to advise HNWD that regardless of whether a loan is pursued through the USDA, the HNWD must still comply with applicable Federal and State wildlife laws. The Service is providing the following comments pursuant to the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.), the Endangered Species Act (ESA) of 1973 (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.), the Migratory Bird Treaty Act (MBTA) of 1918 (40 Stat. 755; 16 U.S.C. 703-712), and the Bald and Golden Eagle Protection Act (BGEPA) of 1940 (54 Stat. 250, as amended; 16 U.S.C. 668-668d).

Fish and Wildlife Resources

The following federally listed species have been documented in Highland County and may occur in the project area: Virginia Northern flying squirrel (*Glaucomys sabrinus fuscus*), Indiana bat (*Myotis sodalis*), the Virginia big-eared bat (*Corynorhinus townsendii virginianus*) and the bald eagle (*Haliaeetus leucocephalus*).

The Virginia northern flying squirrel, federally listed endangered, has been documented in the vicinity of the project. The Virginia northern flying squirrel is usually associated with boreal habitats, especially spruce-fir and northern hardwood forests (USFWS 1990). In Virginia, all records for this species are at elevations above 3,000 feet. Habitat fragmentation, destruction, or alteration has been identified as a threat to this species (USFWS 1990). The Service continues to recommend that suitable habitat for the Virginia northern flying squirrel be surveyed and mapped in areas at or adjacent to the tower sites. This information is necessary to assess any anticipated impacts to the squirrel. As described in the Recovery Plan, suitable habitat is described as boreal conifer-hardwood forest, comprised of red spruce and Fraser fir, associated with American beech, sugar or red maple, yellow birch, hemlock and black cherry.

The Indiana bat and/or the Virginia big-eared bat, both federally listed endangered, have been documented in three caves that are approximately 14, 15, and 17 miles from the project area. Bat mortality at wind turbine sites have been documented during late summer and early fall migration and during inclement weather. The potential for adverse effects to bats at this particular location is unknown. However, data from nearby wind turbine sites indicate that there is a high likelihood that bats will be adversely affected by wind turbines. At the Mountaineer Wind Energy Center in West Virginia, the total number of bats estimated to be killed in a 6-week period in 2004 was 1,364-1,980 (Arnett 2004). Due to the potential for adverse effects to bats, we recommend that bats be monitored concurrently with migratory birds when conducting pre- and post-construction monitoring of wind power projects.

The bald eagle and the golden eagle (*Aquila chrysaetos*) are known to migrate through this area. The golden eagle is not federally listed under the ESA, however, it is protected by the MBTA and the BPEPA. The BGEPA prohibits the taking of bald and golden eagles or their nests and eggs. Under the BGEPA, taking is defined as "to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb."

Section 9 of the ESA (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.) makes it illegal for any person subject to the jurisdiction of the United States to "take" any federally listed endangered or threatened species of fish or wildlife without a special exemption. "Person" is defined under the ESA to include individuals, corporations, partnerships, trusts, associations, or any other private entity; local, state, and Federal agencies; or any other entity subject to the jurisdiction of the United States. Under the ESA, "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or to attempt to engage in any such conduct. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns such as breeding, feeding, or sheltering. Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Section 11 of the Act provides for both civil and criminal penalties for those convicted of Section 9 violations.

Take incidental to an otherwise lawful activity may be authorized by one of two procedures. If a Federal agency is involved with the permitting, funding, or carrying out of the project and a listed species will be adversely affected, then initiation of formal consultation between that agency and the Service pursuant to section 7 of the ESA is required. Such consultation would result in a biological opinion addressing the anticipated effects of the project to the listed species, and may authorize a limited level of incidental take. If a Federal agency is not involved in the project, and federally listed species may be taken as a result of the project, then an incidental take permit pursuant to section 10(a)(1)(B) of the ESA may be obtained by the private landowner or corporation. The Service may issue such a permit upon completion of a satisfactory habitat conservation plan for the listed species that would be taken by the project. Please be aware that there is no mechanism for authorizing incidental take "after-the-fact."

All native migratory birds (*e.g.*, waterfowl, shorebirds, passerines, hawks, owls, vultures, falcons) are afforded protection under the MBTA of 1918. The MBTA provides that it is unlawful to pursue, hunt, take, capture or kill; attempt to take, capture or kill; possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product, manufactured or not. While the MBTA has no provision for allowing unauthorized take, we recognize that some birds may be killed at structures such as wind turbines even if all reasonable measures to avoid it are implemented.

Impact Assessment Recommendations

Recognizing the potential impacts to wildlife due to the development of wind power, the Service developed *Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines* (http://www.fws.gov/habitatconservation/wind.pdf). These guidelines include recommendations for 1) proper evaluation of wind resource areas; 2) proper siting and design of turbines within development areas; and 3) pre- and post-construction research and monitoring to identify and/or assess impacts to wildlife. We encourage you to review these guidelines. If you are not able to access this document online, we would be glad to send you a copy. Based on the limited information currently available to us, this project has the potential to adversely affect federally listed species and other resident and migratory wildlife. The Service has recommended and continues to recommend that the project sponsor evaluate the potential effects to federally listed species and to resident and migratory bird and bat species for this project.

To evaluate the potential effect to federally listed species and other resident and migratory wildlife, the HNWD should include a review of all available data and literature relevant to this site. In addition, the assessment should identify potential impacts as a result of collisions with turbines, including the potential effects on, but not limited to, raptors, passerines, and bats, as well as cumulative effects of collision mortality from the proposed turbines. The physical disturbance, direct loss, and fragmentation of grassland and forest habitat should also be included in the evaluation.

In order to determine the potential collision-hazard for a particular site, the spatial and temporal uses of the airspace by birds and bats needs to be defined during a multi-year period. This can best be accomplished by using remote sensing technology (radar, acoustic, and infrared) to collect data in various spatial (ridgetops and side slopes) and temporal scales (day and night, season to season, and year to year). Traditional sampling protocols (*e.g.*, visual observation and/or mist netting) are also appropriate to supplement the remote sensing work and would likely be necessary to ground truth the data for individual species. Survey techniques are currently evolving and the applicant should work closely with this office to develop a draft study design prior to conducting any studies. Pre-construction monitoring methods and study designs should be coordinated with the Service, appropriate State agencies, and researchers. Survey results should be submitted to us for review and comment, along with proposed project-specific avoidance and minimization methods to reduce the risk of bat and bird mortality. Pre-construction surveys may allow for the project to be designed in such a way to avoid or minimize the impacts to federally protected species or migratory birds.

The Service recommends that all wind power projects that proceed to construction be monitored for impacts to wildlife following construction and during turbine operation. Post-construction bat and bird mortality monitoring should occur for a minimum of three years. Information gained from post-construction monitoring will continue to aid the Service and project sponsors as we learn more about the potential impacts, or lack thereof, to wildlife in the project area. In 2004, The Bats and Wind Energy Cooperative (BWEC) conducted studies at Mountaineer Wind Energy Center in Tucker County, West Virginia and Meyersdale Wind Energy Center in Somerset County, Pennsylvania to investigate interactions between bats and wind turbines (Arnett 2005). BWEC is a partnership between representatives of government agencies, private industry, academic institutions, and non-governmental organizations. The goal of this research is to establish a basis for developing means of preventing or minimizing bat mortality at wind turbine sites. We encourage you to reference this report and incorporate design and operational recommendations into your project to avoid or minimize bat mortality. Post-construction monitoring methods and study designs should be coordinated with the Service, appropriate State non-game agencies, and researchers. The monitoring reports should be submitted to us within 30 days of the end of monitoring period. This office and the Region 5 Division of Law Enforcement are to be notified within 48 hours should any birds protected under the MBTA or species protected under the ESA be found dead or injured as a direct or indirect result of the implementation of this project. Notification should include the date, time, and location of the carcass, and any other pertinent information, to the following offices:

- Region 5 Division of Law Enforcement; 300 Westgate Center Drive, Hadley, MA 01035-9589 (telephone: 413-253-8343).
- Virginia Field Office, 6669 Short Lane, Gloucester, VA, 23061, (telephone: 804-693-6694).

In summary, we are concerned about the potential risk that construction and operation of the Highland New Wind Development facility may pose to bat and bird species residing and migrating through western Virginia, and the resultant cumulative impacts that could occur following operation of this and any additional wind power facilities on ridge tops in the Eastern United States. Again we strongly recommend that a multi-year pre-construction study be conducted at the proposed project site in order to identify any risks to federally-protected species and migratory bird species that may be associated with operation of the Highland New Wind

Development facility and to investigate means of avoiding potential impacts. The Service looks forward to working with you to evaluate these issues.

If you have any questions, please contact Kim Marbain of this office at (804) 693-6694, extension 126.

Sincerely,

Karen L. Mayne

Karen L. Mayne
Supervisor
Virginia Field Office

cc: USFWS, Law Enforcement, Richmond, VA (Rick Perry)
Highland County, Monterey, VA
Woods Rogers, Roanoke, VA (James Jennings)

Literature Cited

Arnett, E.B., technical editor. 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA.

U.S. Fish and Wildlife Service. 1990. Appalachian Northern Flying Squirrels (*Glaucomys sabrinus fuscus* and *Glaucomys sabrinus coloratus*) Recovery Plan. Newton Corner, Massachusetts. 53 pp.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
3817 Luker Road
Cortland, NY 13045

May 13, 2005

Mr. Patrick McCarthy
Project Biologist
Ecology and Environment, Inc.
Buffalo Corporate Center
368 Pleasant View Drive
Lancaster, NY 14086

Dear Mr. McCarthy:

This responds to your letter of November 24, 2004, requesting information on the presence of Federally-listed or proposed endangered or threatened species in the vicinity of proposed wind power projects in the Town of Altona, and Towns of Ellenburg and Clinton, Clinton County, New York. We will address listed species, but will also provide information regarding the potential for other wildlife-related concerns.

It appears that the proposed projects may affect species under U.S. Fish and Wildlife Service (Service) jurisdiction, however, further information is necessary to adequately make any determinations. This additional information includes a more detailed project description (e.g., estimate of the operational lifespan of the projects, the length of roads to be constructed, whether transmission lines will be buried or overhead), as well as information on habitat and bird and bat use within the project area. We are providing the following comments pursuant to the Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703-712), the Endangered Species Act of 1973 (ESA) (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*), and the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d). In addition to these comments, we may provide additional future comments under other legislation such as the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 *et seq.*).

The Service supports use of renewable energy resources when developed in an environmentally responsible manner. Renewable energy sources, such as solar and wind, can reduce environmental impacts of extraction and emissions associated with burning fossil fuels. To ensure that environmental benefits of renewable energy development outweigh potential impacts, we will work with the project sponsor in identifying ways that protect wildlife.

One purpose of this letter is to advise the project sponsor of the prohibitions and permitting aspects of the applicable Federal wildlife laws. We do this so the project sponsor can make an informed decision regarding site selection, project design, the risk of violating these acts, and whether applying for a permit to cover the anticipated take of the species is appropriate, where such a mechanism is available.

<u>Migratory Species</u>

Background

Migratory birds, such as waterfowl, passerines, and raptors are Federal trust resources and are protected by provisions of the MBTA and the Service is the primary Federal agency responsible for administering and enforcing the MBTA. This act prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests except when specifically authorized by the Service. The word "take" is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect." The unauthorized taking of even one bird is legally considered a "take" under the MBTA and is a violation of the law. Neither the MBTA nor its implementing regulations, 50 CFR Part 21, provide for permitting of "incidental take" of migratory birds that may be killed or injured by wind projects. However, we recognize that some birds may be killed at structures such as wind turbines even if all reasonable measures to avoid it are implemented. Depending on the circumstances, the Service's Office of Law Enforcement may exercise enforcement discretion. The Service focuses on those individuals, companies, or agencies that take migratory birds with disregard for their actions and the law, especially when conservation measures have been developed but are not properly implemented.

Operational wind turbines can adversely affect wildlife in a variety of ways. Foremost, the potential exists for bird and bat collision within the rotor-swept area of each turbine. It has been documented that wind turbines cause bat and bird mortality in a variety of species (Erickson et al. 2001). Research to date indicates that raptors are prone to wind turbine collisions. Songbirds, particularly those individuals migrating at night under poor visibility conditions, are even more susceptible. Recently, it has been reported that large numbers of bats have also been killed by these structures located on ridges. Habitat loss, fragmentation, and degradation are also potential impacts from wind energy development projects. Turbines can affect breeding and feeding behavior in some species, as well.

Recognizing the potential impacts to wildlife due to development of wind power projects, the Service developed *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines* (Guidelines) (Service 2003). A copy of this document may be obtained from our office or found on the Internet at www.fws.gov/r9dhcbfa/wind.pdf. These Guidelines include recommendations for: 1) proper evaluation of wind resource areas; 2) proper siting and design of turbines within development areas; and 3) pre- and post-construction research and monitoring to identify and/or assess impacts to wildlife. We suggest the project sponsor review this information during the development of the project design.

The potential for bat and bird mortality from this type of project appears to be dependent on factors such as wildlife abundance, presence of a migration corridor, geographic location, and particular landscape features. As specified in the Guidelines, the project sites should be evaluated for habitat features such as the presence of breeding, feeding, and roosting areas. Unique habitats, such as wetlands, should also be considered.

Recommendations

The Service agrees that a bat and bird risk assessment should be conducted by the project sponsor. This assessment should include a review of all available data and literature relevant to bat and bird use of these sites. In addition, the assessment should identify potential impacts as a result of collisions with turbines including the potential effects on, but not limited to, raptors, passerines, and bats, as well as cumulative effects of collision mortality from the proposed turbines. The physical disturbance, direct loss, and fragmentation of grassland and forest habitat should also be included in the evaluation. This information should be incorporated into the projects' environmental documents for review.

If the results of the risk assessment indicate there may be the potential for adverse affects, we may recommend pre-construction studies of bird use of the proposed project site. Pre-construction studies of bats for this location are recommended. These studies should be of sufficient rigor to determine the temporal and spatial distribution of resident and migrating bat and bird species in and adjacent to the project areas during various weather conditions (e.g., fog, rain, low cloud ceilings, clear skies, etc.). One source of information on monitoring the project site for wildlife species can be obtained from "Studying Wind Energy/Bird Interactions: A Guidance Document. Metrics and Methods for Determining or Monitoring Potential Impacts on Birds at Existing and Proposed Wind Energy Sites" (National Wind Coordinating Committee 1999).

In order to determine the potential collision-hazard for a particular site, and to account for annual variability, the spatial and temporal uses of the project airspace by birds and bats need to be defined during a multi-year period. This can best be accomplished by using remote sensing technology (radar, acoustic, and infrared) to collect data in various spatial and temporal scales (day and night, season to season, and year to year). Traditional sampling protocols (e.g., visual observation and/or mist netting) may be appropriate to supplement the remote sensing work and would likely be necessary to ground truth the data for individual species. Survey techniques are currently evolving and the project sponsor should work closely with this office and the New York State Department of Environmental Conservation (NYSDEC) to develop a draft study design prior to conducting any studies. Survey results should also be submitted to us for review and comment, along with proposed project-specific avoidance and minimization methods to reduce the risk of bat and bird mortality.

Finally, the Service recommends that all wind power projects that proceed to construction be monitored for impacts to wildlife following construction and during turbine operation. Therefore, we recommend mortality monitoring be completed on a systematic basis around the turbines. Post-construction bat and bird mortality monitoring should occur for a minimum of three years. Methods should be coordinated with both the Service and the NYSDEC. Information gained from post-construction monitoring will continue to aid the Service and project sponsors about the potential impacts, or lack thereof, to wildlife (including listed species - see below) in the project area.

Federally-listed Threatened or Endangered Species

Except for occasional transient individuals, no Federally-listed or proposed endangered or threatened species under our jurisdiction are known to exist in the project impact areas. In addition, no habitat in the project impact areas is currently designated or proposed "critical habitat" in accordance with provisions of the ESA. Should project plans change, or if additional information on listed or proposed species or critical habitat becomes available, this determination may be reconsidered. The most recent compilation of Federally-listed and proposed endangered and threatened species in New York* is available for your information. If the proposed projects are not completed within one year from the date of this determination, we recommend that you contact us to ensure that the listed species presence/absence information for the proposed projects is current.

The above comments pertaining to endangered species under our jurisdiction are provided pursuant to the ESA. This response does not preclude additional Service comments under other legislation.

For additional information on fish and wildlife resources or State-listed species, we suggest you contact the appropriate State regional office(s),* and:

New York State Department of Environmental Conservation
New York Natural Heritage Program Information Services
625 Broadway
Albany, NY 12233-4757
(518) 402-8935

Work in certain waters of the United States, including wetlands, and streams may require a permit from the U.S. Army Corps of Engineers (Corps). If a permit is required, in reviewing the application pursuant to the Fish and Wildlife Coordination Act, the Service may concur, with or without recommending additional permit conditions, or recommend denial of the permit depending upon potential adverse impacts on fish and wildlife resources associated with project construction or implementation. The need for a Corps permit may be determined by contacting the appropriate Corps office(s).* In addition, should any part of the proposed project be authorized, funded, or carried out, in whole or in part, by a Federal agency, such as the Corps, further consultation between the Service and that Federal agency pursuant to the ESA may be necessary.

If you require additional information or assistance please contact Timothy Sullivan at (607) 753-9334. For any future correspondence with us on this project, please reference project file name 50388endn

Sincerely,

for David A. Stilwell
Field Supervisor

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Ecological Monographs, 60(2), 1990, pp. 213–238

STRUCTURE AND ORGANIZATION OF AN AMAZONIAN FOREST BIRD COMMUNITY[1]

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Abstract. To help fill the gap in detailed knowledge of avian community structure in tropical forests, we undertook a census of a 97-ha plot of floodplain forest in Amazonian Peru. The plot was censused over a 3-mo period spanning the 1982 breeding season. The cooperative venture entailed ≈12 person-months of effort. Conventional spot-mapping was the principal method used, but several additional methods were required to estimate the numbers of non-territorial and group-living species: direct counts of the members of mixed flocks, saturation mist-netting of the entire plot, opportunistic visual registrations at fruiting trees, determination of the average size of parrot flocks, color banding of colonial icterids, etc.

Two hundred forty-five resident species were found to hold territories on the plot, or to occupy all or part of it. Seventy-four additional species were detected as occasional-to-frequent visitors, wanderers from other habitats, or as migrants from both hemispheres. By superimposing territory maps or the areas of occupancy of individual species, we determined that point (alpha) diversities exceeded 160 species in portions of the plot. About 1910 individual birds nested in 100 ha of this floodplain forest, making up a biomass conservatively estimated at 190 kg/km². The total number of breeding birds was equivalent to that in many temperate forests, but the biomass was about five times as great. Predominantly terrestrial granivores contributed the largest component of the biomass (39%), followed by largely arboreal frugivores (22%). Considering only insectivores, the biomass (34 kg/km²) is somewhat less than that in the forest at Hubbard Brook, New Hampshire (40 kg/km²), although it is greater (55 kg/km²) if one includes omnivores. The number of insectivores was considerably less than at Hubbard Brook, due to their 60% larger average body size (32 vs. 20 g).

Even though a large majority of the species were patchily distributed, the 97-ha plot was found to include 99% of the bird species that regularly occupy mature floodplain forest at Cocha Cashu. The most abundant species occupied territories of 4–5 ha, and 84 species (26%) had population densities of ≤1 pair per square kilometre. Of these, 33 (10% of the total community) were judged to be constitutively rare (i.e., having low population densities everywhere), rather than being merely locally rare. Many of these are predicted to be vulnerable to forest fragmentation and disturbance. Comparison of these results with those from other tropical forests proved difficult due to a lack of standardized methodology.

Key words: biomass; bird; census; community structure; guilds; patchiness; rarity; species diversity; territory; tropical forest.

Introduction

Until recently the journal *American Birds* annually published over 200 breeding-bird censuses of North American habitats. The censuses were conducted using standard protocols that included measurements of the vegetation as well as counts of resident birds (James and Shugart 1970). The nearly universal applicability of this standard methodology in temperate North America is indicated by the publication of censuses for such widely different habitats as forests, swamps, marshes, prairies, and arctic tundra. The reliability and

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ease of execution of the methodology is attested by the fact that most of the census takers were amateur birdwatchers. This largely volunteer effort has provided us with a broad overview of the North American avifauna—which species breed in which habitats at what densities.

For tropical habitats we do not have comparably detailed information on avian community structure. The paucity of information is particularly acute in the case of mature tropical forests, where levels of avian syntopy may be several times higher than in temperate habitats. Although the literature contains a number of reports on the structure of tropical forest bird communities, most of these accounts do not meet standards of comprehensiveness and precision that are routinely attained in studies conducted in the temperate zone.

Several reasons account for the slow development of an accepted census methodology for tropical habitats. Species diversities are very high, and few workers have attained the skill necessary to carry out comprehensive censuses. A number of published reports on tropical forest bird communities consequently have included only common or "regular" species (MacArthur et al. 1966, Orians 1969, Karr 1971). Other workers, being impressed at the number of cryptic species present in tropical forests, and being unable to recognize the calls of some of them, have relied heavily on mist nets (Karr 1971, 1976, 1980, Terborgh 1971, Fogden 1972, Lovejoy 1975, Lovejoy et al. 1986, Wong 1986). But mist nets provide a severely biased sample of most communities, and may capture no more than 40% of the species present in a tall forest, even when the sample is very large (Terborgh 1977, 1985). Handicapped by the difficulty of recognizing calls, workers in the tropics have seldom applied the spot-mapping technique that is the standard temperate census methodology, and instead have frequently resorted to indirect methods, such as transect counts (Thiollay 1986) and tabulating the number of sightings in a plot (McClure 1969, Pearson 1975, 1977, Bell 1982). Species that possess non-territorial or gregarious social systems present special difficulties that have not been adequately addressed. Finally, the nearly universal tendency in past efforts to use study plots of <5 ha has prevented the accurate determination of population densities, biomasses, or territory sizes of the majority of species present (Davis 1955, MacArthur et al. 1966, Orians 1969, Karr 1971, Zimmerman 1972, Bell 1982). For all these reasons, reliable quantitative information on the structure and composition of tropical forest bird communities is scarce and sorely needed.

Prior to initiating the work reported here, each of us had intensively studied one or another component of the Amazonian avifauna. Through mutual instruction on vocalizations, we had collectively acquired a knowledge of the songs, calls, and notes of nearly all of the 500+ species that regularly occur in the vicinity of our study site (Terborgh et al. 1984). The first author conducted preliminary trials with the methodology in 1980 and 1981, and in 1982 we all participated in a concerted effort to achieve a complete and accurate census of a 97-ha plot of mature tropical floodplain forest. Here we report the results of this census, presenting, for 245 species, data on population densities, territory sizes, biomasses, and other parameters of interest.

A major portion of the paper is devoted to expounding our methodology. Most of the techniques we used are more or less standard. What is new about our approach is the use of many techniques in combination to achieve the best possible accuracy in counts of species possessing widely different social and territorial systems. The process is labor intensive, as ≈12 person-months of field time went into the effort. While this may represent some overkill, we felt that on the first time through it would be better to err on the side of excess than on the side of parsimony. Subsequently, we have been able to achieve equivalent results in plots of similar size with efforts of 4–6 person-months.

METHODS

Preamble

When the first author began studying Amazonian birds more than 20 years ago there were no field guides to the region, and the vocalizations of most species were unknown to the scientific community. In the intervening period, the incomparably rich bird fauna of tropical South America has become a subject of nearly fanatical interest to a small group of dedicated amateur and professional ornithologists. Many of these people have participated in the gradual but cumulative process of tracking down bird sounds, usually by first making a recording, and then playing it back to attract the singer. Through sharing knowledge and recordings with each other and with other ornithologists, we have been able to acquire the skill needed to census Amazonian birds. This skill is the cornerstone of our work, and is a sine qua non for studies at the community level.

The study site.—The bird community we studied inhabits the mature floodplain forest around Cocha Cashu Biological Station in Peru's Manu National Park (11°54′ S, 71°18′ W, elevation ≈400 m). With a mean annual temperature of 23°–24°C, and rainfall somewhat in excess of 2000 mm, the site lies near the climatic boundary between Tropical and Subtropical Moist Forest in the Holdridge system (Holdridge 1967). The botanical characteristics of the site have been described at length in a number of previous publications (Terborgh 1983, 1985, Terborgh et al. 1984, Gentry and Terborgh, *in press*) and will only briefly be reiterated here.

Cocha Cashu is a 2.3 km long oxbow lake that lies in the 6 km wide meander belt (floodplain) of the whitewater Manu River. The vegetation of the meander belt is a complex mosaic of stands of widely varying age and composition. This heterogeneity results from the surprisingly rapid meandering of the river. Measurements made along the Rio Manu indicate that meander loops routinely elongate by 10–20 m/yr (Kalliola et al. 1987). The entire floodplain is thus maintained in a dynamic steady-state in which much of the vegetation is in early stages of primary succession (Foster 1980, 1986, Terborgh 1983, Salo et al. 1986).

Within the meander belt are patches of mature forest of impressive stature and high tree species diversity. A 1-ha plot contained 204 tree and liane species with diameter at breast height (dbh) > 10 cm (Gentry 1988). Such forests have a successional age of > 300 yr, and are located on well-drained ground slightly more elevated than much of the surrounding floodplain (Terborgh and Petren, *in press*). These areas remain above the annual flooding of the river except in rare (once in > 15 yr) general inundations.

The census plot.—The 97-ha census plot is entirely composed of mature floodplain forest and is located along the eastern margin of Cocha Cashu. It is bounded on the west by the lake, on the north by a seasonal stream that flows into the lake, on the northeast by a large expanse of similar forest, on the southeast by a *Ficus trigona* swamp (Terborgh 1983), and on the south by less mature, seasonally inundated, successional vegetation (Fig. 1).

Preliminary observations indicated that a large majority of the bird species in this forest could be heard for distances of 100 m or more, a finding that has been corroborated for species nesting in the temperate forests of North America (Emlen and DeJong 1981). Accordingly, we augmented a pre-existing trail system so that parallel elements of the grid were ≈200 m apart. By the same criterion, we considered that the area censused extended 100 m beyond the bounding trails, except in the south and southeast where we truncated the plot to coincide with the limit of mature forest.

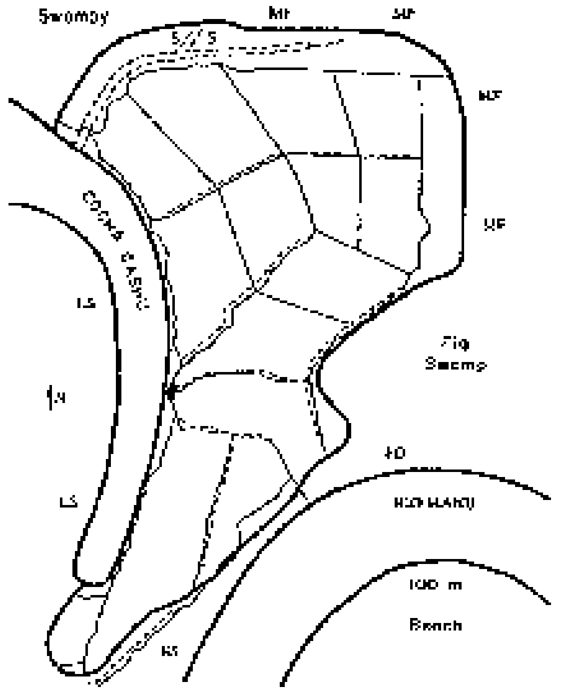

FIG. 1. Map of the census plot showing the lake (Cocha Cashu), river (Rio Manu), and surrounding habitats. The plot is outlined by a heavy line, the trails are indicated by thin lines, and the locations of mist nets by dashed lines paralleling the trails in which they were set. Key: ES = early successional vegetation on land recently deposited by the river; FD = flood-disturbed vegetation; LS = late successional vegetation; MF = mature floodplain forest; S = seasonal stream.

Census methods

In the forest we have been studying, the most abundant species occupy territories of 4–5 ha, and species of average abundance maintain densities of merely 2–4 pairs per 100 ha. The 97-ha plot represents what we hoped would be an optimum compromise between scale and thoroughness of coverage.

Spot-mapping.—The primary census method was spot-mapping. We followed traditional practice, noting the estimated position of singing birds as a perpendicular distance from the nearest trail marker, these being located at 25-m intervals on all trails (Kendeigh 1944). Whenever possible we recorded the positions of countersinging territorial neighbors, as these observations provided invaluable information on the location of territorial boundaries. We censused nearly every morning of suitable weather from 15 August through 10 November 1982, having previously established that this period encompasses the main portion of the breeding season at Cocha Cashu. On any day, each participating observer covered one of seven routes that varied in length from 1.5 to 2.0 km. Coverage of the routes was rotated systematically, as was the direction walked.

We found that it was important to be out at least 15 min before the sky showed even the faintest brightening, because a number of species sing only or mainly in this pre-dawn period (e.g., some tinamous, cracids, forest falcons, owls, potoos, caprimulgids, woodcreepers, becards, and others). Vocal activity quickly reached a maximum with the first light to penetrate the forest, at which time nearly all other species joined the chorus. High levels of vocal activity continued for 2 or 3 h, depending on weather conditions and (during September, especially) acoustic competition from cicadas. We found that census walks taken during the middle hours of the day were unproductive and failed to uncover species that were not amply evident in the hours after dawn. We therefore confined our efforts to the early morning hours and to evening counts conducted in the 2-h period centered on nightfall. The latter were very useful in documenting a suite of species that participate in a regular dusk chorus (e.g., many tinamous, wood-quail, owls, potoos, nightjars, and many woodcreepers). Over the entire 1982 season we logged > 15 000

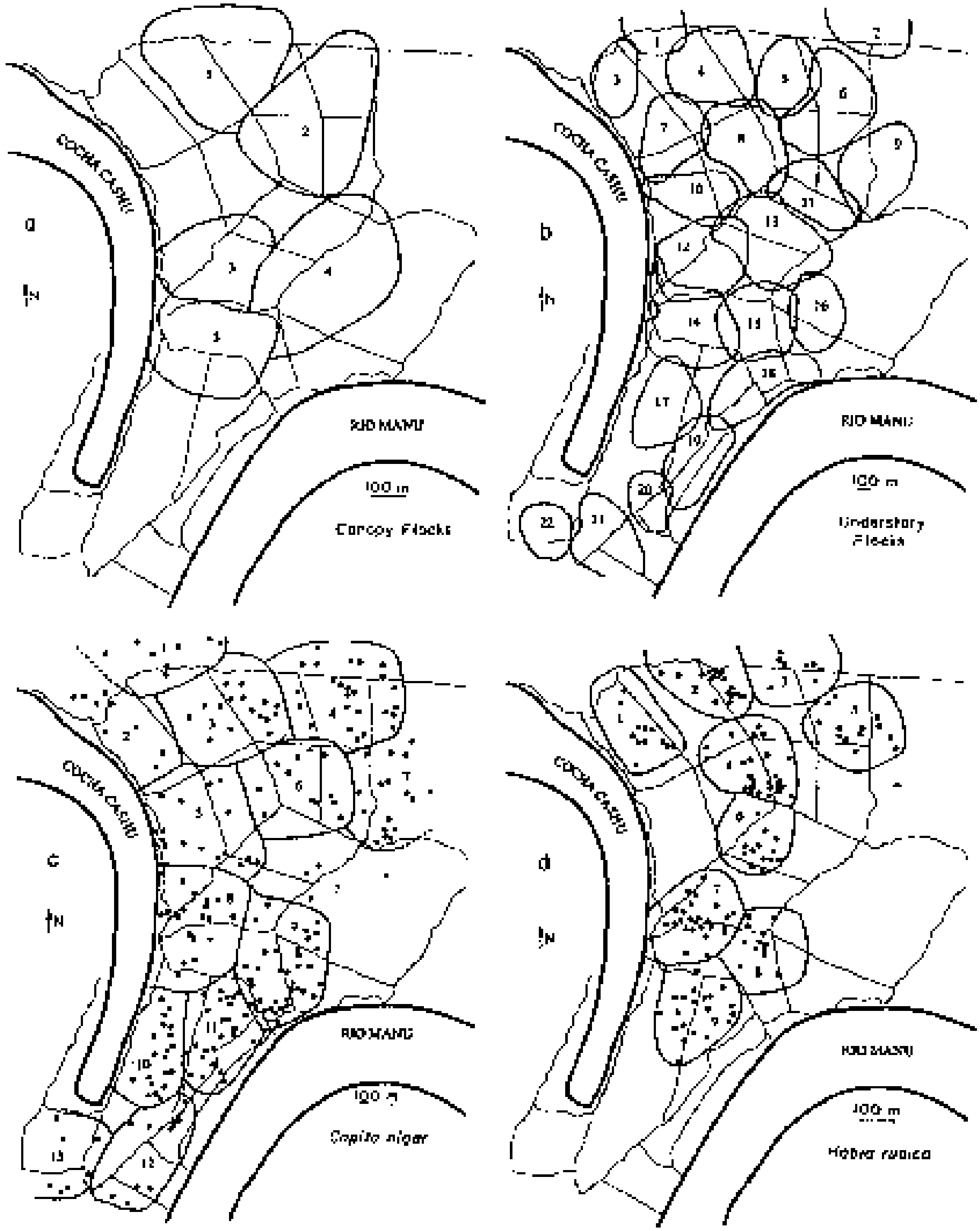

FIG. 2. Specimen territory maps. (a) canopy flocks; (b) understory flocks; (c) complete occupancy of mature forest plot (*Capito niger*, Capitonidae); (d) partial occupancy of mature forest (*Habia rubica*, Thraupidae); (e) territories located along edges (*Myiopagis gaimardii*, Tyrannidae); (f) territories located in microhabitat patches (*Heliconia* thickets: *Myrmoborus leucophrys*, Formicariidae); (g) large territories (*Chamaeza nobilis*, Formicariidae); (h) single male song perches (*Tyranneutes stolzmanni*, Pipridae).

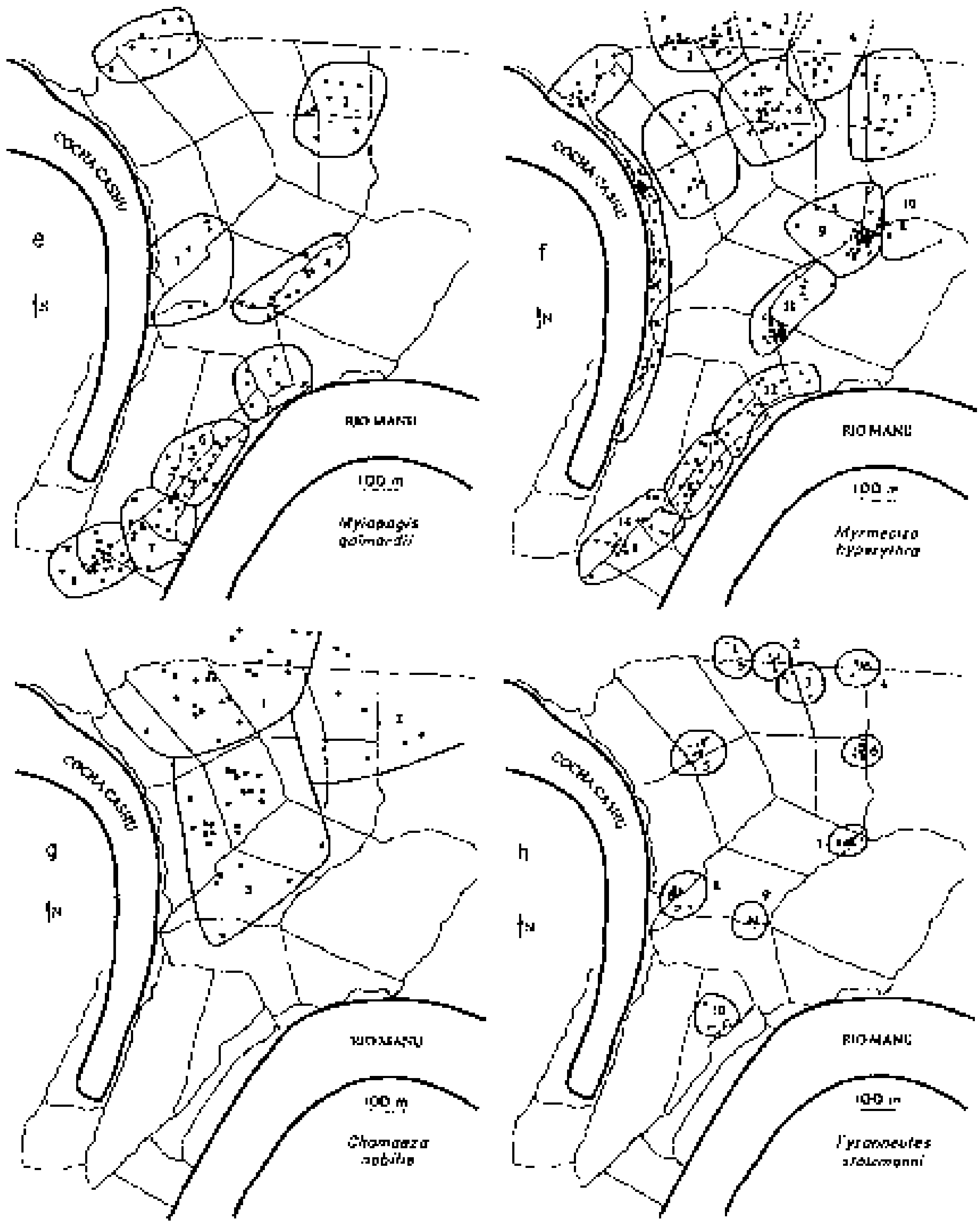

FIG. 2. Continued.

spot-map registrations. This amounts to an average of ≈15 independent detections of each pair of birds that occupied the plot.

Of the 245 species found to be resident on the plot, two-thirds behaved as if they possessed conventional territories, and were thus amenable to censusing by the spot-map technique. We judged this from the fact that what seemed to be the same individuals were reliably in the same areas day after day. This impression was supported in most cases by maps showing discrete clusters of registrations (Fig. 2). In a moderate number of cases direct confirmation of the identity of territory holders was confirmed with color-banded individuals. The spot-mapping technique can thus be applied in a perfectly straightforward fashion to census a majority of the species that inhabit the Amazonian forest. Nevertheless, there are some special considerations that pertain to the tropical situation that merit further comment.

A complication that besets voice-based censusing in the Neotropical forest is that the females as well as the males of many species sing territorial songs. This is true of families across the whole phylogenetic scale: wood-quail, rails, doves, motmots, trogons, woodcreepers, ovenbirds, antbirds, wrens, and others. In a few cases there is no ambiguity, because the territorial song is normally a duet that engages both members of a pair (e.g., *Odontophorus*, *Aramides*, *Monasa*, *Thryothorus*). In other cases the ambiguity is minimal because the members of a pair normally forage together, e.g., trogons, jacamars, most antbirds. Successive registrations that are >50 m apart can safely be assumed to represent different territory-holders. But there are still other cases, tinamous being a prime example, in which one is confronted with ambiguities. Nine species of tinamous were recorded on the plot, and several of them are abundant. Little is known about the social systems of forest tinamous, although one species has been suspected of being polyandrous (Beebe 1925). We suppose that both males and females sing, but since the sexes forage apart and are identical in appearance, we can only guess. The same difficulties pertain to many woodcreepers (Dendrocolaptidae; 17 species) and ovenbirds (Furnariidae: 11 species), that is, the males and females look alike and forage apart. From the work of one of us on color-banded and/or radio-tagged lepidocolaptine woodcreepers, we know that the vocal repertoires of birds of both sexes are similar (Pierpont 1986). Fortunately, most woodcreepers and ovenbirds can be censused in their respective mixed flocks (see Other Methods, below). With tinamous we are consigned to using educated guesswork.

In temperate North America one can census birds in any habitat without having to resort to special techniques to estimate the numbers of species with unconventional social systems. Group-breeding species, such as Acorn Woodpeckers and Scrub Jays, represent a tiny minority, and non-territorial species, e.g., hummingbirds, swifts, and swallows, are seldom included in breeding-bird censuses.

In the tropical forest, social and non-territorial species are legion, and the need to deal with them is unavoidable. Most of these cannot be properly censused by spot-mapping. There are a few exceptions, for which spot-mapping does provide useful information. These are lekking species and a few others in which males call from traditional song perches to attract females. In our community, species of *Phaethornis*, *Threnetes*, *Pipra* and *Lipaugus* form multi-male leks that can be censused directly. However, such lek counts may misrepresent the breeding population, because the number of reproductively active females may not equal the number of lekking males. For hermits (hummingbirds—*Phaethorninae*) and manakins (*Pipra* spp.), we supplemented information on the number of lekking males with data from netting (see next paragraph). For *Lipaugus* we had no other recourse than to count the number of males that displayed within the plot. In addition to these lekking species, there are three others, *Pipra coronata*, *Tyranneutes stolzmanni* and *Laniocera hypopyrrha*, in which solitary males (occasionally groups of two or three) display from traditional perches. For these, as in *Lipaugus*, we simply counted the number of displaying males, realizing that this perhaps results in somewhat distorted population estimates. We shall now describe several additional methods that we used to estimate the numbers of social and/or non-territorial species that did not call from leks.

Mist-netting.—Mist-netting proved useful, first, as a means of capturing birds for color-banding, and second, as a means of roughly estimating the numbers of some non-vocal and non-territorial understory species. Numerous species were color-banded to verify that the same individuals remained permanently in possession of fixed territories. Much of this work is reported in Munn (1985) and Pierpont (1986). To estimate the numbers of some understory species that were otherwise difficult to census, we conducted a concerted campaign to saturate the entire plot with nets (Fig. 1). Altogether we operated nets for 3 or 4 d in 138 positions organized in six separate lines, capturing, in a total of 522 net-days, 755 different individuals of >80 species. We used the information in three ways, according to the species.

1) For several territorial but anomalously non-vocal species, the capture data provided minimum estimates of the number of individuals present in the plot and the number of distinct locations in which birds, presumably pairs, were resident. We obtained estimates in this manner for species of *Malacoptila*, *Nonnula*, *Picumnus*, *Glyphorynchus*, and *Conopophaga*.

2) For species classified as "professional ant-followers" by Willis and Oniki (1978), we set the number of pairs at one-third of the total number of birds captured, to allow for the presence of non-breeding 1st-yr birds in the population and for the fact, established by color-

banding, that many individuals captured within the plot regularly ranged far outside it to attend ant swarms. The individuals of some ant-following species (e.g., *Myrmeciza fortis*, *Gymnopithys salvini*) sang regularly in the mornings, permitting more precise counts of the number of resident breeding units.

3) For several species of hummingbirds and manakins of the genus *Pipra* we had no alternative to taking the total of individuals captured and dividing by 3 to obtain an estimated number of breeding units (all birds were individually banded or, for hummingbirds, were tail-clipped for future recognition). We cannot say whether the estimates derived in this fashion are low or high. Surely we did not catch every individual in the plot (resulting in low estimates); but both manakins and hummingbirds are opportunistic feeders on ephemeral resources, and probably move over large areas in search of food. In the case of *Pipra* spp. we know this to be true from radio-tracking studies (M. Foster, *personal communication*). Hence the nets might have captured more individuals than were actually resident on the plot, leading to overestimates. The numbers given for these groups should thus be taken as being only approximate.

Transect methods.—Whereas a great majority of the species in this community can be heard for > 100 m, as mentioned above, a few have feeble voices that are audible for lesser distances. These included species of *Myiornis*, *Terenotriccus*, *Platyrinchus*, *Hemitriccus*, *Mionectes*, and a few others. Nearly all our registrations of these species were within 40 m of a trail. Since the territories of these species tend to be small, it is likely that we missed a few individuals, and minor corrections, as appropriate, were made accordingly. This constituted our only need to resort to transect methods.

Other methods.—(1) *Known or suspected communal breeders.*—These included wood-quail (*Odontophorus*), trumpeters (*Psophia*), toucans (*Ramphastos*, *Pteroglossus*), motmots (*Momotus*), woodpeckers (*Celeus*, *Melanerpes*), wrens (*Cyphorhinus*, *Campylorhynchus*) and jays (*Cyanocorax*). For each such species we counted breeding groups rather than pairs. For the purpose of calculating biomasses, we used a value of 4 to represent average group size.

(2) *Visual counts.*—A sizeable number of species in this community live in permanent mixed flocks, the members of which share a common territory (Munn and Terborgh 1979). Flocks of different composition inhabit the understory and canopy of the forest. Some of the members of these flocks are notably quiet, singing mainly during chance encounters of neighboring flocks along territorial boundaries. In these cases, spot-mapping becomes problematical, but the fact that membership in these flocks is permanent opens the possibility of direct counts. One of us (C. Munn) has systematically censused every flock in the plot (see Munn 1985). For regular flock members, direct counts of adult pairs have been used in preference to estimates obtained by other means. Since young birds frequently remain in their natal flocks for many months after fledging, these flock counts provide a rare opportunity to enumerate non-breeding individuals as well as established adult pairs.

Visual observations were also used to verify the presence on the plot of a few species not regularly detected by other means. Examples are various raptors, *Piculus* spp., *Cotinga* spp. *Gymnoderus*, *Porphyrolaema*, and *Tangara* spp. The latter four genera are frugivores that were most readily detected in watches at fruiting trees.

(3) *Colonial icterids.*—Large numbers of caciques (*Cacicus cela*) and oropendolas (*Clypicterus*, *Psarocolius* spp., *Gymnostinops*) nest in tightly aggregated colonies in the vicinity of Cocha Cashu. Caciques have been subject to intensive study, and > 1000 individuals have been color banded (Robinson 1985). Banding has served to estimate the total number of individuals in the Cocha Cashu population, and observations of color-marked individuals have provided information on the foraging radii of females resident at the various colonies (Robinson 1986). Knowing the size of the population, and the foraging zones utilized by the members of each colony, we assigned an appropriately pro-rated number of individuals to the census plot. Because oropendolas were not color marked, estimates for the four species are probably less accurate than for caciques.

(4) *Species that habitually occur in monotypic flocks.*—Rather few species show this behavior at Cocha Cashu, the principal ones being parrots and toucans. Censusing parrots is particularly difficult because their numbers fluctuate widely in accordance with the local availability of food resources. We present rough estimates based on the following procedure.

All parrots perched on the plot during census walks were recorded. These registrations consisted of a species identification and an estimated location, but not a number of individuals, since this was often difficult to ascertain. These data were then organized to give an average number of encounters for each species for each of the seven routes. Since each route covered a definite portion of the plot, these results were easily adjusted to give an average number of encounters for each complete coverage of the 97 ha. We then assumed that averaging these counts over the 3-mo period of the census would remove most of the noise due to short-term fluctuations in parrot numbers.

To convert these average encounter rates to numbers of individuals, an average group size for each species was required. These were obtained independently by one of us (S. Robinson) who, in studying caciques, spent hundreds of hours in a canoe on the lake with a full view of the sky. Each time a group of parrots flew over, S. Robinson noted the species and the number of individuals. An average group size for each of the 18 local species was calculated from a total of 1173 group counts. The estimated number of parrots of each species was then calculated as the average encounter rate per unit coverage of the plot times the average group size.

For *Ramphastos* and *Pteroglossus* toucans we used a somewhat modified procedure. These live in stable (possibly communally breeding) groups. Censusing these groups can be confusing, because the members often scatter widely and counter-call to one another. Listening to these counter-calling bouts, one cannot be certain whether the birds are members of one or two groups. To reduce the confusion, we employed two remedies. In one species (*Pteroglossus beauharnaesii*) our regular spot map registrations were conspicuously clustered, presumably around nest sites. Counting the groups was therefore trivially easy. Individuals of the two *Ramphastos* species, however, could appear anywhere on the plot in any sized group from one to several. We attempted to distinguish different groups by sending out two observers simultaneously to opposite ends of the plot. These observers then kept track of where *Ramphastos* toucans were calling and of the time. Comparing notes after the census, the observers could then sometimes verify the simultaneous presence in the plot of two groups, each composed of one or more subgroups. We have accordingly assigned 1.5 groups of each species to the plot.

Subsequent methodology.—This concludes our presentation of census methods. The reader is surely wondering by now whether so massive an effort is necessary merely to conduct a bird census. Having been through the process once, we have simplified the procedure somewhat in our subsequent efforts. A plot could be sampled with mist nets, for example, rather than exhaustively covered. The counts of parrot-group sizes would not have to be repeated for another nearby locality. Caciques and oropendolas could be counted by transect methods on regular census walks, rather than by banding at the colonies. Minor concessions such as these save labor at the sacrifice of little accuracy. What should not be short-cut, however, is time spent in the field doing census walks. Because different species reach their singing peaks at different times in the season, censusing should be extended over most or all of the regular breeding period. Two or three months are therefore required to do an adequate job in a tropical forest, whereas the same number of weeks may suffice in a temperate locality. Each route should be covered many times to assure the detection of cryptic and rare species. We shall see in the Results that communities such as the one we are studying contain numerous species with densities in the range of 0.5–2 pairs per 100 ha. Adequate numbers of registrations of many of these low-density species are accumulated slowly over the course of many repeated censuses.

Scale.—Finally, a note on the matter of scale. Given the presence of many low-density species, working on a large scale is essential. But of course there are practical limits. Further experience has proven that two skilled observers can cover 60–90 ha in a single morning's period of high vocal activity. Later, we shall see that the 97-ha plot was sufficiently large to include 99% of the bird community of mature floodplain forest, suggesting that a plot of this size provides an adequate representation of the community.

Bird masses.—To calculate guild and community biomasses and size distributions, it was necessary to obtain masses for all species in the community. Ten years of netting activity in the region provided data on several hundred species. John Fitzpatrick has kindly given us masses of others from his personal netting and collecting records, all of which refer to birds obtained in Madre de Dios, the Peruvian department in which the Manu park is located. Masses for the remaining species were obtained from specimens in the Museum of Natural Science of Louisiana State University, many of which were also obtained in Madre de Dios, or in nearby Pando, Bolivia.

RESULTS

Three hundred nineteen species were recorded on the plot during the course of the census (see Appendix). Of these, 245 were present at a density of 0.5 pair or more per 100 ha, and were judged to be resident breeders. The remaining 74 species fall into a variety of categories, as will be explained later. For each of the 245 species whose densities we were able to estimate, we provide the following data: mean mass, the number of pairs or reproductive individuals resident on the plot, the method used to arrive at the stated density estimate, the biomass density, the mean territory size in mature floodplain forest, the percent of the plot occupied by reproductive units, and guild membership.

Species richness

A little more than 20 years ago MacArthur et al. (1966) raised the question of whether the alpha diversity of tropical bird communities was truly greater than that of temperate communities, or whether the additional species were accommodated in the landscape through higher beta diversity. By superimposing territory maps (or occurrence maps for non-territorial species) we can determine a point diversity for each location within the 97-ha plot (Fig. 3). Lines of equal diversity are drawn through the points to produce a diversity contour map (Terborgh and Winter 1983). The map shows that point diversities exceed 160 species in some portions of the plot, a value that is 4–5 times as great as would be found in any uniform habitat type in temperate North America.

Levels of point diversity over the plot are surprisingly non-uniform. In particular, there are two areas bordering on the lake where diversity levels fall to about half of the maximum value. There is nothing about the forest in these places that strikes the eye as peculiar. We noticed during the census that we obtained few registrations while walking the trail that fringes the lake, but assumed that the deficiency was due to the fact that the trail skirted open water on one side, so

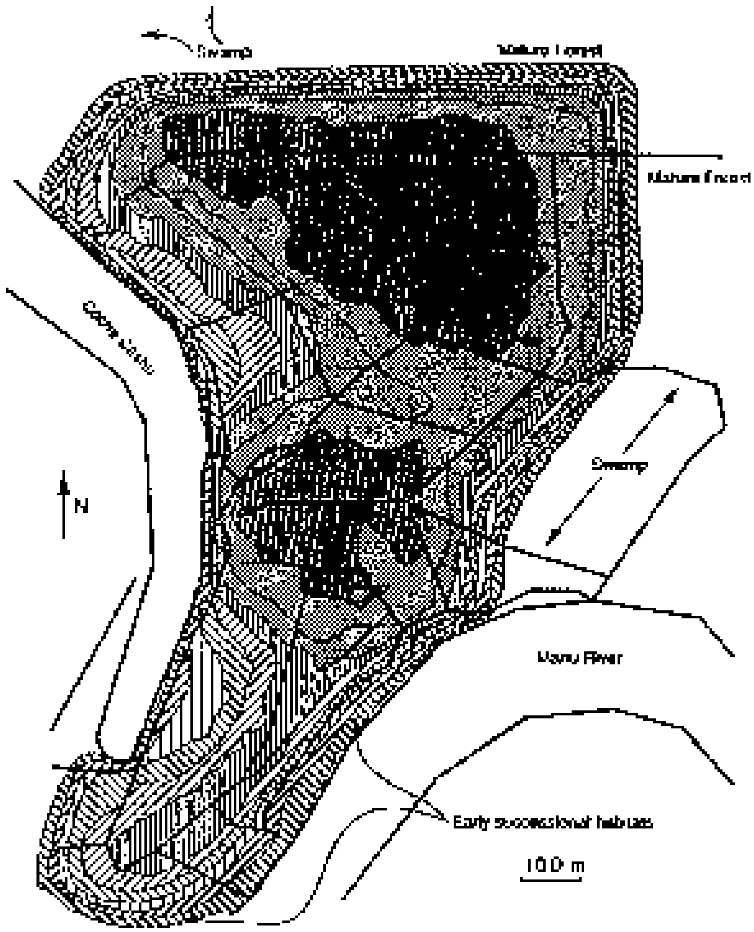

Fig. 3. Distribution of bird species diversity over the 97-ha census plot. The figure was compiled by superimposing the territories or areas of occurrence of all species having measurable densities on the plot. The contours connect points of equal diversity. The large area of fine-grained vertical hatching in the upper middle part of the figure represents ≥150 superimposed territories/areas of occurrence; from this highest level the concentrically arranged designations step down by intervals of 15 species. The pileup of contour lines along the lakefront represents the water's edge; the somewhat more gradual attenuation of species numbers along the north and northeast boundaries of the plot reflects the varying distances to which species' vocalizations could be detected. Notice that there was little or no apparent decrease in species concentrations within 100 m of the outermost trails, supporting our contention (see Methods: Preamble) that nearly all species are audible for ≥100 meters. The still more gradual attenuation of species numbers along the east-central, southeastern, and southern boundaries of the plot results from a real (as opposed to apparent) decline in diversity in adjoining early-successional habitats (Terborgh 1983).

that registrations could be obtained on the other side only. This would have reduced the number of registrations scored per unit distance of trail covered, but should not have affected the number of species detected.

Another possible explanation relates to the presence around the lake of several cacique and oropendola colonies. These colonies at times contained >100 active nests, and served to attract over 500 birds to the vicinity. This large concentration of icterids resulted in an exceptionally heavy foraging pressure on the forest canopy near the lake (Robinson 1986), and thus other species might have avoided the area. This explanation is consistent with the absence of canopy flocks, and not of understory flocks, from the low-diversity zones along the lakefront. It does not, however, accord with the presence of a high-diversity zone near the lake in the center of the plot. Perhaps there are other more elusive factors involved.

Edge effects

Edges of one sort or another occur around the entire margin of the plot, except in the northeast (see Methods: Preamble: The Census Plot). We initially imagined that larger numbers of species would occur along these edges than in the forest interior. This expectation proved

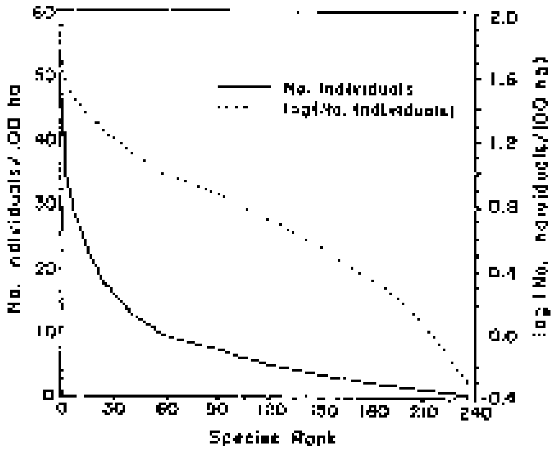

FIG. 4. Abundance vs. rank order curve for the 245 species that were present on the plot in measurable numbers.

to be unwarranted. Regardless of the type of edge (open water, swamp, early successional habitat), we recorded either unchanging or decreasing species numbers, and never an increase. The areas of maximal diversity were unambiguously located in interior forest (cf. Figs. 1 and 3). Edges in Amazonia may be associated with high rates of avifaunal turnover, but evidently not with high point diversity.

Species-abundance relationships

The most abundant territorial species in this forest maintain population densities in the range of 10–20 pairs per 100 ha. In addition, a few non-territorial species approach or surpass this level of abundance (*Cacicus cela*, *Pipra fasciicauda*, *Brotogeris cyanoptera*). These most common species have population densities a full order of magnitude lower than their counterparts in temperate forests. Birds of average abundance live at still lower densities. Among the species present in measurable numbers, the median abundance was 2.5 pairs per 100 ha (Fig. 4). Eighty-four species were represented by <1 pair in the 97-ha plot. Many of these are birds, such as raptors, macaws, and some large woodpeckers, that use all the available habitat and simply have intrinsically low densities. The remainder are species that choose particular types of patches (e.g., large treefalls, swampy areas) within the forest matrix (see Discussion: Rarity, below).

Another noteworthy feature of this community is found in the evenness of its abundance relationships. The data in Fig. 4 indicate a considerably greater equitability of population densities than is predicted even by MacArthur's "broken stick" model, which, of all the current theoretical formulations of abundance relationships, lies at the extreme of equitability (May 1975). A striking evenness of abundances characterizes the community whether one looks at (a) the entire community, (b) territorial species only, or (c) single guilds, such as arboreal insectivores. One of the reasons for this is that large numbers of species are permanent members of mixed flocks, in which membership is restricted to one pair per species (Munn and Terborgh 1979, Munn 1985). Many flocking species thus maintain nearly identical abundances. Perhaps there are other mechanisms in addition that favor evenness of abundances.

Biomass

We conservatively estimate the biomass of this community at ≈190 kg/km² (Appendix). In arriving at the figures shown in the Appendix table we used the number of pairs of each species, this being the accepted practice in temperate avian ecology. Not all tropical species readily lend themselves to this type of enumeration, however. In the case of group-breeding species we arbitrarily counted four members of each group as reproductives. For lekking and non-territorial species (e.g., hummingbirds), we followed procedures described in the Methods (see Census methods: Spot-mapping). These procedures expressly exclude non-breeding individuals, which were almost certainly present on the plot at the time of the census.

An independent estimate of the number of non-breeders in the population comes from the flock censuses conducted by C. Munn. The flocks contained 12 species in which the young continue to forage with their parents until the onset of the succeeding breeding season. Direct counts of these species prior to the breeding season in all flocks resident on the plot demonstrated the presence of 0.5 juvenile per pair of adults. This suggests that the stated biomass should be increased by 25% to account for unpaired juvenile birds. Moreover, we deleted all migrants and local species that did not regularly occupy the plot or include it within an established territory, thereby excluding numerous non-resident individuals that were harvesting resources on the plot. The biomass figures we give are thus understated.

Territory size

Spot-mapping data permitted the estimation of territory sizes for 111 species (Fig. 5). The sample is biased toward common species because it was seldom possible to measure territories >40 ha, since such territories tended to extend beyond the bounds of the plot. Given these limitations of the data set, mean territory sizes for all guilds are nevertheless very large (Table 1). The mean for all insectivores was 14 ha, and 11 ha for omnivores. Gleaners tended to have smaller territories than sallier/snatchers (8 vs. 12 ha), but the difference seems best accounted for by their considerably smaller mean size (23 vs. 54 g). Woodpeckers (bark-interior guild) are large bodied and have correspondingly large territories, while woodcreepers (bark-surface guild) have average territories and body masses for insectivores. Terrestrial insectivores were similarly representative of the average for both body size and territory size. Relative to the spatial requirements of their temperate zone counterparts, the territory sizes of Amazonian birds are roughly an order of magnitude larger.

Patchiness of spatial distributions

Nearly all natural environments contain heterogeneities at one or more spatial scales, and the one we have studied is no exception. One could define numerous scales of patchiness, starting at the level of individual trees, and concluding at the mosaic of forest types that makes up the landscape as a whole. Within the 97-ha plot, no two hectares would have the same tree species composition, as each hectare offers a sample of ≈200 species (dbh ≥ 10 cm) out of a possible total of >500. The spacing of crowns at 40 m in the canopy is many times greater than at 2 m in the understory. Every hectare is marked with the signs of recent and past treefalls. One such sign is the presence of elevated vine tangles, a favored haunt of several bird species. Slight undulations in the monotonously level terrain, differences of merely 10 or 20 cm, produce a patchwork of pools and emergent ridges after heavy rains. Where these pools form, the ground vegetation is dominated by *Heliconia metallica*, while a fern, *Trichomanes incisa*, predominates on the high spots. Different bird species forage near the ground in these areas. On a still larger scale there are vague patterns in drainage that appear to influence the frequency of treefalls and hence the tree turnover rate. The levee along the lake front, for example, is better drained than the forest 200 or 400 m inland, a fact that is reflected in a greater abundance of large trees. On a still larger scale, the plot itself has edges, the lake on the west, a seasonal stream on the north, a fig swamp on the southeast, etc. What is the effect of all these levels of patchiness on the distribution of birds?

A facile answer is that it depends on the bird. About 30 species occupy the entire plot, but the majority do not (Fig. 6). Of those that do not, some show obvious habitat associations, e.g., canopy vine tangles: *Cercomacra cinerascens*; *Heliconia* thickets: *Myrmeciza hyperythra*; margins of treefall openings: *Syristes sibilator*, *Ornithion inerme*; vine-covered rotting logs from bygone treefalls: *Microcerculus marginatus*, *Liosceles thoracicus*; tangled recent treefalls: *Myrmotherula campanisona*. Further examples are legion (cf. Schemske and Brokaw 1981). We shall return to the issue of patchiness in the Discussion (see Discussion: Patchiness, below).

TABLE 3. Mean territory sizes and body masses for some avian guilds in mature Amazonian floodplain forest.*

Guild	*N*	Mean territory size (ha)	Mean body size (g)*
Insectivore	83	14	30
Arboreal			
Gleaning	24	8	23
Sallying	10	12	34
Bark			
Interior	4	43	150
Surface	6	15	45
Terrestrial	9	13	51
Omnivore	16	12	50

* Only includes species having ≥1 territory completely contained within the census plot. Mean masses may differ from those given in Table 2 because the number of species was limited by this criterion.

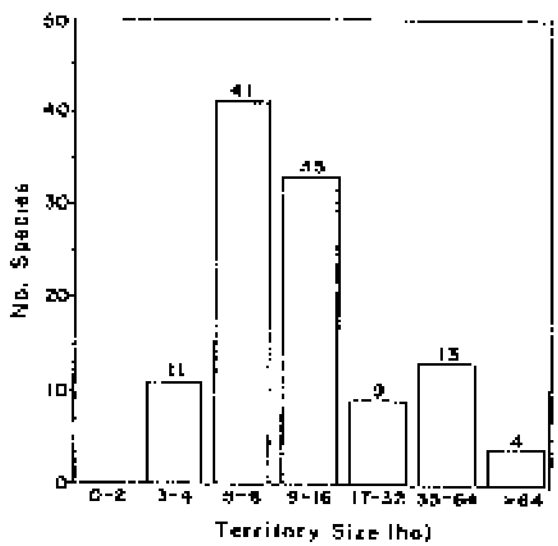

FIG. 5. The distribution of territory size among the 111 species whose territories could be measured. The number of species falling into each class is indicated atop the bars. No species occupied a territory of <2 ha and the median was 9 ha.

Guild structure of the community

Following conventional practice, we have classified the species into a set of trophic-behavioral guilds (Terborgh and Robinson 1986). When the guilds are compared with respect to biomass, some rather striking patterns emerge (Table 2). Insectivores, which almost completely monopolize many temperate bird communities, contribute only 18% of the biomass of the tropical community. Instead, granivores (43%) plus frugivores (15%) plus omnivores (11%) make up nearly three-fourths of the biomass, while accounting for only one-third of the species. The distribution of biomass is so skewed that 51% of it is contributed by only 13 species, a mere 5% of the total (3 tinamous, 2 cracids, a wood-quail, a trumpeter, a toucan, 2 icterids, a pigeon, a parrot, and a trogon). Significantly, this list includes the species most avidly sought by hunters, and several of them are now scarce or lacking in unprotected localities throughout the Neotropics (Terborgh

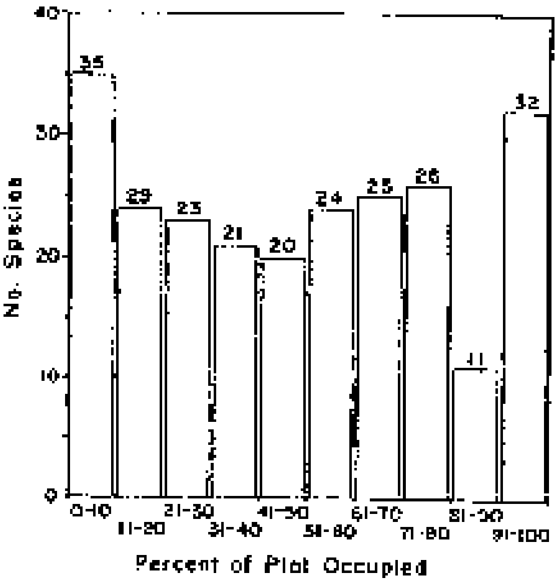

FIG. 6. The distribution of occupancy of the census plot among the 245 species with measured abundances. Numbers of species are indicated atop the bars. Fewer than 15% of the species occupied the entire plot.

et al. 1986). For this reason, biomass data from any but the most rigorously protected parks and reserves should be regarded with skepticism.

The data contain some further patterns worthy of comment. Granivores make by far the largest contribution to total biomass, 43%, and frugivores, with 19%, fall into second place. These two guilds show strongly contrasting levels of arboreality, as 77% of the granivore biomass is composed of terrestrial species, while 72% of the frugivore biomass is made up of arboreal species. This pattern is almost precisely mirrored by the mammals of this ecosystem (Terborgh 1986).

Passerines predominate among gleaning insectivores (including dead-leaf gleaners: 94% of biomass), while non-passerines predominate among species that harvest prey on the wing (57%). The latter group of species includes the members of five families that exhibit an energy-conserving, sit-and-wait foraging behavior (Nyctibiidae, Caprimulgidae (some), Momotidae, Galbulidae, Bucconidae). In contrast, nearly all the active searchers in the community are passerines.

Body size relationships

The mean size of species differs drastically among guilds (Fig. 7). Granivores are uniformly large, as all of the 22 species weigh >67 g. Raptorial birds are also large, and comprehend a somewhat greater size range. Frugivores likewise span a broad spectrum of sizes, from a 9-g manakin to a 1300-g guan. Nectarivores (all hummingbirds) are uniformly small, averaging only 5 g. Omnivores in general are much smaller than obligate frugivores, the median masses of the two guilds being, respectively, 35 g and >70 g. Finally, among insectivores, the median non-passerine, at 85 g is more than three times the size of the 25-g median passerine.

DISCUSSION

Species richness

The extraordinary species diversity of tropical forest bird communities has fascinated generations of ornithologists and ecologists, and its causes are still only partly understood (Terborgh 1980, 1985). The tropical vs. temperate contrast in bird diversity particularly intrigued Robert MacArthur, and in a 1966 paper with two associates the question was raised of whether the higher species numbers found in tropical bird communities were due to truly greater levels of alpha diversity, or merely to higher beta diversity (finer subdivision of habitats) (MacArthur et al. 1966).

In the light of hindsight, it is clear that the data presented did not resolve the issue, because the census

TABLE 2. Guilds and guild biomass in the bird community of a mature Amazonian floodplain forest.

Guild	No. spp	No. inds.*	Mean mass (g)	Biomass density (g/100 ha)†
Aquatic	8	9.5	430	3075
Carrion	1	0.5	1200	600
Folivore		...	...	...
Frugivore				
Arboreal	23	192	224	25 504
Terrestrial	2	17	553	9830
Granivore				
Arboreal	12	80	485	18 295
Terrestrial	10	200	850	61 475
Insectivore				
Aerial	1	2	87	174
Antfollower	7	13	79	1565
Arboreal				
Dead Leaf	6	43	28	970
Gleaner	37	410	23	8185
Sallier/Snatch	40	306	47	14 605
Bark				
Interior	9	38.5	120	4235
Surface	12	84.5	44	3045
Terrestrial				
Gleaner	11	108	46	4910
Sallier	2	13	35	455
Nectarivore	11	44	5	226.5
Omnivore, Arboreal	35	302	60	21 295
Raptor				
Diurnal	11	13.5	384	4608
Nocturnal	5	23.5	324	7630
	245	1856		186 547.5

* We use number of individuals because not all species were in pairs. The values given here are taken from the Appendix with each pair counted as two individuals.

† The biomass figures presented here are for the 97-ha census plot. The total rounds off to 190 kg/100 ha, regardless of whether or not it is adjusted to an even 100 ha.

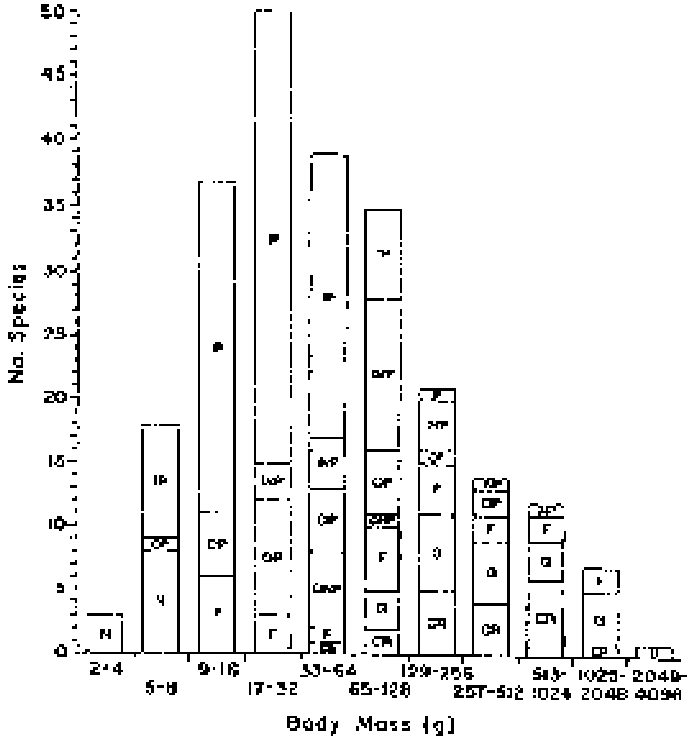

FIG. 7. The distribution of body mass by guild among 237 non-aquatic species that maintained measurable abundances on the plot. Median body mass is 44 g. Key: CR = carnivore/raptor; F = frugivore; G = granivore; INP = non-passerine insectivore; IP = passerine insectivore; N = nectarivore; ONP = non-passerine omnivore; OP = passerine omnivore.

of 25 pairs of birds on Barro Colorado Island included only 17 species, a number that is easily surpassed in rich deciduous forests in the U.S.

A subsequent survey of the same locality by Willis (1980) reported 95 species from the mature forest sector of the island. How is it possible that two studies of the same forest could differ in the number of bird species recorded by a factor of more than 5? The question does more than raise a straw man, because such glaring disparities characterize the entire literature on tropical forest bird communities (e.g., contrast Davis 1955, McClure 1969, Orians 1969, and Karr 1971 with Terborgh and Weske 1969, Pearson 1975, Thiollay 1986, and Brosset 1989).

The source of these disparities seems clearly to lie in the matter of scale. The authors who have reported low species numbers for their localities have invariably studied small plots (Davis 1955: 6 ha; MacArthur et al. 1966: 5 ha; McClure 1969: <2 ha; Orians 1969: 1.5 ha; Karr 1971: 2 ha), while those who have reported high numbers of species have studied much larger areas (Terborgh and Weske 1969: ≈25 ha; Pearson 1975: 15 ha; Willis 1980: 1500 ha; Thiollay 1986: ≈7000 ha; Brosset 1989: 200 ha).

Our finding that the Amazonian forest can harbor >160 species whose territories or areas of occupancy overlap at a point is conclusive evidence that the alpha diversity of Neotropical forest bird communities is indeed very high (also see Terborgh 1980). If 160 species can overlap at a point, why then do small plots lead to such serious underestimates of alpha diversity? The answer seems to be that species with large territories become nearly invisible in small areas. Karr (1971, 1977), for example, accorded "irregular" status to 77 (52%) of 148 non-migratory species recorded in his plot over many months of observation. If one were to include Karr's "irregular" species with those in his "resident" (56 spp) and "regular" (15 spp) categories, then his numbers would not be too different from ours (allowing for the fact that there are somewhat fewer species in lowland Panama than in Amazonia). A 2-ha plot simply cannot do justice to a community in which numerous species possess territories that are larger than the plot. Small plot size seems also to lead to errors in the estimation of abundances, as we shall see below.

Patchiness

The contribution of patchy distributions to the total diversity of the community is suggested by the fact that the 97-ha plot contained ≈45% more species than overlapped at any single point. This raises the question

TABLE 3. Correlates of rarity in two Neotropical bird communities (classification based on Karr [1977]). Data are numbers of species.

	Panama (Karr 1977)	Peru (Terborgh et al.) Densities measured (75 spp.)	Peru (Terborgh et al.) Densities not measured* (59 spp.)	Peru (Terborgh et al.) Total (134 spp.)
I. Species associated with other habitats				
A. Aquatic habitats	5	14	10	24
B. Wanderers from nearby habitats	16	34	35	69
C. Foothill forms	6	0	5	5
D. Species typical of dry forest	4	0	0	0
II. Species rare due to sampling problems				
A. Large species with large home ranges	15	19	9	28
B. Difficult to observe canopy species	4	5	0	5
C. Nocturnal species easily overlooked	4	2	0	2
III. Species exhibiting seasonal movements				
A. Move out in late wet and dry seasons	6	0	0	0
B. Move in during dry season from Pacific slope	7	0	0	0
IV. Rare due to food or feeding behavior				
A. Food resource rare—follow army ants	4	2	0	2
B. Specialized hunting techniques (bird hawks)	3	1	0	1
V. Reason unknown	3	0	0	0

* Resident species with population densities too low to measure (<0.5 pairs/km²) plus vagrants from other habitats and elevational migrants (see Discussion: Rarity).

of how large an area must be censused to include all the regular members of the community.

In the course of 15 yr of ornithological work at Cocha Cashu we have become well acquainted with ≈10 km² of floodplain habitat that is served by the station's trail system. More than half of this area is covered by mature forest (Terborgh et al. 1984). In this much larger area we have documented the occurrence of only three resident species that were not recorded in our census of the 97-ha plot (referring strictly to mature floodplain forest). The scale on which we chose to conduct the census was thus adequate to account for 99% of the species that regularly breed in the habitat, though we could not have said so in advance. Retrospectively, it can be concluded that a plot size of anything less than 30–50 ha would have missed a significant fraction of the species present.

Wide-ranging species, such as raptors, parrots, and colonial icterids, are prominently represented among the species found to occupy the entire plot, although some small territorial insectivores are included as well. Members of most avian families were included in the much longer list of species that used the plot in a patchy fashion. Many of these have preferences for particular microhabitats, such as vine tangles, treefall openings, etc., as suggested above (Results: Patchiness of Spatial Distributions). Some obligate members of mixed flocks might have been restricted by the occurrence of flocks, rather than by the habitat per se. A few species were found to be restricted in their occurrence by aggressive interactions with related species (Pierpont 1986). Generally speaking, the evidence suggests that the phenomenon of patchy habitat use has no single explanation, but rather several.

The distribution of mixed flocks may reflect different scales of patchiness in the understory and canopy. The average understory flock defends ≈5 ha, while the average canopy flock occupies >20 ha, although similar numbers of individuals are included in both types of flock (Munn 1985). In spite of the seemingly greater possibility of integrating patchiness in their larger territories, canopy flocks seem to view the plot as less homogeneous, as they occupy only about two-thirds of it, while understory flocks blanket the entire area. Perhaps this is a consequence of the radically different patch size in their respective environments, i.e., the crown diameters of canopy trees are commonly in the range of 20–40 m (300–1200 m²) while those of understory trees are usually in the range of 2–4 m (3–12 m²).

Beyond the issue of crown size is the patchiness of the canopy itself. Treefall openings of various size and age punctuate the entire forest. Canopy flocks seem to avoid areas where openings are especially frequent (Munn 1985). These matters of patchiness and scale need to be addressed systematically before questions about habitat use can be answered in detail.

Rarity

Karr (1977) has analyzed the correlates of rarity in the avifauna of a 2-ha plot in Panama. Rare species were those that fell into his "irregular" category, mentioned above—those that were recorded only occasionally or seasonally. Twenty-four of the 77 species were detected only once, and another 22 only twice. Detectability was not a condition of rarity in our situation, as most of the rare species on our plot were detected from several to many times. For the sake of creating a classification compatible with Karr's, we have designated three categories of species as rare: (1) resident species with measured population densities of ≤1 but ≥0.5 pair/km², (2) resident species with population densities too low to measure (<0.5 pair/km²) and (3) non-resident species, including vagrants, occasional visitors from aquatic habitats, and elevational migrants, but excluding aerial species and latitudinal migrants. These three categories include a total of 134 species, 75 of which had measured population densities (Table 3).

The largest class of rare species in both Karr's plot and ours consisted of birds that live more commonly in other nearby habitats. In our case the habitats in question were, in order of decreasing importance, early successional vegetation, upland forest, swamps, streams, lake margins, and bamboo patches. The 69 species from other habitats recorded by us were either wanderers or single resident pairs that lived partially or entirely on the plot. Of course, such birds are not rare in any absolute sense, but only in the habitat sampled by the census. Including them in the tabulation creates an inflated sense of rarity in the community as a whole.

The next largest category of rarity in both Panama and Peru consisted of birds that are large, or large for their guilds, and that maintain low population densities everywhere. Such species are constitutively rare, and merit special attention in conservation planning. The 28 such species in our plot included 13 raptors, 6 parrots and 3 woodpeckers, plus a few others that were among the largest members of their guilds (e.g., *Neomorphus geoffroyi*, *Nyctibius grandis*, *Jacamerops aurea*, *Nasica longirostris*). Many of these are vulnerable to habitat fragmentation and human intervention. Having densities of <1 pair/km², they require large areas of intact habitat for the maintenance of stable populations.

Most of the remaining categories in Karr's classification—foothill forms, species typical of dry forest, etc.—are concerned with local, rather than with global, rarity. Rare professional ant-followers (e.g., *Neomorphus*) and specialized bird hawks (*Accipiter* spp.) seem better included in class IIA with all other species having intrinsically large home ranges. If one admits these two exceptions to Karr's classification, it reduces to extreme simplicity: rare species are those that are rare locally but common somewhere else, or those that are (usually) large and intrinsically limited to low population densities. In our community the latter category included 33 species (the sum of Karr's categories IIA, IVA and IVB) or ≈10% of the total of 319.

Comparisons with Other Forest Bird Communities

Some temperate forest bird communities

Hubbard Brook, New Hampshire, USA.—One of the best studied bird communities in North America is the one at Hubbard Brook. This is a secondary northern hardwood forest dominated by beech, sugar maple, and yellow birch, with white ash and red spruce as minor components. Twenty-nine species have bred in a 10-ha plot during 15 yr of monitoring, although only 24 species are present in an average year (Holmes et al. 1986). About 1,000 pairs of birds, comprising a biomass of ≈40 kg/km², breed in 100 ha of this forest (Holmes and Sturges 1975).

Surprisingly, in view of the many differences in community structure, the density of breeding individuals at Cocha Cashu is very similar—≈1920 birds/100 ha—roughly equivalent to 955 pairs. However, the avian biomass at Cocha Cashu is five times greater than in New Hampshire. This is due mostly to the presence of large-bodied granivores and frugivores, trophic categories that are entirely missing at Hubbard Brook. (The three finch species at Hubbard Brook feed mostly on insects during the breeding season. Nevertheless, one should bear in mind that the principal granivores of the deciduous forest, the Wild Turkey and Passenger Pigeon, are either locally or globally extinct, as is the primary source of mast, the American chestnut. The pre-Columbian avian biomass of the deciduous forest might have been considerably higher than today's.)

Considering only insectivores, the Hubbard Brook forest actually supports a higher biomass (40 vs. 34 kg/km²), but if one includes the omnivore category, the Cocha Cashu total is then higher (55 kg/km²). Since the average insectivore in the New Hampshire forest weighs 20 g, while its Peruvian counterpart weighs 32 g, it emerges that the temperate forest harbors a larger number of smaller insectivores than the tropical forest. The larger size of tropical insectivorous birds has previously been noted (Schoener 1971), and is almost certainly due to the larger mean size of tropical insects (Schoener and Janzen 1968). Moreover, Neotropical insectivorous birds of a given size tend to have heavier bills than their temperate counterparts, an apparent consequence of the fact that hard-bodied orthoptera are the main category of prey in the tropical forest, while soft-bodied lepidopteran larvae are the mainstay of the temperate forest (Greenberg 1981, Holmes et al. 1986).

Bialowieza.—Primary forests in the north temperate regions of our planet have in this century become almost vanishingly scarce, and the few that remain have largely been neglected by ornithologists. An exception is the magnificent forest of Bialowieza in Poland, which preserves a 50-km² sample of the European urwald. The birds of Bialowieza have been meticulously censused in a series of 13 plots of 24–32 ha representing the major stand types to be found in the forest (Tomialojc et al. 1984). Bird densities at Bialowieza are distinctly less than at Hubbard Brook or at Cocha Cashu. Four tracts of oak–hornbeam forest contained about 40 species each at a combined density of 620 pairs/100 ha, while three tracts of mixed or coniferous forest harbored about 35 species at a density of ≈330 pairs/

100 ha. Tomialojc et al. note that these densities are lower than reported for many secondary temperate forests, and speculate that a high diversity of avian and mammalian predators at Białowieża may limit the numbers of nesting birds. To this point, Holmes et al. (1986) document a decline in the densities of 70% of the species breeding at Hubbard Brook between 1969 and 1984, as the age of the forest increased from 60 to 75 yr.

Tropical forest bird communities

The possibilities for making detailed comparisons of the Cocha Cashu bird community with other similar communities are severely limited by the fact that no two tropical studies have employed the same methodology. For many sites, species lists are all that is available, sometimes accompanied by qualitative estimations of abundance (e.g., Slud 1960, Brosset and Erard 1986). Quantitative data on population structure are scarce indeed. We review below the few tropical data sets known to us.

Panama.—Karr reports a total population density of 1820 pairs/km² and a standing crop biomass of 131 kg/km² for his 2-ha plot in Panama. His density value is nearly twice ours, while his biomass estimate is only two-thirds as great. While the two localities undoubtedly differ in the abundance and biomass of birds, it seems probable that some of the discrepancy can be attributed to identifiable circumstances. The data at face value suggest that birds are smaller and more numerous at the Panamanian site. It seems more likely that the smaller average size (low biomass) of the birds on Karr's plot was due to the fact that several of the largest species, namely, curassows, guans, and macaws were locally extinct, and that others (tinamous, wood-quail) were seriously depleted by hunting. If present in the same numbers as in Peru, the members of these groups would eliminate the biomass discrepancy between the two sites.

The greater density of individuals recorded by Karr could in part be an artifact of the small size of his plot. No bird at Cocha Cashu has a territory as small as 2 ha, although the four most abundant species on Barro Colorado Island apparently do (Greenberg and Gradwohl 1986). Karr lists 12 species as having abundances of ≥1 pair/2 ha. Overall, the mean density of the 56 "resident" species for which Karr gives population estimates is >7 times greater than that of the mean species at Cocha Cashu. Even if we consider only the 56 most abundant species at Cocha Cashu, the mean density per species recorded by Karr is still nearly three times higher. We do not wish to discount the possibility that birds are actually more numerous at the Panamanian site, but, given that Karr's plot included only 2 ha, it seems likely that the territory sizes of many species might have been underestimated, leading to overestimation of their densities. Proper reconciliation of the two sets of results will require a large-scale census of the Panamanian site.

French Guiana.—A recent publication by Thiollay (1986) reports on the bird community at three forested localities in French Guiana. The methodology, adapted from Balph et al. (1977), derives population estimates from the accumulated results of numerous short (250-m) strip transects walked on random compass lines through the habitat. We shall consider the results from Belvédère, the most thoroughly studied of the three sites. Thiollay reports an aggregate density equivalent to 760 pairs/km² for a total of 263 species, comprising a biomass of 148 kg/km². This represents a valiant effort, although some aspects of the methodology can be questioned. The use of transects for estimating densities is likely to favor the more conspicuous species, with a resultant tendency to underestimate the rest. This may in part explain why nearly 60% of the species at the three sites were estimated to have densities of ≤1 pair/km² (vs. 31% at Cocha Cashu). Another factor that may contribute to the low reported densities for many species is the fact that the results from all three sites combine transects walked through several distinct habitat types, e.g., palm swamp, riparian forest, poorly drained forest on level ground, slope and ridge forest, granite "inselbergs," etc. Habitat specialists would appear to be rare, while habitat generalists would appear common, quite independently of their actual ecological densities. Nevertheless, the effort to carry out systematic sampling of 70 km² of tropical habitat is the first of its kind and is to be commended.

Gabon.—The most comprehensive work on forest birds in Africa is that of Brosset and Erard at M'Passa in Gabon. Two recent publications report on the results of 20 yr of study focused on a 2-km² plot of primary lowland forest (Brosset and Erard 1986, Brosset 1990). Their methodology paralleled our own in that it involved "a combination of approaches including visual observations, captures and recaptures, location and identification of the nests, pointing on maps of colour-marked individuals met on the quadrats, localizing the singers, provoking territorial contests by tape recording and play-back, following and observing the mixed parties" (Brosset 1990). Unfortunately, there is no more detail given than this, so one has to assume that the methodology was applied in a quantitative fashion.

A total of 364 species was recorded in the 2-km² plot which fronted on the Ivindo River. Of these, 175 are "strict inside the untouched primary forest," another 138 occurred in disturbed vegetation bordering the river and on the campus of the research station, and an additional 51 were palearctic migrants, also confined to edges and disturbed vegetation. Brosset reports a total population density of 3690 individuals/km², of which 1235 individuals/km² were bulbuls (Pycnonotidae) of 25 species. The most common species, *Andropadus latirostris* (Pycnonotidae), is reported to have a density of 500 individuals/km², fully 10 times that of the most abundant species at Cocha Cashu (*Cacicus cela*, Icteridae), and the densities of three additional species were estimated at 100–150 individuals/km². Despite the high concentration of individuals, the biomass is given as 187 kg/km², the same as at Cocha Cashu, suggesting that the average biomass per individual in this African forest is only half as great as in Peru. This could be due to a scarcity of large frugivores and granivores, or simply to the occurrence of poaching in the area. Without full details, no definite conclusion can be drawn.

New Guinea.—One further tropical forest site for which there is quantitative population data is a 2.5-ha plot located in lowland floodplain forest near Port Moresby (Bell 1982). The results probably suffer from distortions of over- and underestimation resulting from the small size of the plot. Nevertheless, the data should be comparable to those of Karr from Panama, because the larger frugivores and granivores were locally extinct in both localities, and because the plot sizes were similar. Eighty-six species are listed as resident, another 16 as "probably resident" and 2 more as breeding visitors, for a total of 104. Aggregate population density, adjusted to a standard 100 ha, is given as the equivalent of 3450 pairs, a value that is nearly twice that of any of the other localities we have considered. Equally remarkable is the biomass of 496 kg/km², which takes into account only the 84 species for which Bell made population-density estimates. This surprising biomass is mainly contributed by the high reported density of individuals, because the average biomass per bird (72 g) is intermediate between the values found in Panama (50 g) and Peru (100 g). Despite the missing large frugivores, the proportion of the biomass that is contributed by frugivores (including granivores) and omnivores is the same as in Peru (73%). Perhaps the absence of primates and general scarcity of arboreal mammals in New Guinea is partially compensated for by an increased avian biomass.

Coda

The reader will now appreciate that the comparative study of tropical bird communities is currently in its infancy. In order for us to progress beyond today's state of the art, it will be necessary for groups working in different parts of the tropics to employ standard methodology, and to study their respective communities on a sufficient scale to include most or all the resident species, not just the more common ones. In many parts of the tropics there is no time to lose, because, as we have already seen, much of the effort invested to date has been expended on localities in which the species that contribute most to biomass have been extirpated or drastically reduced by hunting. Pristine localities carrying the full natural complement of species at unperturbed population densities are a thing of the past in eastern North America. In Europe there is only Bialowieza. There is still time to document nature in its pre-human condition in parts of the tropics, but probably not much time. We should therefore not delay in getting on with the task.

Acknowledgments

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Literature Cited

Balph, M. H., L. C. Stoddart, and D. F. Balph. 1977. A simple technique for analyzing bird transect counts. Auk 94:606–607.

Beebe, W. 1925. The variegated tinamou, *Crypturellus variegatus variegatus*. Zoologica 6:195–227.

Bell, H. L. 1982. A bird community of lowland rainforest in New Guinea. I. Composition and density of the avifauna. Emu 82:24–41.

Brosset, A. 1990. A long term study of the rain forest birds in M'Passa (Gabon). *In* A. Keast, editor. Biogeography and ecology of forest birds. SPB Academic, The Hague, The Netherlands.

Brosset, A., and C. Erard. 1986. Les oiseaux des régions forestières du nord-est du Gabon, Volume 1. Écologie et comportement des espèces. Société Nationale de Protection de la Nature, Paris, France.

Davis, L. I. 1955. Bird census 27. Audubon Field Notes 9: 425–426.

Emlen, J. T., and M. J. DeJong. 1981. The application of song detection threshold distance to census operations. Studies in Avian Biology 6:346–352.

Fitzpatrick, J. W. 1981. Search strategies of tyrant flycatchers. Animal Behavior 29:810–821.

Fogden, M. P. L. 1972. The seasonality and population dynamics of equatorial forest birds in Sarawak. Ibis 114: 307–343.

Foster, R. B. 1980. Heterogeneity and disturbance in tropical vegetation. Pages 75–92 *in* M. E. Soulé and B. A. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts, USA.

Foster, R. B., J. B. Arce, and T. S. Wachter. 1986. Dispersal and the sequential plant communities in Amazonian Peru floodplain. Pages 357–370 *in* A. Estrada and T. H. Fleming, editors. Frugivores and seed dispersal. Dr. W. Junk, Dordrecht, The Netherlands.

Gentry, A. H. 1988. Tree species richness of upper Amazonian forests. Proceedings of the National Academy of Sciences (USA) 85:156–159.

Gentry, A. H., and J. Terborgh. In press. Composition and turnover of the Cocha Cashu mature floodplain forest. *In* A. H. Gentry, editor. Four Neotropical forests. Yale University Press, New Haven, Connecticut, USA.

Greenberg, R. 1981. Dissimilar bill shapes in tropical versus temperate forest foliage-gleaning birds. Oecologia (Berlin) 49:143–147.

Greenberg, R., and J. Gradwohl. 1986. Constant density and stable territoriality in some tropical insectivorous birds. Oecologia (Berlin) 69:618–625.

Holdridge, L. R. 1967. Life zone ecology. Occasional Papers of the Tropical Science Center (San Jose, Costa Rica).

Holmes, R. T., T. W. Sherry, and F. W. Sturges. 1986. Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook. Ecological Monographs 56: 201–220.

Holmes, R. T., and F. W. Sturges. 1975. Avian community dynamics and energetics in a northern hardwoods ecosystem. Journal of Animal Ecology 44:175–200.

James, F. C., and H. H. Shugart. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727–736.

Kalliola, R., J. Salo, and Yrjö Mäkinen. 1987. Regeneración natural de selvas en la Amazonia peruana 1: dinámica fluvial y sucesión ribereña. Memorias del Museo de Historia Natural "Javier Prado" Number 18.

Karr, J. R. 1971. Structure of avian communities in selected Panama and Illinois habitats. Ecological Monographs 41: 207–233.

———. 1976. Within- and between-habitat avian diversity in African and Neotropical lowland habitats. Ecological Monographs 46:457–481.

———. 1977. Ecological correlates of rarity in a tropical forest bird community. Auk 94:240–247.

———. 1980. Geographical variation in the avifaunas of tropical forest undergrowth. Auk 97:283–298.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecological Monographs 14:67–106.

Lovejoy, T. E. 1975. Bird diversity and abundance in Amazon forest communities. Living Bird 13:127–191.

Lovejoy, T. E., R. O. Bierregaard, Jr., A. B. Rylands, J. R. Malcolm, C. E. Quintela, L. H. Harper, K. S. Brown, Jr., A. H. Powell, G. V. N. Powell, H. O. R. Schubart, and M. B. Hays. 1986. Edge and other effects of isolation on Amazon forest fragments. Pages 257–285 *in* M. E. Soulé, editor. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts, USA.

MacArthur, R. H., H. Recher, and M. L. Cody. 1966. On the relation between habitat selection and species diversity. American Naturalist 100:319–332.

May, R. M. 1973. Stability and complexity in model ecosystems. Princeton University Press, Princeton, New Jersey, USA.

McClure, H. E. 1969. Estimations of bird population density in primary forest of Malaya. Malay Nature Journal 22:179–183.

Munn, C. A. 1985. Permanent canopy and understory flocks in Amazonia: species composition and population density. Pages 683–712 *in* P. A. Buckley, M. S. Foster, E. S. Morton, R. S. Ridgely, and F. G. Buckley, editors. Neotropical Ornithology. Ornithological Monographs Number 36. American Ornithologists' Union, Washington, D.C., USA.

Munn, C. A., and J. Terborgh. 1979. Multi-species territoriality in Neotropical foraging flocks. Condor 81:338–347.

Orians, G. H. 1969. The number of bird species in some tropical forests. Ecology 50:783–801.

Pearson, D. L. 1975. The relation of foliage complexity to ecological diversity of three Amazonian bird communities. Condor 77:453–466.

———. 1977. A pantropical comparison of bird community structure on six lowland forest sites. Condor 79:232–244.

Pierpont, N. 1986. Interspecific aggression and the ecology of woodcreepers (Aves: Dendrocolaptidae). Dissertation. Princeton University, Princeton, New Jersey, USA.

Robinson, S. K. 1985. Coloniality in the Yellow-rumped Cacique as a defense against nest predators. Auk 102:506–519.

———. 1986. Three-speed foraging during the breeding cycle of the Yellow-rumped Cacique (Icterinae: *Cacicus cela*). Ecology 67:394–405.

Salo, J., R. Kalliola, I. Häkkinen, Y. Mäkinen, P. Niemelä, M. Puhakka, and P. D. Coley. 1986. River dynamics and the diversity of Amazon lowland forest. Nature 322:254–258.

Schemske, D. W., and N. Brokaw. 1981. Treefalls and the distribution of understory birds in a tropical forest. Ecology 62:938–945.

Schoener, T. W. 1971. Large-billed insectivorous birds: a precipitous diversity gradient. Condor 73:154–161.

Schoener, T. W., and D. H. Janzen. 1968. Notes on environmental determinants of tropical versus temperate insect size patterns. American Naturalist 102:207–224.

Slud, P. 1960. The birds of finca "La Selva" Costa Rica, a tropical wet forest locality. Bulletin of the American Museum of Natural History 121:49–148.

Terborgh, J. 1971. Distribution on environmental gradients: theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. Ecology 52:23–40.

———. 1977. Bird species diversity on an Andean elevational gradient. Ecology 58:1007–1019.

———. 1980. Causes of tropical species diversity. Proceedings of the International Ornithological Congress XVII:955–961.

———. 1983. Five New World primates: a study in comparative ecology. Princeton University Press, Princeton, New Jersey, USA.

———. 1985. Habitat selection in Amazonian birds. Pages 311–338 *in* M. L. Cody, editor. Habitat selection in birds. Academic Press, New York, New York, USA.

———. 1986. Community aspects of frugivory in tropical forests. Pages 371–384 *in* A. Estrada and T. H. Fleming, editors. Frugivores and seed dispersal. Dr. W. Junk, Dordrecht, The Netherlands.

Terborgh, J., L. H. Emmons, and C. Freese. 1986. La fauna silvestre de la Amazonia: el despilfarro de un recurso renovable. Boletín de Lima 8:77–85.

Terborgh, J., J. W. Fitzpatrick, and L. Emmons. 1984. Annotated checklist of bird and mammal species of Cocha Cashu Biological Station, Manu National Park, Peru. Fieldiana (Zoology, New Series) 21:1–29.

Terborgh, J., and K. Petren. *In press*. Development of habitat structure through succession in an Amazonian floodplain forest. *In* S. S. Bell, E. D. McCoy, and H. R. Mushinsky, editors. Habitat structure: the physical arrangement of objects in space. Chapman and Hall, London, England.

Terborgh, J., and S. K. Robinson. 1986. Guilds and their utility in ecology. Pages 65–90 *in* J. Kikkawa and D. J. Anderson, editors. Community ecology: pattern and process. Blackwell Scientific, Melbourne, Australia.

Terborgh, J., and J. S. Weske. 1969. Colonization of secondary habitats by Peruvian birds. Ecology 50:765–782.

Terborgh, J., and B. Winter. 1983. A method for siting parks and reserves with special reference to Colombia and Ecuador. Biological Conservation 27:45–58.

Thiollay, J. M. 1986. Structure comparée du peuplement avien dans trois sites de forêt primaire en Guyane. Révue d'Ecologie la Terre et la Vie 41:59–105.

Tomiałojć, L., T. Wesołowski, and W. Walankiewicz. 1984. Breeding bird community of a primaeval temperate forest (Białowieża National Park, Poland). Acta Ornithologica 20: 241–310.

Willis, E. O. 1980. Ecological roles of migratory and resident birds on Barro Colorado Island, Panama. Pages 205–225 *in* A. Keast and E. S. Morton, editors. Migrant birds in the Neotropics. Smithsonian Institution Press, Washington, D.C., USA.

Willis, E. O., and Y. Oniki. 1978. Birds and army ants. Annual Review of Ecology and Systematics 9:243–263.
Wong, M. 1986. Trophic organization of understory birds in a Malaysian Dipterocarp forest. Auk 103:100–116.
Zimmerman, D. A. 1972. The avifauna of the Kakamega forest, Western Kenya, including a bird population study. Bulletin of the American Museum of Natural History 149: 255–340.

APPENDIX

Population data for 319 species recorded in the 97-ha census plot between 15 August and 10 November 1982.*

Species†	Mass (g)	No. pairs/100 ha‡	No. inds./100 ha§	Biomass density (g/100 ha)	Census method‖	Terr. size¶ (ha) Mean (N)	% plot occup.#	Guild**
TINAMIDAE (9 species)								
Tinamus tao	2000	0.50		2000	SM		25	G, T
Tinamus major	1170	8.50		19 900	SM		100	G, T
Tinamus guttatus	600	-			SM			G, T
Crypturellus cinereus (E)	450	1.50		1350	SM		15	G, T
Crypturellus soui (E)	205	1.00		410	SM		10	G, T
Crypturellus bartletti	241	13.00		6270	SM		100	G, T
Crypturellus variegatus	350	0.50		350	SM		15	G, T
Crypturellus atrocapillus (V)	453	+			SM			G, T
Crypturellus undulatus (E, ES)	540	5.00		5400	SM		60	G, T
ARDEIDAE (3 species)								
Agamia agami (LE, SI)	609	0.25		305	VO		5	Aquat.
Tigrisoma lineatum (LE, SI)	840	0.25		420	VO		5	Aquat.
Cochlearius cochlearius (LE, SI)	550	0.25		275	VO		5	Aquat.
THRESKIORNITHIDAE (1 species)								
Mesembrinibis cayennensis (LE, SI)	670	0.25		335	VO		5	Aquat.
CATHARTIDAE (3 species)								
Sarcoramphus papa (A)	3125	-			VO			Carr.
Coragyps atratus (A)	1375	–			VO			Carr.
Cathartes melambrotus (A)	1200	0.25		600	VO			Carr.
ACCIPITRIDAE (14 species)								
Elanoides forficatus (A)	400	+			VO			I, Aer.
Leptodon cayanensis	550	0.25		275	VO		30	R, D
Harpagus bidentatus (P)	260	1.00		520	SM		50	R, D
Ictinia plumbea (A)	240	+			VO			I, Aer.
Ictinia mississippiensis (M, A)					VO			I, Aer.
Accipiter bicolor (E)	210	0.25		105	VO		25	R, D
Accipiter superciliosus	120	0.25		60	VO		?	R, D
Buteo brachyurus	490	+			VO		?	R, D
Leucopternis schistacea (ES, Sw)	555	0.25		150	SM		20	R, D
Morphnus guianensis	1750	+			VO		100?	R, D
Harpia harpyja	4500	+			VO		100?	R, D
Spizastur melanoleucus	850	+			VO		100?	R, D
Spizaetus ornatus	925	0.25		465	VO		100	R, D
Spizaetus tyrannus	1025	-			VO		100?	R, D
FALCONIDAE (7 species)								
Herpetotheres cachinnans	550	1.00		1100	SM		75	R, D
Micrastur semitorquatus	550	0.25		275	SM		15	R, D
Micrastur ruficollis	230	1.50		690	SM	≥40 (1)	90	R, D
Micrastur gilvicollis	220	1.50		660	SM	≥40 (1)	70	R, D
Daptrius ater (ES)	370	-			VO			R, D
Daptrius americanus	585	-			SM		100?	R, D
Falco rufigularis (A, E)	155	0.25		78	SM		35	R, D
CRACIDAE (4 species)								
Ortalis motmot (ES)	415	+			SM		15	F, A
Penelope jacquacu (E)	1280	1.00		2560	SM		20	F, A
Aburria pipile	1200	2.50		6000	SM		50	F, A
Crax mitu (E)	3060	2.50		15 300	SM		90	G, T
PHASIANIDAE (1 species)								
Odontophorus stellatus	310		32	9920	SM	8 (8)	100	G, T
OPISTHOCOMIDAE (1 species)								
Opisthocomus hoazin (LE)	555	–			VO			Fol. A
PSOPHIIDAE (1 species)								
Psophia leucoptera	990		9	8910	SM	>100 (1)	100	F, T
RALLIDAE (1 species)								
Aramides cajanea (LE, SI)	515	1.50		1550	SM		20	Aquat.
EURYPYGIDAE (1 species)								
Eurypyga helias (LE, SI)	190	0.25		95	SM, VO		10	Aquat.

APPENDIX. Continued.

Species†	Mass (g)	No. pairs/100 ha‡	No. indivs./100 ha‡	Biomass density (g/100 ha)	Census method§	Terr. size¶ (ha) Mean (N)	% plots occup.#	Guild**
COLUMBIDAE (5 species)								
Columba cayennensis (LE)	260	–			SM			F, A
Columba subvinacea (E)	125	+			SM			F, A
Columba plumbea	210	8.50		3570	SM		80	F, A
Leptotila rufaxilla (E)	175	1.50		525	SM		25	G, T
Geotrygon montana (E)	115	4.00		920	MN		100	F, T
PSITTACIDAE (18 species)								
Ara ararauna	1125	1.00		2250	SM × GC		100	G, A
Ara macao	1015	1.00		2030	SM × GC		100	G, A
Ara chloroptera	1250	1.00		2500	SM × GC		100	G, A
Ara severa (ES)	430	1.00		860	SM × GC		25	G, A
Ara manilata (V)	370	+			SM × GC			G, A
Ara couloni	250	–			SM × GC			G, A
Aratinga weddellii (ES)	110	–			SM × GC		10	G, A
Aratinga leucophthalmus	190	3.00		1140	SM × GC		60	G, A
Pyrrhura picta	67	4.00		536	SM × GC		40	G, A
Pyrrhura rupicola	75	3.50		525	SM × GC		90	G, A
Forpus sclateri (ES)	25	+			SM × GC			G, A
Brotogeris cyanoptera	67	16.00		2144	SM × GC		100	G, A
Brotogeris sanctithomae (ES)	64	+			SM × GC			G, A
Pionites leucogaster	155	6.00		1860	SM × GC		80	G, A
Pionopsitta barrabandi	140	0.50		140	SM × GC		70	G, A
Pionus menstruus (ES)	295	+			SM × GC		15	G, A
Amazona ochrocephala (E)	510	1.00		1020	SM × GC		60	G, A
Amazona farinosa	800	2.00		3200	SM × GC		100	G, A
CUCULIDAE (5 species)								
Coccyzus americanus (M)	48	+			SM			I, A, G
Coccyzus melacoryphus (E)	52	+			SM			I, A, G
Piaya cayana	105	4.00		840	SM		90	I, A, G
Crotophaga major (LE)	180	+			SM		5	I, A, G
Neomorphus geoffroyi	340	0.25		170	SM	>100?	100?	I, AF
STRIGIDAE (7 species)								
Otus watsonii	145	5.50		1600	SM	19 (5)	100	R, N
Lophostrix cristata	510	2.00		2040	SM	80 (2)	80	R, N
Pulsatrix perspicillata	795	0.75		1190	SM	>100?	90	R, N
Glaucidium minutissimum	60	5.00		600	SM	14 (4)	85	R, N
Glaucidium brasilianum (ES)	67	1.00		130	SM		15	R, N
Ciccaba huhula	370	1.50		1110	SM		>50	R, N
Ciccaba virgata	320	1.50		960	SM		>70	R, N
NYCTIBIIDAE (3 species)								
Nyctibius grandis	575	1.00		1150	SM	80 (1)	80	I, A, S
Nyctibius griseus (E)	175	+			SM			I, A, S
Nyctibius bracteatus (?)	(125)	1.00		250	SM		?	I, A, S
CAPRIMULGIDAE (5 species)								
Lurocalis semitorquatus	87	1.00		174	SM		+	I, Aer.
Chordeiles rupestris (A)		+			VO			I, Aer.
Chordeiles minor (M, A)		+			VO			I, Aer.
Nyctidromus albicollis (E)	65	+			SM		5	I, T, S
Nyctiphrynus ocellatus	43	2.50		215	SM		50	I, T, S
APODIDAE (5 species)								
Streptoprocne zonaris (A)	110	+			VO			I, Aer.
Chaetura cinereiventris (A)	19	+			VO			I, Aer.
Chaetura brachyura (A)		+			VO			I, Aer.
Panyptila cayennensis (A)		+			VO			I, Aer.
Tachornis squamata (A, E)		+			VO			I, Aer.
TROCHILIDAE (14 species)								
Glaucis hirsuta (E)	6		2	12	MN		5	N, A
Threnetes leucurus	5		9	45	MN		100	N, A
Phaethornis superciliosus	5		8	40	MN		100	N, A
Phaethornis hispidus	5		4	20	MN		100	N, A
Phaethornis stuarti	3		1	3	MN		30	N, A

APPENDIX. Continued.

Species†	Mass (g)	No. pairs/100 ha‡	No. inds./100 ha§	Biomass density (g/100 ha)	Census method‖	Terr. size¶ (ha) Mean (N)	% plot occup.#	Guild**
Eutoxeres condamini (V)	10	1			MN			N, A
Campylopterus largipennis (ES)	8		2	16	MN		5	N, A
Florisuga mellivora	7		5	35	VO		100	N, A
Popelairia popelairii	2.5		1	2.5	VO		?	N, A
Thalurania furcata (E)	4.5		6	27	MN		100	N, A
Hylocharis cyanus (F)	4.5	-			VO		?	N, A
Chrysuronia oenone	4		5	20	MN		•	N, A
Polyplancta aurescens	6		1	6	VO		•	N, A
Heliothryx aurita (SI)	6	--			VO		5	N, A
TROGONIDAE (5 species)								
Trogon melanurus	122	33.00		3870	SM	5 (13)	90	O, A
Trogon collaris	59	8.00		940	SM	8 (6)	70	O, A
Trogon curucui	61	8.50		1040	SM	7 (8)	90	O, A
Trogon violaceus	44	3.50		310	SM	14 (2)	60	O, A
Trogon viridis	[illegible]	+			SM			O, A
ALCEDINIDAE (2 species)								
Chloroceryle inda (LE, SI)	54	0.50		55	SM, VO		5	Aquat.
Chloroceryle aenea (LE, SI)	14	1.50		40	MN		30	Aquat.
MOMOTIDAE (2 species)								
Electron platyrhynchum (E)	65	2.00		260	SM	7 (2)	35	I, A, S
Momotus momota (E)	111	6.00		1330	SM	5 (5)	40	I, A, S
GALBULIDAE (2 species)								
Galbula cyanescens (E)	24	3.00		145	SM	8 (1)	20	I, A, S
Jacamerops aurea	79	1.00		160	SM	16 (1)	25	I, A, S
BUCCONIDAE (7 species)								
Notharchus macrorhynchos	120	2.00		480	VO		60	I, A, S
Bucco macrodactylus (ES, Sw)	25	1.00		50	MN		30	I, A, S
Nystalus striolatus (E)	47	2.50		235	SM	9 (2)	75	I, A, S
Malacoptila semicincta	44	2.00		180	MN		40	I, A, S
Nonnula ruficapilla (E)	22	+			MN			I, A, S
Monasa nigrifrons (E, F)	85		28	2380	SM	8 (6)	70	I, A, S
Monasa morphoeus	74		4	295	SM	6 (5)	10	I, A, S
CAPITONIDAE (3 species)								
Capito niger	64	10.50		1340	SM	8 (8)	100	O, A
Eubucco richardsoni	35	4.00		280	SM	10 (2)	65	O, A
Eubucco tucinkae (ES)	41	0.50		40	SM		5	O, A
RAMPHASTIDAE (8 species)								
Aulacorhynchus prasinus (S)	132	+			SM × GC			F, A
Pteroglossus castanotis (E)	310	+			SM × GC			F, A
Pteroglossus inscriptus (E)	126		1	125	SM × GC		10	F, A
Pteroglossus flavirostris	135		2	270	SM × GC		40	F, A
Pteroglossus beauharnaesii	203		8	1624	SM × GC	20 (2)	65	F, A
Selenidera reinwardtii	138	1.00		275	SM × GC		35	F, A
Ramphastos vitellinus	369		4	1475	SM × GC	≥40 (3)	75	F, A
Ramphastos cuvieri	734		6	4405	SM × GC	≥50 (2)	100	F, A
PICIDAE (12 species)								
Picumnus rufiventris	21	4.00		170	MN		50	I, B, I
Piculus leucolaemus	69	1.50		210	SM		50	I, B, I
Piculus chrysochloros	88	1.00		175	SM		25	I, B, I
Celeus elegans (F)	136	—			SM			I, B, I
Celeus grammicus	79		8	630	SM (CB)	35 (2)	80	I, B, I
Celeus flavus	201		4	800	SM (CB)	≥50 (1)	50	I, B, I
Celeus torquatus	134		3	400	SM (CB)	≥45 (1)	35	I, B, I
Dryocopus lineatus (E)	209	+			SM		30	I, B, I
Melanerpes cruentatus	59		12	710	SM (CB)	14 (3)	50	O, A
Veniliornis affinis	36	4.00		290	SM		60	I, B, I
Campephilus melanoleucos (E)	231	0.25		115	SM		10	I, B, I
Campephilus rubricollis	220	1.00		440	SM	≥40 (2)	20	I, B, I

APPENDIX. Continued

Species†	Mass (g)	No. pairs/100 ha‡	No. inds./100 ha§	Biomass density (g/100 ha)	Census method‖	Terr. size¶ (ha) Mean (N)	% plot occup #	Guild**
DENDROCOLAPTIDAE (17 species)								
Dendrocincla fuliginosa	31	4.00		250	SM	13 (3)	80	I, A, S
Dendrocincla merula (AF)	46	8.00		735	MN		100	I, AF
Deconychura longicauda	28	2.00		110	SM	16 (2)	50	I, A, S
Sittasomus griseicapillus	16	6.50		210	SM	9 (3)	70	I, B, S
Glyphorynchus spirurus	14	2.75		75	MN, UFC		30	I, B, S
Nasica longirostris (LE)	92	0.25		45	SM		15	I, B, S
Dendrexetastes rufigula	70	3.50		490	SM	14 (3)	75	I, A, G
Xiphocolaptes promeropirhynchus	136	1.00		270	SM	≈25 (1)	60	I, B, S
Dendrocolaptes certhia	73	2.50		365	SM	15 (2)	70	I, A, S
Dendrocolaptes picumnus	80	2.00		320	SM	21 (2)	65	I, A, S
Xiphorhynchus picus (LE)	41	+			SM			I, B, S
Xiphorhynchus obsoletus (Sw)	39	0.25		20	SM		10	I, B, S
Xiphorhynchus ocellatus	32	1.50		95	MN, UFC	14 (1)	30	I, B, S
Xiphorhynchus spixii	40	3.50		280	SM	13 (3)	60	I, B, S
Xiphorhynchus guttatus	65	11.00		1430	SM		100	I, B, S
Lepidocolaptes albolineatus	33	5.00		330	SM, CFC	14 (2)	90	I, B, S
Campylorhamphus trochilirostris (E)	38	0.50		40	SM		5	I, B, S
FURNARIIDAE (11 species)								
Furnarius leucopus (LE)	44	+			SM			I, T, G
Hyloctistes subulatus	29	2.50		145	SM	12 (3)	50	I, A, DL
Philydor erythrocercus	25	4.50		225	SM, CFC		55	I, A, DL
Philydor pyrrhodes (V)	29	+			VO			I, A, DL
Philydor erythropterus	30	2.50		150	CFC		40	I, A, G
Philydor ruficaudatus	29	3.00		175	SM	12 (2)	45	I, A, DL
Automolus infuscatus	38	1.50		115	SM	12 (1)	25	I, A, DL
Automolus ochrolaemus	34	2.50		170	SM	11 (2)	30	I, A, DL
Xenops rutilans	13	4.00		105	CFC		55	I, B, S
Xenops minutus	12	6.00		145	SM, UFC	9 (4)	60	I, B, S
Sclerurus caudacutus	36	3.00		215	SM	18 (3)	65	I, T, G
FORMICARIIDAE (44 species)								
Cymbilaimus lineatus (CV)	40	7.50		600	SM	8 (7)	70	I, A, G
Taraba major (E)	60	+			SM			I, A, G
Thamnophilus aethiops (TF)	27	1.00		55	SM	10 (1)	15	I, A, G
Thamnophilus schistaceus (CV)	21	10.50		440	SM	6 (8)	80	I, A, G
Pygiptila stellaris	25	7.50		375	SM	8 (5)	70	I, A, G
Neoctantes niger (V)	32	+			MN			I, A, G
Thamnomanes ardesiacus	18	13.00		470	UFC		80	I, A, S
Thamnomanes schistogynus	17	11.00		375	UFC		90	I, A, S
Myrmotherula brachyura	8	45.00		710	SM	5 (9)	80	I, A, G
Myrmotherula sclateri	8	4.00		65	CFC		50	I, A, G
Myrmotherula hauxwelli	11	11.00		240	SM	4 (9)	70	I, A, G
Myrmotherula leucophthalma	10	7.00		140	UFC		40	I, A, DL
Myrmotherula axillaris	8	16.00		255	UFC		35	I, A, G
Myrmotherula longipennis	9	11.00		200	UFC	5 (7)	50	I, A, G
Myrmotherula iheringi	8	3.00		50	UFC	4 (1)	20	I, A, G
Myrmotherula menetriesii	9	15.00		270	UFC	6 (8)	85	I, A, G
Dichrozona cincta	16	4.50		145	SM	7 (3)	50	I, T, G
Microrhopias quixensis (E)	11	2.00		45	UFC	4 (1)	10	I, A, G
Terenura humeralis	13	6.00		155	CFC	6 (4)	50	I, A, G
Cercomacra cinerascens (CV)	20	17.00		680	SM	5 (17)	70	I, A, G
Cercomacra nigrescens (V)	18	–			MN			I, A, G
Cercomacra serva (Sw)	17	–			SM			I, A, G
Myrmoborus leucophrys (ES)	21	+			SM			I, T, G
Myrmoborus myotherinus	20	20.00		800	SM	4 (20)	90	I, T, G
Hypocnemis cantator (TF)	13	1.00		25	SM	4 (1)	10	I, A, G
Hypocnemoides maculicauda (LE, Sw)	13	0.50		15	SM		10	I, A, G
Percnostola lophotes (ES)	28	0.50		30	SM	8 (1)	10	I, A, G
Sclateria naevia (LE, Sw)	22	0.50		20	SM		10	I, A, G
Myrmeciza hemimelaena	16	9.00		290	SM	4 (9)	70	I, A, G
Myrmeciza hyperythra (Sw)	41	6.50		535	SM	6 (5)	45	I, A, G

APPENDIX. Continued.

Species†	Mass (g)	No. pairs/100 ha‡	No. inds/100 ha§	Biomass density (g/100 ha)	Census methods‖	Terr. size¶ (ha) Mean (N)	% plot occup.#	Guild**
Myrmeciza goeldii (ES)	42	1.50		125	SM	16 (1)	20	I, A, G
Myrmeciza fortis (AF)	46	1.00		90	SM	>50 (1)	60	I, AF
Gymnopithys salvini (AF)	25	0.50		25	SM	>25 (1)	30	I, AF
Rhegmatorhina melanosticta (AF)	32	2.00		130	MN	>25 (2)	65	I, AF
Hylophylax naevia (Sl)	12	1.50		40	SM	15 (1)	20	I, A, G
Hylophylax poecilonota (AF)	18	0.25		10	SM		10	I, AF
Phlegopsis nigromaculata (AF)	45	4.50		405	MN	14 (3)	75	I, AF
Chamaeza nobilis	123	2.00		490	SM	30 (2)	65	I, T, G
Formicarius colma	49	5.00		490	SM	14 (4)	80	I, T, G
Formicarius analis	58	13.00		1510	SM	6 (11)	100	I, T, G
Formicarius rufifrons (ES)		+			SM			I, T, G
Hylopezus berlepschi (Sw)	48	+			SM			I, T, G
Myrmothera campanisona (TF)	47	4.50		425	SM	11 (4)	60	I, T, G
Conopophaga peruviana	13	5.00		140	MN		40	I, T, G
RHINOCRYPTIDAE (1 species)								
Liosceles thoracicus	81	2.00		325	SM	15 (1)	50	I, T, G
TYRANNIDAE (34 species)								
Zimmerius gracilipes	9	2.00		35	CFC		30	O, A
Ornithion inerme (TF)	7	2.00		30	SM		25	I, A, S
Tyrannulus elatus	8	2.50		40	SM	6 (3)	25	O, A
Myiopagis gaimardii (ES)	12	4.00		95	SM	4 (5)	30	I, A, S
Myiopagis viridicata (Sw)	21	+			SM			I, A, S
Mionectes olivaceus (M?)	15		3	45	MN			O, A
Mionectes oleagineus (L)	11		4	45	MN			O, A
Leptopogon amaurocephalus (E)	11	3.50		55	SM	3 (2)	50	I, A, S
Corythopis torquata	17	7.00		240	SM	6 (7)	70	I, T, S
Myiornis ecaudatus	6	10.00		120	SM + T	3 (6)	35	I, A, S
Hemitriccus zosterops	9	5.00		90	SM + T	3 (4)	20	I, A, S
Hemitriccus iohannis (ES)	10	–			SM			I, A, S
Todirostrum chrysocrotaphum	7	3.50		50	SM	7 (3)	35	I, A, S
Ramphotrigon fuscicauda (TF)	19	1.00		40	SM		15	I, A, S
Ramphotrigon ruficauda	19	2.50		95	SM	8 (2)	20	I, A, S
Tolmomyias assimilis	17	4.00		135	CFC	6 (2)	35	I, A, S
Tolmomyias poliocephalus (E)	11	3.00		65	SM	5 (3)	20	I, A, S
Tolmomyias flaviventris (ES)	14	–			SM		5	I, A, S
Platyrinchus coronatus	10	7.50		150	SM + T	5 (6)	45	I, A, S
Platyrinchus platyrhynchos	12	6.00		145	SM + T	5 (6)	35	I, A, S
Onychorhynchus coronatus	14	0.50		15	MN		10	I, A, S
Terenotriccus erythrurus	7	2.00		30	SM + T		20	I, A, S
Contopus virens (M, ES)	14	+			SM			I, A, S
Empidonax euleri	11	1.50		35	SM	5 (1)	10	I, A, S
Attila bolivianus (E)	45	4.00		360	SM	12 (3)	70	I, A, S
Attila spadiceus	35	4.00		280	SM	12 (3)	55	I, A, S
Rhytipterna simplex	36	4.50		325	SM	12 (3)	60	I, A, S
Laniocera hypopyrrha (L)	51		2	100	SM + MN		20	O, A
Sirystes sibilator	38	2.00		150	SM	38 (1)	40	I, A, S
Myiarchus swainsoni (M, ES)		+			SM			I, A, S
Myiarchus tuberculifer (ES)	20	+			SM			I, A, S
Myiozetetes granadensis (ES)		+						I, A, S
Legatus leucophaius	23	1.50		70	SM	7 (1)	15	O, A
Tyrannus tyrannus (M, ES)	41	+			SM			I, A, S
PIPRIDAE (6 species)								
Schiffornis major (L, Se)	31		1	30	SM + MN		60	F, A
Piprites chloris	20	5.50		220	SM	8 (5)	45	I, A, G
Tyranneutes stolzmanni (L)	9		20	180	SM + T		30	F, A
Pipra coronata (L)	9		7	65	MN		80	F, A
Pipra fasciicauda (L)	17		45	765	MN		100	F, A
Pipra chloromeros (L)	17		1	15	MN		10	F, A
COTINGIDAE (21 species)								
Pachyramphus polychopterus (M?, E)	22	+			SM			I, A, S
Pachyramphus marginatus	18	4.00		145	CFC	[illegible] (4)	55	I, A, S

APPENDIX. Continued.

Species†	Mass (g)	No. pairs/100 ha‡	No. inds./100 ha§	Biomass density (g/100 ha)	Census method‖	Terr. size¶ (ha) Mean (N)	% plot occup.#	Guild**
Pachyramphus minor	37	3.00		220	CFC	8 (2)	45	I, A, S
Tityra cayana (E)	66	1.50		200	SM		35	O, A
Tityra semifasciata	88	4.00		705	SM		75	O, A
Lipaugus vociferans (L)	81		20	1620	SM		70	F, A
Porphyrolaema porphyrolaema	60		2	120	VO		?	F, A
Cotinga maynana (E)	69	+			VO		?	F, A
Conioptilon mcilhennyi (E)	90		1	90	SM		10	F, A
Gymnoderus foetidus (E)	275		2	550	VO		25	F, A
Querula purpurata	125		10	1250	SM	25 (1)	75	F, A
TROGLODYTIDAE (4 species)								
Campylorhynchus turdinus (CV, E)	25		6	150	SM (CB)	25 (1)	30	I, A, G
Thryothorus genibarbis (Sw)	19	0.50		20	SM		5	I, A, G
Microcerculus marginatus	18	2.00		70	SM, MN		20	I, T, G
Cyphorhinus arada	30		10	300	SM (CB)	11 (3)	50	I, T, G
TURDINAE (3 species)								
Catharus ustulatus (M, E)	27	+			VO			O, A
Turdus hauxwelli (E)	72	8.50		1220	SM	6 (6)	75	O, A
Turdus albicollis	52	3.00		310	SM	14 (3)	45	O, A
EMBERIZINAE (1 species)								
Arremon taciturnus (Sc)	28	0.50		30	SM		10	O, A
CARDINALINAE (2 species)								
Saltator maximus (S)	46	+			SM			O, A
Passerina cyanoides (E, Sw)	27	1.50		80	SM	15 (1)	20	O, A
THRAUPINAE (24 species)								
Lamprospiza melanoleuca	39		3	115	SM (CB)	>40	35	O, A
Hemithraupis guira	15		1	15	CFC		15	I, A, G
Hemithraupis flavicollis	15		1	15	CFC		15	I, A, G
Lanio versicolor	19	4.50		170	CFC		60	I, A, S
Tachyphonus rufiventer	17	4.50		155	CFC		50	I, A, G
Tachyphonus luctuosus	13	6.00		155	CFC		80	I, A, G
Habia rubica	33	8.50		560	SM	6 (9)	60	I, A, G
Piranga olivacea (M)	29	+			VO			O, A
Thraupis palmarum (LE)	36	+			SM			O, A
Euphonia chrysopasta (E)	15	4.00		120	SM	5 (2)	25	F, A
Euphonia minuta	10	2.00		40	CFC		30	F, A
Euphonia xanthogaster	14	3.00		85	CFC		40	F, A
Euphonia rufiventris	15	9.00		270	SM	5 (8)	60	F, A
Chlorophonia cyanea (V)	13	+			VO			F, A
Tangara mexicana	19		8	150	CFC		65	O, A
Tangara chilensis	24		14	335	CFC		80	O, A
Tangara schrankii	20		12	240	CFC		80	O, A
Tangara nigrocincta	17	+			CFC			O, A
Tangara velia	21		1	20	CFC		40	O, A
Tangara callophrys	23		2	45	CFC		40	O, A
Dacnis lineata	13		8	105	CFC		40	O, A
Dacnis cayana	14		8	110	CFC		40	O, A
Chlorophanes spiza	18		6	110	CFC		40	O, A
Cyanerpes caeruleus	36	+			CFC			O, A
VIREONIDAE (4 species)								
Vireolanius leucotis	20	5.50		145	SM	9 (4)	55	I, A, G
Vireo olivaceus (E, M?)	15	1.50		45	CFC		15	I, A, G
Hylophilus hypoxanthus (Check W?)	17	4.50		155	CFC		40	I, A, G
Hylophilus ochraceiceps	11	7.50		165	SM, CFC	6 (6)	50	I, A, G

APPENDIX. Continued.

Species*	Mass (g)	No. pairs/100 ha‡	No. inds/100 ha§	Biomass density (g/100 ha)	Census method‖	Terr. size¶ (ha) Mean (N)	% plot occup.#	Guild**
ICTERIDAE (7 species)								
Psarocolius oseryi	132		6	790	CPR		60	O, A
Psarocolius decumanus	289	+			VO			O, A
Psarocolius angustifrons	286		12	3430	CPR		100	O, A
Psarocolius yuracares	360		2	720	CPR		50	O, A
Cacicus cela	85		50	4250	CPR		100	O, A
Cacicus solitarius (Sw)	84		1	85	SM		15	O, A
Icterus cayanensis (E)	39	1.00		80	SM	8 (1)	15	O, A
CORVIDAE (1 species)								
Cyanocorax violaceus (ES)	262	+			SM (CB)			O, A

* All species recorded on the plot during the period are listed with the exception of a number of aquatic and terrestrial birds that frequent the lake margin without entering the adjoining forest.

† The principal habitat of each species is coded in parentheses beside the name. Where there is no code letter, the principal habitat is understood to be mature forest. Commensals of army ants and primates, flocking species, and migrants are also indicated.

Key:

A = aerial;
AF = ant follower;
CV = canopy vine tangles;
E = edges;
ES = early successional vegetation;
L = males in leks;
LE = lake edge;
M = migrant;
P = follows primate troops;
ST = forest streams;
TF = tree fall openings;
V = vagrant.

‡ Numerical values correspond to the populations found on the 97-ha plot. Pluses (+) designate all additional records, including migrants and vagrants, as well as species with densities too low to measure.

§ Numbers of individuals were estimated for communal breeders, and for non-territorial and lekking species. (See Methods: Census Methods for details.)

‖ Key:

CB = communal breeder;
CFC = censused in canopy flocks;
CPR = prorated fraction of colony membership assigned to plot (colonial Icterids only);
GC = group count;
MN = populations estimated by mist netting;
SM = spot mapping;
SM × GC = spot mapping combined with group counts;
T = transect estimates used as a supplementary method;
UFC = censused in understory flocks;
VO = visual observation (see Methods: Census Methods: Other Methods for further details).

¶ Territory sizes were estimated for pairs or individuals that could be spot mapped, and whose territories did not extend beyond the bounds of the plot. We followed the conventional practice of drawing convex perimeters around the clusters of points representing individual pairs or males and measuring the included areas. Records of countersinging between neighbors were used whenever possible to establish the locations of territorial boundaries. Where territories adjoined it was usually assumed that the intervening space was included. Species that resided permanently in mixed flocks, but that also sang regularly, were found through mapping flock movements to occupy larger areas than was indicated via spot mapping. For consistency, when both types of information were available, we took the (smaller) territory size obtained from spot mapping, since this was the method used for most non-flocking species.

\# Occupancy was generously interpreted as the area within the plot that included sightings and/or spot mapping records. For territorial species it was the sum of areas included within territories within the plot boundaries. Occupancies are generally greater than the average territory size multiplied by the number of territories used in computing the average (column to left), because partial territories that extended beyond the plot boundaries were not used in estimating average territory sizes.

** Key:

Aquat. = water birds, such as herons, rails and kingfishers that use the lake margin and the seasonal stream at the north end of the plot;
Carr. = carrion, i.e., vultures;
Fol. A = arboreal folivore (hoatzin);
F, A = arboreal frugivore;
F, T = terrestrial frugivore;
G, A = arboreal granivore;
G, T = terrestrial granivore;
I, A, DL = dead-leaf-searching arboreal insectivore;
I, Aer. = aerial insectivore, used to designate swifts, kites and some nightjars;
I, AF = ant-following insectivore;
I, A, G = arboreal gleaning insectivore;
I, A, S = arboreal, sallying insectivore (here "sallying" is used broadly to include species that hawk, hover, snatch or strike [Fitzpatrick 1981]);
I, B, I = bark-drilling insectivores feeding in trunk interiors, i.e., woodpeckers;
I, B, S = bark-dwelling insectivores feeding superficially, i.e., some dendrocolaptids and furnariids;
I, G, T = gleaning terrestrial insectivore;
I, T, S = sallying terrestrial insectivore;
N = nectarivore (used only for hummingbirds);
O, A = arboreal omnivore;
R, D = diurnal raptor;
R, N = nocturnal raptor, i.e., owls.

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CLIMATE AND FOOD SYNCHRONIZE REGIONAL FOREST BIRD ABUNDANCES

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Abstract. Analysis of synchrony in population fluctuations can help to identify factors that regulate populations and the scales at which these factors exert their influence. Using 15 years of data on the abundances of songbirds at four replicate forest sites in New Hampshire, USA, we addressed two main questions: (1) Are forest bird populations synchronous at the scale measured (tens of kilometers), and if so, (2) what environmental factors are responsible for the synchrony? Nine of the 10 bird species we examined exhibited significant spatial synchrony across the four sites. Within nesting and foraging species groups, tree nesters and foliage gleaners exhibited the highest spatial synchrony. Long-distance (Neotropical) migrants exhibited higher spatial synchrony than did short-distance migrants or year-round residents. Synchrony within and among six species of long-distance, migratory, insectivorous birds was correlated with synchronous fluctuations in the abundance of lepidopteran larvae, a primary food type during the breeding season, which in turn have been shown to be influenced by El Niño/La Niña global climate patterns. Abundances of year-round resident species were related to another large-scale climatic phenomenon, the North Atlantic Oscillation. Winter weather can have both direct (e.g., via temperature-mediated mortality) and indirect (e.g., via winter food availability) effects on year-round resident species. We do not believe that predation on adults or nests accounted for the observed synchrony. Dispersal among regional populations in this system may have played a role but is likely a product of the influence of regionally synchronous caterpillar fluctuations on bird reproduction. Long-term regional population trends may have contributed to the observed synchrony for some species, but we do not consider these trends to be primary factors. Our findings of population synchrony support the importance of food and climate in influencing forest bird abundances and have broad implications for potential responses of bird and insect populations to climate change.

Key words: avian population dynamics; climate; El Niño/Southern Oscillation; food abundance; forest bird abundance; New Hampshire (USA); North Atlantic Oscillation; spatial synchrony; temperate forest.

INTRODUCTION

Synchrony in population fluctuations has been identified as an important component of population dynamics (Royama 1992) and has been studied in a wide variety of taxa, including insects (Hanski and Woiwod 1993, Williams and Liebhold 1995, Sutcliffe et al. 1996), mammals (Moran 1953, Ranta et al. 1997, Stenseth et al. 1998, 1999, Haydon et al. 2001), and birds (Ranta et al. 1995*a*, Paradis et al. 1999, 2000, Koenig 2001). Theoretical and empirical studies have identified three classes of processes that can contribute to population synchrony: dispersal (e.g., dispersing individuals couple locally regulated populations; Bjørnstad et al. 1999, Kendall et al. 2000), trophic interactions (e.g., predators synchronizing prey abundances over time or space; Ims and Andreassen 2000), and spatially correlated density-independent factors, the Moran effect (e.g., environmental variables influencing fecundity or survival; Moran 1953, Royama 1992, Ranta et al. 1995*a*). Identifying the mechanisms underlying synchrony helps to identify local and regional factors affecting population dynamics and abundances (Bjørnstad et al. 1999, Koenig 1999).

To determine the degree to which abundances of forest birds were synchronous at a regional scale and to identify the ecological processes that influence population synchrony, we intensively censused populations of birds at four forest sites (separated by an average of 11 km, and bounding an area of ~400 km²) within the White Mountains of north-central New Hampshire, USA, from 1986–2000 (Holmes and Sherry 2001). Here, we addressed three main questions regarding population synchrony across the four sites: (1) Are forest bird populations synchronous across this region, (2) what are the environmental factors affecting these patterns, and (3) what are the implications of understanding the factors or processes that influence these populations? Specifically, we tested two hypotheses. First, population synchrony within and among foliage-foraging insectivorous species is related to regional changes in the abundance of their major food (Lepidoptera larvae), which are, in turn, related to climatic

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variation (e.g., El Niño Southern Oscillation; Sillett et al. 2000). Second, population synchrony of year-round resident species is related to the severity of winter weather.

Methods

Study sites

The four study sites were selected to be replicates of the same northern hardwood forest type, at the same elevation, aspect, and with the same management and disturbance history. Each was situated within a large tract of continuous forest within the White Mountain National Forest, but on different mountain systems separated by intervening valleys containing roads, agricultural lands, and human habitations. Each plot consisted of a gridded 10-ha area on south/southeast facing slopes and at elevations of 500–600 meters above sea level. The four study sites were separated by distances ranging from 8 to 25 km (average of 11.3 km) and bounded a total area of ~400 km². These plots were located (1) in the Hubbard Brook Experimental Forest (the long term study site of Holmes et al. 1986, Holmes and Sherry 2001); (2) on the southeast slope of Mt. Moosilauke, north of Hubbard Brook, in Woodstock, New Hampshire; (3) on Stinson Mountain, to the southwest, in Rumney, New Hampshire; and (4) near Russell Pond, to the northeast, in Thornton, New Hampshire. All contained at least one permanent stream along with additional intermittent watercourses. Each site was selectively logged in the early 1900s, but had remained free of any direct human disturbance since that time. Natural disturbances, such as a major hurricane in 1938, fungal pathogens, and sporadic ice and windstorms, have also impacted these forests (Merrens and Peart 1992, Leak and Smith 1996).

The vegetation on all four plots was dominated by American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and yellow birch (*Betula alleghaniensis*), with occasional white ash (*Fraxinus americana*) and red spruce (*Picea rubens*). Forest canopies averaged 20–25 m in height. The shrub layer on each plot consisted primarily of hobblebush (*Viburnum alnifolium*), striped maple (*A. pensylvanicum*), and seedlings and saplings of the dominant tree species (except yellow birch and white ash, which were essentially absent from the shrub layer).

Bird surveys

Birds were surveyed annually during the peak of the breeding period, from late May through early July 1986–2000 (using methods described in details by Holmes and Sherry 2001). Briefly, these consisted of timed surveys along transects and extensive territory mapping, supplemented by information on nest locations and other observations. Data represent best estimates of absolute densities of each species (males plus females) on 10 ha of northern hardwood forest. Additionally, each species was classified by its primary nesting substrate, foraging location, and migratory strategy (Appendix).

Caterpillar surveys

On each plot, we quantified caterpillar abundances by visually searching 80 samples of 50 leaves (i.e., 4000 leaves and supporting petioles and small twigs) on saplings of each of two common understory plant species, American beech and sugar maple. Two 50-leaf samples were examined at each of 40 points spaced at 50-m intervals on the 10-ha survey grid. The body length of each caterpillar encountered was recorded, and lengths were converted to biomass using length–mass regressions (J. C. Schultz and R. T. Holmes, *unpublished data*). Biomass was then totaled for all individuals in the 8000 leaf sample. All free living caterpillars were counted, most of which were in two families (Geometridae and Noctuidae; R. T. Holmes, *unpublished data*). Surveys were conducted 4–5 times each year at 2-wk intervals between late May and late July at each of the four sites. For this paper, we used data from two sampling periods, 10–20 June and 21–30 June, which correspond with the time when most young birds are fledging. Previous research on our study site has indicated that caterpillar biomass in the understory is positively related to caterpillar biomass higher in the forest canopy (Holmes and Schultz 1988).

Synchrony analyses

We used average cross correlations (CC) as our index of synchrony (Ranta et al. 1995b, Paradis et al. 2000, Buonaccorsi et al. 2001). We chose CCs as our index of synchrony as they provide a good trade-off between the amount of information provided by the statistics and the assumptions required to utilize them (Buonaccorsi et al. 2001). Average CCs were calculated for individual species or species groups across the four sites with no time lag (i.e., abundance in year t at each site). An examination of the autocorrelation and partial autocorrelation functions for each of the data series (70 total) yielded only two significant terms ($0.03 < P < 0.05$), implying a low occurrence of autocorrelation in the data set. As a result, we opted to use raw, rather than detrended, abundance values to calculate average CCs. Large positive CC values indicated a high degree of synchrony, values near zero indicated a low degree of synchrony, and large negative values implied that populations are fluctuating out of phase.

We used a standard bootstrap approach (Efron and Tibshirani 1993) to test whether observed mean CCs were significantly different from zero. New time series were generated from the existing values using resampling with replacement within each site–species or site–group time series, and a new mean CC was calculated. The procedure was performed 1000 times for each species or site. The standard deviation of these 1000 mean CCs is the bootstrap estimate of the standard error of the mean (SE_{mean}). For each mean CC, we constructed a 95% confidence interval with mean CC ± 2 × SE_{mean}. If this interval did not include zero, we considered the mean CC to be significantly different from zero (Buonaccorsi et al. 2001); for example, a positive CC whose 95% CI did not include zero would indicate bird populations were significantly synchronous across the four sites. The accuracy of the bootstrap approach is negatively affected by the presence of autocorrelation (Buonaccorsi et al. 2001), however, given the general lack of autocorrelation detected in our data sets, we felt that this effect would be minimal.

For the individual species analyses, we included the 10 most commonly detected species: Yellow-bellied Sapsucker, Hairy Woodpecker, Hermit Thrush, Red-eyed Vireo, Black-throated Blue Warbler, Black-throated Green Warbler, American Redstart, Ovenbird, Scarlet Tanager, Rose-breasted Grosbeak (scientific names in Appendix). For the analyses by nesting substrate, foraging behavior, and migratory strategy, we also included abundance data for all other species occurring in the forest (see Holmes and Sherry 2001) for each group.

In our examination of foliage-gleaner synchrony, we assessed the relationship between caterpillar biomass and bird abundance. Previous research at Hubbard Brook found that food abundance in one year was positively associated with annual fecundity in the same year (Sillett et al. 2000) and overall abundance in the next year (Holmes et al. 1991) of a foliage gleaning insectivore, the Black-throated Blue Warbler. Annual fecundity in one year was positively correlated with juvenile recruitment in the next year (Sillett et al. 2000). Accordingly, for each of the four sites in this study, we calculated CCs between caterpillar biomass in year t with the abundance in year $t + 1$ of each the six foliage insectivorous birds used in the individual species analyses (see the Appendix). These six CC values were then averaged and tested using the aforementioned bootstrap approach.

Recently, a great deal of attention has been paid to the influences the North Atlantic Oscillation (NAO) has on the dynamics of organisms in both terrestrial and aquatic ecosystems in the Northern Hemisphere (Ottersen et al. 2001, Blenckner and Hillebrand 2002, Jonzén et al. 2002, Nott et al. 2002). The NAO index is often treated as a measure of winter severity in north temperate regions (Forchhammer et al. 1998, Post et al. 1999, Ottersen et al. 2001). In eastern North America, positive values of the NAO index are generally indicative of milder winter temperatures and lower amounts of snowfall (Hurrell 1995). We examined the relationship between the NAO index and breeding abundances of year-round resident species on our four study sites. To do so, we calculated CCs at each of the four sites between the NAO index December–March average (Hurrell and van Loon 1997, Climate Prediction Center [available online[6]]) with the combined abundance of all year-round resident bird species in the following breeding season. We lumped abundances of all year-round resident species (Appendix) for this analysis, as only the Hairy Woodpecker was abundant enough at all sites to perform species level synchrony analyses. The four CC values were then averaged and tested using the aforementioned bootstrap approach. To test the long-term relationship between the NAO index and winter weather, we examined the relationship between the Dec–Mar NAO index, snow depth, and mean temperature for the longest data set available (1956–2001) for the Hubbard Brook Experimental Forest (available online).[7]

Results

Species and group synchrony

Nine of the ten species exhibited significant synchrony in abundance across the four sites from 1986 to 2000 (Fig. 1). The American Redstart showed the highest synchrony (mean CC = 0.655), while the Black-throated Blue Warbler showed the lowest (mean CC = 0.214). Only the Scarlet Tanager (mean CC = 0.048) did not exhibit significant synchrony across the four sites (i.e., the 95% CI included zero). None of the species examined had negative CC values.

We detected significant synchrony in annual abundances for all species groups that we examined. When species were considered by nest locations, tree nesters exhibited the highest synchrony (mean CC = 0.648), while shrub nesters exhibited the lowest (mean CC = 0.314) (Fig. 2A). Among foraging groups, foliage gleaners exhibited the highest synchrony (mean CC = 0.656) while bark-gleaners exhibited the lowest (mean CC = 0.236) (Fig. 2B). Finally, among migratory groups, Neotropical migrants exhibited the highest synchrony (mean CC = 0.647), short-distance migrants exhibited the lowest (mean CC = 0.267), while year-round residents were intermediate (mean CC = 0.521) (Fig. 2C).

Food abundance and foliage-gleaning insectivores

To test the hypothesis that fluctuations in food abundance can synchronize population fluctuations of foliage gleaning birds, we determined whether: (1) food abundance in one year was positively correlated to bird abundance the following year at each of the four sites for our six focal species, and (2) fluctuations in caterpillar biomass were synchronous across the four study sites. We detected a significant positive relationship between food biomass and abundance of the six foliage-gleaner species, at three study sites (not Stinson): Hubbard Brook mean CC (with 95% CI in parentheses) = 0.250 (0.054, 0.446), Moosilauke mean CC = 0.238 (0.036, 0.439), Russell mean CC = 0.259

[6] URL: (http://www.cpc.ncep.noaa.gov/data/teledoc/nao.html)
[7] URL: (http://www.hbrook.sunysb.edu/data)

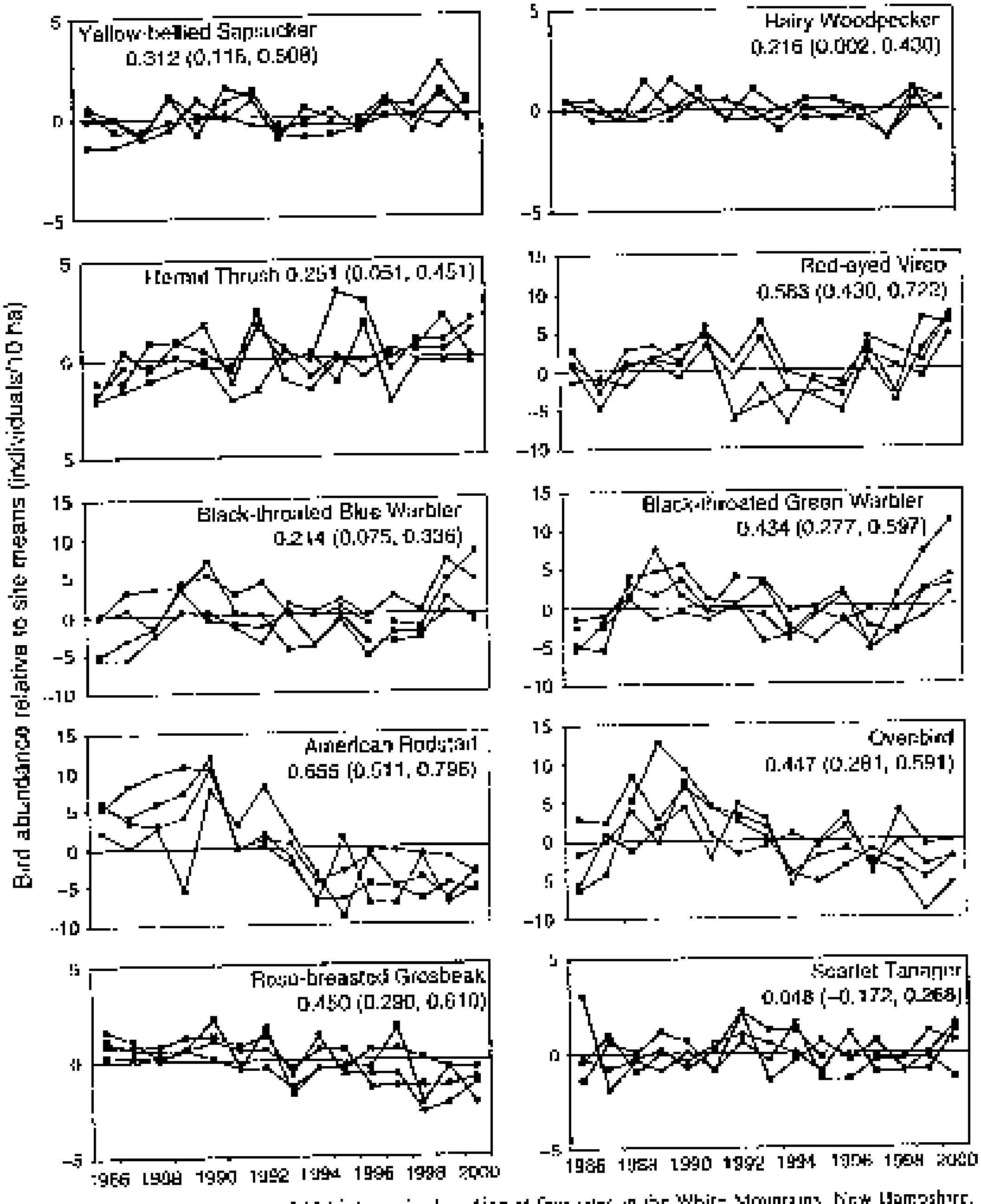

FIG. 1. Population fluctuations of 10 bird species breeding at four sites in the White Mountains, New Hampshire, from 1986 to 2000. Individual lines represent abundances at each study site. The mean cross-correlation coefficients (with lower 95% confidence interval and upper 95% confidence interval in parentheses) are given for each species. The y-axis represents the number of individuals relative to the site mean for the entire 15-year time series for each site. Note that scales on y-axes vary among panels.

(0.116, 0.402), and Stinson mean CC = 0.081 (−0.153, 0.315). These positive relationships were not driven by a single species; for example, at Hubbard Brook, Black-throated Blue Warblers, Black-throated Green Warblers, and Red-eyed Vireo all exhibited strong correlations with food biomass ($r > 0.4$), while at Russell Pond the highest correlations ($r > 0.5$) were detected for American Redstarts, Black-throated Green Warblers, and Rose-breasted Grosbeaks (J. Jones, P. J. Doran, and R. T. Holmes, *unpublished data*).

We detected highly significant spatial synchrony in total caterpillar biomass across the four sites (Fig. 3).

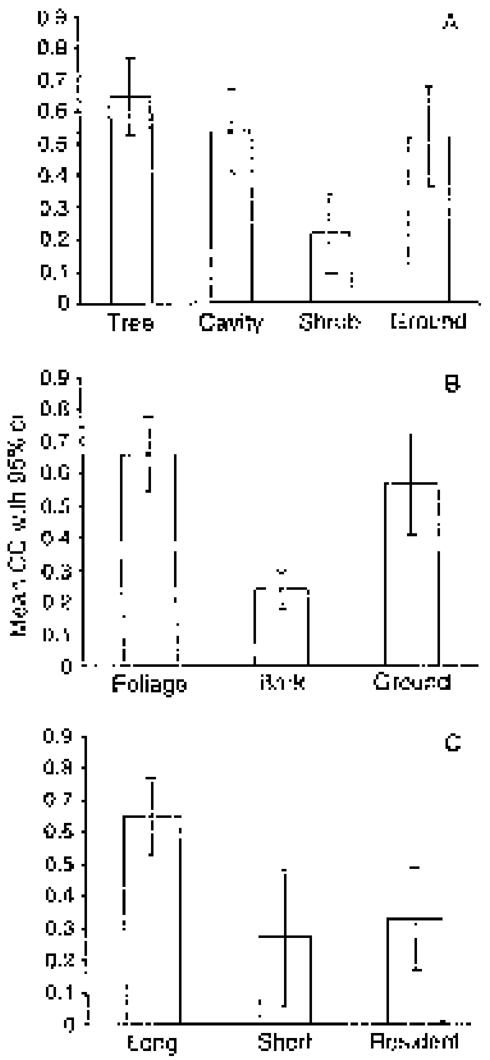

FIG. 2. Relative synchrony for birds grouped by (A) nesting substrate, (B) primary foraging location, and (C) migratory strategy.

biomass changes in a single lepidopteran species were not driving our overall synchrony pattern, as the Lepidoptera in the samples were represented by several species in at least two families, Geometridae and Noctuidae. Further analyses of annual fluctuations in biomass of these two families showed that they each exhibited significant synchrony among the sites: geometrid mean CC = 0.585 (0.504, 0.781), and noctuid mean CC = 0.658 (0.533, 0.817).

Winter weather and year-round residents

The abundance of year round resident species in the breeding season at the four sites was positively correlated with the Dec–Mar NAO index (Fig. 4): mean CC = 0.312 (0.036, 0.569). From 1956–2001, the Dec–Mar NAO index was negatively correlated with average Dec–Mar snow depth at Hubbard Brook (Fig. 5A) and, contrary to expectations, positively correlated with average Dec–Mar temperature (Fig. 5B). Thus, at the Hubbard Brook Experimental Forest, winters with a high, positive NAO index were characterized by low snowfall and warm temperatures, and following such winters, the combined abundance of year-round resident species was higher.

DISCUSSION

Species and group synchrony

We detected a high level of synchrony in population fluctuations across the four study sites for the majority of bird species and species groups. This generalized pattern of interspecific and intergroup synchrony implies some common factors affecting bird species across this region. Within both the individual species and the group analyses, the highest levels of synchrony were observed among species and groups that all rely heavily on caterpillars as a primary food source. Food abundance, therefore, appears to be a primary factor driving bird synchrony across this region.

Synchronizing effects of food abundance and climatic variation

Food abundance has often been cited as influencing avian population dynamics (Newton 1998). Previous research at Hubbard Brook on Black-throated Blue Warblers has documented a strong relationship between food abundance (i.e., caterpillar biomass) and bird reproductive performance (Holmes et al. 1986, Rodenhouse and Holmes 1992, Sillett et al. 2000, L. Nagy and R. T. Holmes, *unpublished manuscript*). Caterpillar biomass affected recruitment and abundance by influencing fecundity: birds had higher reproductive success in years of high caterpillar biomass (Sillett et al. 2000). Our results provide further evidence that food abundance is an important driver of avian population dynamics. By linking synchronous fluctuations in caterpillar biomass with synchronous fluctuations in a larger number of avian insectivores, we demonstrate that the relationship between food and bird abundance operates at a regional scale across multiple bird species.

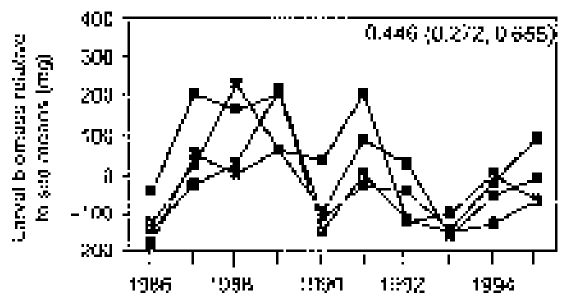

FIG. 3. Fluctuations of lepidopteran larval biomass at four sites in the White Mountains, New Hampshire, from 1986 to 2000. See Fig. 1 for details.

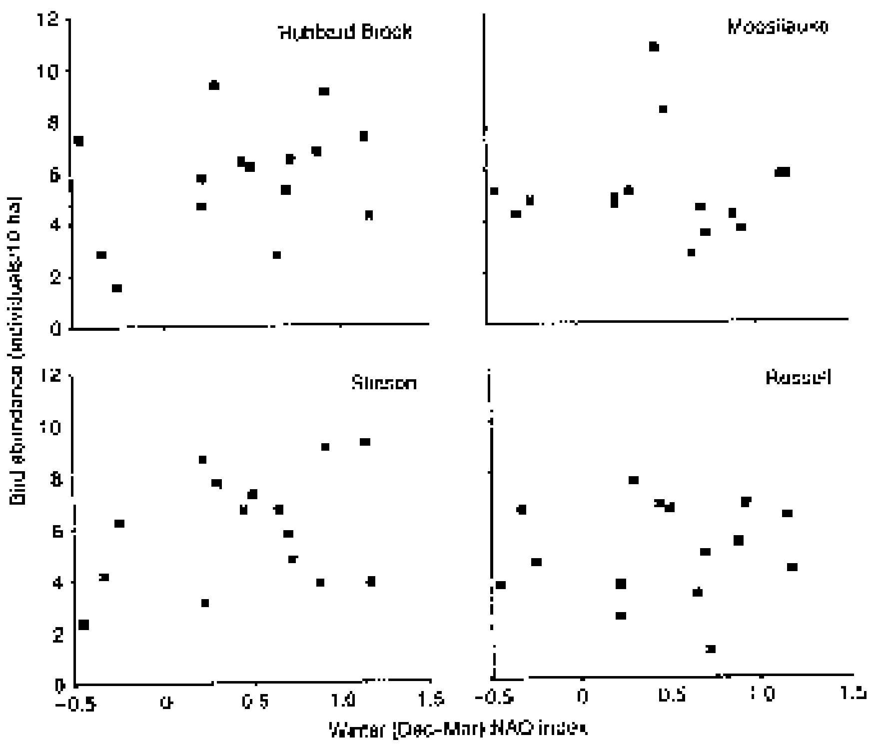

FIG. 4. Scatterplots of winter resident bird populations and winter (December–March) NAO index at four sites in the White Mountains, New Hampshire, from 1986 to 2000.

The strong, multi-taxa synchrony in caterpillar biomass across the study region implies an exogenous force influencing the population demographics of a variety of lepidopteran species. Large-scale climatic fluctuations (e.g., El Niño Southern Oscillation) potentially influence insect populations on a local scale at Hubbard Brook (Sillett et al. 2000) and probably more broadly in the region. Specifically, caterpillar biomass is higher in La Niña years than in El Niño years (Sillett et al. 2000). Across the northeastern United States, La Niña spring and summers tend to be wet and warm, while El Niño spring and summers tend to be dry and cool (Ropelewski and Halpert 1986). Both temperature and precipitation influence caterpillar growth rates and can exert indirect effects on lepidopteran populations via leaf quality, particularly by influencing water and nitrogen and secondary metabolite concentrations in leaves (Scriber and Slansky 1981, Ayres 1993). Hence, the link between food abundance and bird population dynamics may ultimately be driven by regional climate patterns.

Climatic conditions could also contribute to synchronous fluctuations in bird abundance by directly affecting reproductive performance or adult mortality. However, it is unlikely that climate has a direct influence on the observed foliage-gleaner synchrony given the rarity of weather related nest failure and adult bird mortality during the breeding period in New England forests (Rodenhouse 1992, Sillett and Holmes 2002, R. T. Holmes, *unpublished data*). Similarly, because most of the foliage-gleaning species that we examined spend the nonbreeding season in different regions of the Neotropics (Ehrlich et al. 1988), it is unlikely that nonbreeding season climatic effects on survival could be responsible for their population synchrony on the breeding grounds.

In contrast, winter climatic conditions do appear to influence overwinter survival of birds that are year-round residents in New England forests. Our results indicate that, across this region, breeding populations of winter residents were higher following winters with lower snowfall and higher mean temperatures. High snowfall has been shown to negatively affect overwinter survival of birds, primarily through its effects on food availability (Greenwood and Baillie 1991, Newton et al. 1998, Doherty and Grubb 2002). Extremely low temperatures have also been shown to negatively affect overwinter survival, both directly (e.g., via temperature-related mortality) and indirectly (e.g., via prey inactivity) (Ekman 1984, Nilsson 1987, Greenwood and Baillie 1991). Our results lend support for the hypothesis that winter is the season that most affects bird populations that reside year round at north temperate

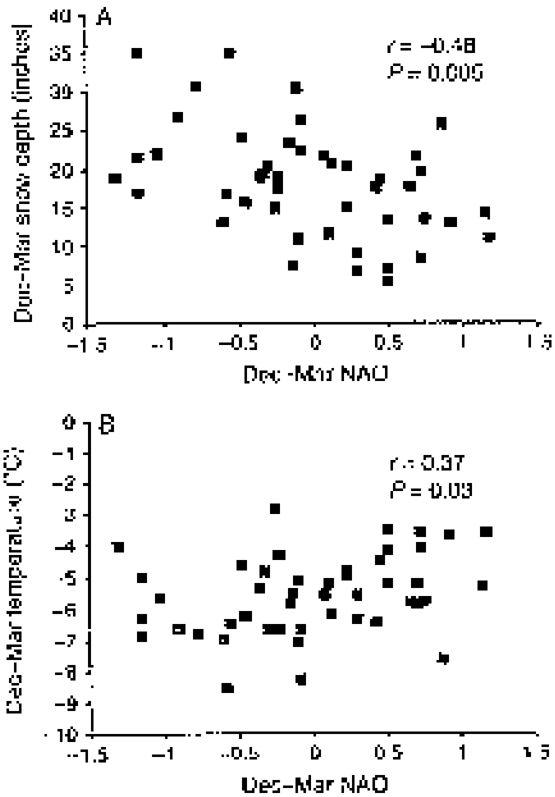

FIG. 5. Statistically significant correlations between winter NAO (December–March) index and (A) average winter snow depth (1 inch = 2.54 centimeters) and (B) average winter temperatures at the Hubbard Brook Experimental Forest (1956–2001).

or higher latitudes (Lack 1954, Fretwell 1972, Holmes et al. 1986, Lahti et al. 1998).

Alternative synchronizing mechanisms

While we have shown a strong link between foliage gleaner synchrony and insect synchrony, and between year-round resident synchrony and climate, this does not exclude the possibility that other factors contributed to bird synchrony in this region. Many of the species included in our analysis show both negative and positive population trends over the last 30 years in the study area (Holmes and Sherry 2001). However, in an analysis of North American Breeding Bird Survey data in the northeast, we have detected significant population synchrony at distances up to 300 km for many species (e.g., American Redstart) after removing the long-term trends from the time series (J. Jones, P. J. Doran, and R. T. Holmes, *unpublished data*). These results imply that while long-term trends likely contributed to the population synchrony we observed in this study, they are not its sole generator.

Predation on nestlings and adult birds could synchronize population fluctuations if predator populations had equal impact on each of our focal species at all four sites. This is unlikely, however, given their diverse reproductive ecologies and activity patterns, in combination with the largely synchronous fluctuations of the focal species within individual sites. For example, Black-throated Green Warblers and Red-eyed Vireos nest and forage high in the forest canopy, while American Redstarts and Black-throated Blue Warblers nest and forage in the lower canopy and the shrub layer, respectively. It is unlikely that these species are exposed to the same predation pressures, on adults or nests (Sloan et al. 1998). Furthermore, as previously mentioned, adult survival during the breeding season tends to be extremely high, at least at Hubbard Brook (e.g., Black-throated Blue Warbler, Sillett and Holmes 2002). Thus, we do not believe that predation is a major contributor to synchrony in bird abundances in our study.

The dispersal of individuals between populations has also been identified as a dominant mechanism maintaining spatial population synchrony (Royama 1992). At our study site, years of high reproductive success are followed by high recruitment that is, presumably, the result of high juvenile dispersal among regional breeding populations (Sillett et al. 2000). However, annual pulses in natal dispersal are ultimately linked to food abundance, given the critical influence that food has on reproductive success (reviewed by Newton 1998). Ultimately, dispersal among regional populations in this system may be the realization of the influence of regionally synchronous caterpillar fluctuations on bird reproduction.

CONCLUSIONS

Of the three processes previously highlighted as potential synchrony mechanisms (see *Introduction*), our study demonstrates that food (i.e., trophic interactions) and climate (i.e., Moran effect) are major influences on local and regional bird population abundances in New England. In the case of the foliage gleaners, the existence of a general pattern of spatial population synchrony across trophic levels has implications for regional populations of forest insects, avian insectivores, and forest ecology, especially in the context of global warming and long-term climate change (Forchhammer et al. 1998, Harrington et al. 1999, Easterling et al. 2000, Stenseth et al. 2000, Sanz 2002, Walther et al. 2002). Any alteration of leaf phenology, production, or quality will likely affect the development and abundance of herbivorous insects (Raupp et al. 1988). While insect populations may be able to shift annual cycles to meet new climatic situations (Visser et al. 1998), migratory bird populations may be more limited given the temporal restrictions imposed by a migratory lifestyle (Both and Visser 2001). In contrast, the role that winter weather events play in regulating and limiting north temperate bird populations may be becoming less important, given the trends to more positive NAO values in recent years (Hurrell 1995).

Over the duration of our study, the six foliage-gleaning species accounted for 73% of the Neotropical migratory individuals and 68% of all birds in our study areas. Consequently, any ecological factor that influences the population dynamics of these species could have a dramatic impact on the bird community as a whole. In particular, spatial population synchrony increases the potential detrimental impact of a spatially correlated disturbance (e.g., a severe winter storm), by limiting the ability of local populations to "rescue" one another via recolonization (Johst and Wissel 1997). Given the level of conservation concern surrounding many North American bird populations (e.g., Terborgh 1989), field research should focus on spatial relationships between populations and the ability of populations and species to respond to changes in climatic conditions.

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LITERATURE CITED

Ayres, M. P. 1993. Plant defense, herbivory, and climate change. Pages 75–94 in P. M. Kareiva, J. G. Kingsolver, and R. B. Huey, editors. Biotic interactions and global change. Sinauer, Sunderland, Massachusetts, USA.

Bjørnstad, O. N., R. A. Ims, and X. Lambin. 1999. Spatial population dynamics: analyzing patterns and processes of population synchrony. Trends in Ecology and Evolution 14:427–432.

Blenckner, T., and H. Hillebrand. 2002. North Atlantic Oscillation signatures in aquatic and terrestrial ecosystems: a meta-analysis. Global Change Biology 8:203–212.

Both, C., and M. E. Visser. 2001. Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. Nature 411:296–298.

Buonaccorsi, J. P., J. S. Elkinton, S. R. Evans, and A. M. Liebhold. 2001. Measuring and testing for spatial synchrony. Ecology 82:1668–1679.

Doherty, P. F., Jr., and T. C. Grubb, Jr. 2002. Survivorship of permanent-resident birds in a fragmented forested landscape. Ecology 83:844–857.

Easterling, D. R., G. A. Meehl, C. Parmesan, S. A. Changnon, T. R. Karl, and L. O. Mearns. 2000. Climate extremes: observations, modeling, and impacts. Science 289:2068–2074.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman and Hall, New York, New York, USA.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook. Simon and Schuster, New York, New York, USA.

Ekman, J. 1984. Density-dependent seasonal mortality and population fluctuations of the temperate-zone Willow Tit (*Parus montanus*). Journal of Animal Ecology 53:119–134.

Forchhammer, M. C., E. Post, and N. C. Stenseth. 1998. Breeding phenology and climate. Nature 391:29–30.

Fretwell, S. D. 1972. Populations in a seasonal environment. Princeton University Press, Princeton, New Jersey, USA.

Greenwood, J. J. D., and S. R. Baillie. 1991. Effects of density-dependence and weather on population changes of English passerines using a non-experimental paradigm. Ibis 133:S121–133.

Hanski, I., and I. P. Woiwod. 1993. Spatial synchrony in the dynamics of moth and aphid populations. Journal of Animal Ecology 62:656–668.

Harrington, R., I. Woiwod, and T. Sparks. 1999. Climate change and trophic interactions. Trends in Ecology and Evolution 14:146–150.

Haydon, D. T., N. C. Stenseth, M. S. Boyce, and P. E. Greenwood. 2001. Phase coupling and synchrony in the spatiotemporal dynamics of muskrat and mink populations across Canada. Proceedings of the National Academy of Sciences, USA 98:13149–13154.

Holmes, R. T., and J. C. Schultz. 1988. Food availability for forest birds: effects of prey distribution and abundance on bird foraging. Canadian Journal of Zoology 66:720–728.

Holmes, R. T., and T. W. Sherry. 2001. Thirty-year bird population trends in an unfragmented temperate deciduous forest: importance of habitat change. Auk 118:589–610.

Holmes, R. T., T. W. Sherry, and F. W. Sturges. 1986. Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook. Ecological Monographs 56:201–220.

Holmes, R. T., T. W. Sherry, and F. W. Sturges. 1991. Numerical and demographic responses of temperate forest birds to annual fluctuations in their food abundance. Acta XX Congressus Internationalis Ornithologici 1559–1567.

Hurrell, J. W. 1995. Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269:676–679.

Hurrell, J. W., and H. van Loon. 1997. Decadal variations in climate associated with the North Atlantic Oscillation. Climatic Change 36:301–326.

Ims, R. A., and H. P. Andreassen. 2000. Spatial synchronization of vole population dynamics by predatory birds. Nature 408:194–196.

Johst, K., and C. Wissel. 1997. Extinction risk in a temporally correlated fluctuating environment. Theoretical Population Biology 52:91–100.

Jonzén, N., A. Hedenström, C. Hjort, Å. Lindström, P. Lundberg, and A. Andersson. 2002. Climate patterns and the stochastic dynamics of migratory birds. Oikos 97:329–336.

Kendall, B. E., O. N. Bjørnstad, J. Bascompte, T. H. Keitt, and W. F. Fagan. 2000. Dispersal, environmental correlation, and spatial synchrony in population dynamics. American Naturalist 155:628–636.

Koenig, W. D. 1999. Spatial autocorrelation of ecological phenomena. Trends in Ecology and Evolution 14:22–26.

Koenig, W. D. 2001. Spatial autocorrelation and local disappearances in wintering North American birds. Ecology 82:2636–2644.

Lack, D. 1954. The natural regulation of animal numbers. Clarendon, Oxford, UK.

Lahti, K., M. Orell, S. Rytkönen, and K. Koivula. 1998. Time and food dependence in Willow Tit winter survival. Ecology 79:2904–2916.

Leak, W. B., and M. L. Smith. 1996. Sixty years of management and natural disturbance in a New England forest. Forest Ecology and Management 81:63–73.

Merrens, E. J., and D. R. Peart. 1992. Effects of hurricane damage on individual growth and stand structure in a hardwood forest in New Hampshire, USA. Journal of Ecology 80:787–795.

Moran, P. A. P. 1953. The statistical analysis of the Canadian lynx cycle. II. Synchronization and meteorology. Australian Journal of Zoology 1:291–298.

Newton, I. 1998. Population limitation in birds. Academic Press, San Diego, California, USA.

Newton, I., P. Rothery, and L. C. Dale. 1998. Density-dependence in the bird populations of an oak wood over 22 years. Ibis 140:131–136.

Nilsson, S. 1987. Limitation and regulation of population density in the nuthatch *Sitta europaea* (Aves) breeding in natural cavities. Journal of Animal Ecology 56:921–937.

Nott, M. P., D. F. DeSante, R. B. Siegel, and P. Pyle. 2002. Impacts of the El Niño-Southern Oscillation and the North Atlantic Oscillation on avian productivity in forests of the Pacific Northwest of North America. Global Ecology and Biogeography 11:333–342.

Ottersen, G., B. Planque, A. Belgrano, E. Post, P. C. Reid, and N. C. Stenseth. 2001. Ecological effects of the North Atlantic Oscillation. Oecologia 128:1–14.

Paradis, E., S. R. Baillie, W. J. Sutherland, and R. D. Gregory. 1999. Dispersal and spatial scale affect synchrony in spatial population dynamics. Ecology Letters 2:114–120.

Paradis, E., S. R. Baillie, W. J. Sutherland, and R. D. Gregory. 2000. Spatial synchrony in populations of birds: effects of habitat, population trend, and spatial scale. Ecology 81:2112–2125.

Post, E., M. C. Forchhammer, and N. C. Stenseth. 1999. Population ecology and the North Atlantic Oscillation (NAO). Ecological Bulletins 47:117–125.

Ranta, E., V. Kaitala, J. Lindström, and H. Lindén. 1995*a*. Synchrony in population dynamics. Proceedings of the Royal Society London B 262:113–118.

Ranta, E., V. Kaitala, and P. Lundberg. 1997. The spatial dimension in population fluctuations. Science 278:1621–1623.

Ranta, E., J. Lindström, and H. Lindén. 1995*b*. Synchrony in tetraonid population dynamics. Journal of Animal Ecology 64:767–776.

Raupp, M. J., J. H. Werren, and C. S. Sadof. 1988. Effects of short-term phenological changes in leaf suitability on the survivorship, growth, and development of gypsy moth (Lepidoptera: Lymantriidae) larvae. Environmental Entomology 17:316–319.

Rodenhouse, N. L. 1992. Potential effects of climatic change on migrant landbirds. Conservation Biology 6:263–272.

Rodenhouse, N. L., and R. T. Holmes. 1992. Effects of experimental and natural food reductions for breeding Black-throated Blue Warblers. Ecology 73:357–372.

Ropelewski, C. F., and M. S. Halpert. 1986. North American precipitation and temperature patterns associated with the El Niño/Southern Oscillation (ENSO). Monthly Weather Review 114:2352–2362.

Royama, T. 1992. Analytical population dynamics. Chapman and Hall, New York, New York, USA.

Sæther, B.-E., J. Tufto, S. Engen, K. Jerstad, O. W. Røstad, and J. E. Skåtan. 2000. Population dynamical consequences of climate change for a small temperate songbird. Science 287:854–856.

Sanz, J. J. 2002. Climate change and breeding parameters of great and blue tits throughout the western Palaearctic. Global Change Biology 8:409–422.

Scriber, J. M., and F. Slansky, Jr. 1981. The nutritional ecology of immature insects. Annual Review of Entomology 26:183–211.

Sillett, T. S., and R. T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296–308.

Sillett, T. S., R. T. Holmes, and T. W. Sherry. 2000. Impacts of a global climate cycle on population dynamics of a migratory songbird. Science 288:2040–2042.

Sloan, S. S., R. T. Holmes, and T. W. Sherry. 1998. Depredation rates and predators at artificial nests in an unfragmented northern hardwoods forest. Journal of Wildlife Management 62:529–539.

Stenseth, N. C., K.-S. Chan, H. Tong, R. Boonstra, S. Boutin, C. J. Krebs, E. Post, M. O'Donoghue, N. G. Yoccoz, M. C. Forchhammer, and J. W. Hurrell. 1999. Common dynamic structure of Canada lynx populations within three climatic regions. Science 285:1071–1073.

Stenseth, N. C., W. Falck, K.-S. Chan, O. N. Bjørnstad, M. O'Donoghue, H. Tong, R. Boonstra, S. Boutin, C. J. Krebs, and N. G. Yoccoz. 1998. From patterns to processes: phase and density dependencies in the Canadian lynx cycle. Proceedings of the National Academy of Sciences, USA 95:15430–15435.

Sutcliffe, O. L., C. D. Thomas, and D. Moss. 1996. Spatial synchrony and asynchrony in butterfly population dynamics. Journal of Animal Ecology 65:85–95.

Terborgh, J. 1989. Where have all the birds gone? Princeton University Press, Princeton, New Jersey, USA.

Visser, M. E., A. J. van Noordwijk, J. M. Tinbergen, and C. M. Lessells. 1998. Warmer springs lead to mistimed reproduction in great tits (*Parus major*). Proceedings of the Royal Society of London B 265:1867–1870.

Walther, G.-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389–395.

Williams, D. W., and A. M. Liebhold. 1995. Influence of weather on the synchrony of gypsy moth (Lepidoptera: Lymantriidae) outbreaks in New England. Environmental Entomology 24:987–995.

APPENDIX

A table of the bird species included in the synchrony analyses and their associated functional groups in New Hampshire are available in ESA's Electronic Data Archive: *Ecological Archives* E084-079-A1.

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THIRTY-YEAR BIRD POPULATION TRENDS IN AN UNFRAGMENTED TEMPERATE DECIDUOUS FOREST: IMPORTANCE OF HABITAT CHANGE

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ABSTRACT.—Abundances of forest birds in an unfragmented, undisturbed, and relatively mature temperate deciduous forest at the Hubbard Brook Experimental Forest, New Hampshire, changed markedly between 1969 and 1998. Total numbers of birds (all species combined) declined from 210–225 individuals/10 ha in the early 1970s to 70–90/10 ha in the 1990s. Of the 24 regularly occurring species, 12 decreased significantly (four to local extinction), three increased significantly, and nine remained relatively constant in abundance. Nine of the 12 declining species were Neotropical migrants. Most species exhibited similar trends on Breeding Bird Survey (BBS) routes in New Hampshire during the same 30 year period and on three replicate study sites in nearby sections of the White Mountains from 1986–1998. Probable causes of trends were diverse and differed among species. Most could be accounted for by individual species' responses to events occurring primarily in the local breeding area. The most important local factor affecting bird abundance was temporal change in forest vegetation structure, resulting from natural forest succession and local disturbances. Four species that declined markedly and in some cases disappeared completely from the study plot (Least Flycatcher, *Empidonax minimus*; Wood Thrush, *Hylocichla mustelina*; Philadelphia Vireo, *Vireo philadelphicus*; and American Redstart, *Setophaga ruticilla*) appear to attain peak abundance in early or mid-successional forests. Species preferring more mature forests, such as Black-throated Green Warbler (*Dendroica virens*) and Ovenbird (*Seiurus aurocapillus*), increased significantly in abundance over the 30 year study. Other important factors influencing bird abundances were food availability and events in the migratory and winter periods. Nest-predation rates, although varying among years, showed no long-term pattern that would account for population declines, and brood parasites were absent from this forest. Findings from this study demonstrate that major changes in bird abundances occur over time even in undisturbed and relatively mature forests, and illustrate the need for considering habitat requirements of individual species and how habitat suitability changes over time when trying to assess the causes of their long-term population trends. The results also imply that any conclusions about the effects of other factors affecting forest bird abundances, such as increased nest predation or brood parasitism associated with habitat fragmentation, must also account for successional changes that may be affecting habitat suitability. *Received 28 July 2000, accepted 28 February 2001.*

MANY SPECIES AND POPULATIONS of North American birds have undergone declines in abundance in recent decades, especially migratory songbirds. Some species have declined throughout their breeding range (Robbins et al. 1989, Peterjohn et al. 1995), whereas others have declined in some regions but remained stable or even increased in others (James et al. 1996). The extent and causes of such changes in abundance are much debated (Askins et al. 1990, Hagan and Johnston 1992, Rappole and McDonald 1994, 1998; Sherry and Holmes 1995, 1996; Martin and Finch 1995, Latta and Baltz 1997, Askins 2000). Some explanations have focused on the effects of deforestation and other changes in the tropical habitats where many of these species winter, whereas others emphasize habitat degradation and events in the north temperate breeding grounds. For the latter, extensive fragmentation of large tracts of forest land, with associated increases in nest predation and in brood parasitism by Brown-headed Cowbirds (*Molothrus ater*), is perhaps the most frequently cited factor affecting the abundances of breeding songbirds in North America (Brittingham and Temple 1983, Wilcove and Robinson 1990, Askins et al. 1990, Bohning-

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Gaese et al. 1993, Donovan et al. 1995, Robinson et al. 1995a,b; Rauth 2000).

As a result of those reported declines, research on bird populations, especially long-distance migrants, has expanded greatly in recent years. Many studies have considered effects of habitat fragmentation, forest edges, and other human-mediated changes at both local and landscape scales in breeding and wintering areas as well as along migratory routes (see Keast and Morton 1980, Hagan and Johnston 1992, Martin and Finch 1995, Schmidt and Whelan 1999, Askins 2000). However, relatively few data exist on the degree to which bird populations are changing, or have changed, in undisturbed or unfragmented habitats. Several studies have compared bird abundances at one site over long (e.g. 20–50 year) time intervals (e.g. Ambuel and Temple 1982, Marshall 1988, Wilcove 1988, Kirk et al. 1997), whereas others have tracked populations on a year-to-year basis at single localities (Kendeigh 1982, Leck et al. 1988). In the latter two investigations, in particular, the areas surrounding the study areas had changed in the intervening years, due to human development and increased isolation from other similar habitat, providing interesting but confounded conditions for assessing population trends. Similarly, the continent-wide Breeding Bird Survey (BBS) provides long-term abundance data on bird populations, but those are derived from roadside counts where nearby habitats are subject to encroaching fragmentation and other human-mediated change (e.g. Peterjohn et al. 1995, 1997). Long-term quantitative data on bird populations in undisturbed habitats are rare (see Holmes et al. 1986, Enemar et al. 1994, Wesolowski and Tomiałojć 1997 as examples), yet information from such sites can be useful for understanding what factors determine bird abundances locally and for providing a control against which to compare population changes occurring in more human-influenced habitats.

In this paper, we document changes in bird populations within an unfragmented, relatively mature northern hardwood forest in the White Mountain National Forest, New Hampshire. We present data from the Hubbard Brook Experimental Forest for a continuous 30 year period (1969–1998), updating the long-term record on bird-population trends for that site (Holmes and Sturges 1975, Holmes et al. 1986, Holmes and Sherry 1988). We also provide comparative data on abundances of the same bird species on three replicate forest plots in nearby sections of the White Mountain National Forest from 1986–1998 and on BBS routes across the state of New Hampshire from 1969–1998. These data sets provide a regional perspective to population trends recorded at Hubbard Brook. We interpret causes of observed trends on the basis of available information about requirements of each species, taking advantage of our own intensive ecological and demographic studies of selected species in that same forest and, in some cases, in their winter quarters. We also take into account possible vegetation changes in this forest site that may have influenced the abundances of bird species occurring there. Results demonstrate that bird abundances change, sometimes drastically, even within relatively undisturbed forest habitats, and provide a long-term baseline for population changes of New England forest birds.

STUDY SITES

This study was conducted in the Hubbard Brook Experimental Forest, West Thornton and Woodstock, New Hampshire and in surrounding sections of the White Mountain National Forest. In the mid 1960s, forest within the Hubbard Brook valley was described as "mature second growth" (Bormann et al. 1970:377), "representative of the climax" (Whittaker et al. 1974:233), although still accumulating biomass (Bormann and Likens 1979). Recent evidence suggests that tree biomass accumulation began leveling off in the 1980s (T. G. Siccama unpubl. data) due to approaching steady-state conditions and perhaps to cation leaching effects of acid precipitation reducing forest productivity (Likens et al. 1996).

Birds were censused from 1969 to 1998 on a 10 ha gridded plot, located within continuous, northern hardwood forest (see Holmes and Sturges 1975, Holmes et al. 1986, and Holmes 1990). From 1986 to 1998, we also censused birds on three additional 10 ha plots in nearby parts of the White Mountain National Forest, which were at the same elevation and aspect and had similar cutting history and vegetation characteristics as Hubbard Brook. Those replicate plots were located (1) on the southeast slope of Mount Moosilauke, 8 km north of Hubbard Brook, in Woodstock, New Hampshire, (2) on Stinson Mountain, 13 km to the southwest, in Rumney, New Hampshire, and (3) near Russell Pond, 11 km to the northeast, in Thornton, New Hampshire. All were situated within large tracts of continuous forest but on different mountain systems separated by inter-

TABLE 1. Tree species composition of the Hubbard Brook study area (1967) and of the three replicate study sites (1986) in the White Mountain National Forest, New Hampshire, as measured by the point quarter method (Cottam and Curtis 1956). See text for scientific names for plant species.

Size class/tree species	Hubbard Brook	Moosilauke	Russell Pond	Stinson Mountain
	Importance value[a]			
2–10 cm DBH[b]				
Sugar maple	27.8	40.3	40.5	46.0
American beech	52.1	20.5	41.4	35.6
Yellow birch	1.4	7.3	3.0	4.2
White ash	0.0	0.0	7.4	1.6
Striped maple	11.3	26.4	1.5	6.5
Red spruce	2.6	2.2	0.0	2.1
Other species	2.8	3.3	5.1	8.2
10.1–20 cm DBH				
Sugar maple	43.0	19.6	43.8	25.9
American beech	30.1	35.6	28.1	32.3
Yellow birch	9.2	16.4	7.1	10.4
White ash	0.6	2.1	4.1	14.1
Striped maple	1.7	6.1	1.2	9.2
Red spruce	0.8	1.0	0.0	0.7
Other species	4.6	5.2	5.7	3.6
>20 cm DBH				
Sugar maple	39.7	27.1	43.0	35.7
American beech	25.6	33.6	28.8	31.6
Yellow birch	22.5	23.8	14.7	9.6
White ash	10.4	9.7	10.0	17.0
Others	1.8	7.8	3.5	2.1

[a] Importance value = 100 (relative basal area + relative density + relative frequency)/3.
[b] DBH = diameter at breast height.

verging valleys containing roads, agricultural lands, and human habitations. All were on south-southeast facing slopes and at elevations of 500–600 m above sea level, and all contained at least one permanent stream, along with additional intermittent water courses. Each plot was situated within forest tracts that had been selectively logged in the early 1900s, but had remained free of any direct human disturbance since that time. Influences of natural disturbances such as a major hurricane in 1938, fungal pathogens, and sporadic ice and wind storms (Mertens and Pearr 1992, Leak and Smith 1996) appear to have been similar across those sites, although an ice storm in 1998 was most severe at Stinson Mountain.

Inventories of forest trees made in 1986–1987 showed that vegetation on those replicate plots was similar to that on the long-term census plot at Hubbard Brook (Table 1, see below). All four plots were dominated by American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and yellow birch (*Betula alleghaniensis*), with occasional white ash (*Fraxinus americana*) and red spruce (*Picea rubens*), and forest canopies averaged 20–25 m in height. The shrub layer on each plot consisted primarily of hobblebush (*Viburnum alnifolium*), striped maple (*A. pensylvanicum*), and seedlings and saplings of the dominant tree species (except yellow birch and white ash, which were essentially absent from the shrub layer). Some vegetational differences did occur among plots. The Moosilauke site had relatively fewer large sugar maples than the other three sites, whereas Russell and Stinson had relatively more white ash and less yellow birch (Table 1). In the mid 1980s, the shrub and sapling layers at Hubbard Brook and Moosilauke were thicker, contained more striped maple (Table 1) and hobblebush, and were more heterogeneous than at the other two sites (see Holmes et al. 1996).

METHODS

Birds were censused annually from late May through early July, using methods described by Holmes and Sturges (1975). Those methods, which we used consistently throughout the study on all plots, consisted of timed censuses along transects and extensive territory mapping, supplemented by information on nest locations, mist-net capture data, and other observations. Timed censuses were conducted at least once per week on each plot starting between 0500 and 0600 EST and lasting 1 h. Those consisted of two observers walking at a fixed rate (50 m/6 min) on parallel lines 100 m apart and recording all birds seen or heard within 50 m on either side of the 500 m transect line. Number of individuals (separating males and females where possible) of each species within the boundaries of the 10 ha plot were determined from those data. Following the timed census, the two observers moved systematically about the study plot, recording presence of singing and especially simultaneously singing individuals, presence and activities of males, locations of nests, and other evidence of breeding activity. Mist-netting was conducted at weekly or biweekly intervals during the breeding season in some years and locations (1969–1985 and 1989–1992 at Hubbard Brook, and 1989–1995 at Moosilauke). Number of net-captures of each species helped to confirm the visual census and territory mapping data (Holmes and Sturges 1975), but contributed little new information, so large-scale mist-netting was discontinued in later years. Some species under intensive study (especially American Redstart and Black-throated Blue Warbler, see Table 2 for scientific names) were captured and given unique combinations of color bands, which facilitated identification of individuals and hence census determinations.

All positional data (e.g. locations of singing males, simultaneous singing by neighboring conspecifics, females, nests, and mist-net captures when available) from the census period were plotted on daily maps for each species on each plot. Numbers of ter-

TABLE 2. Frequency of occurrence, median (range), mean density, and variability in abundance of 24 bird species breeding on 10 ha study plot at Hubbard Brook Experimental Forest, New Hampshire, 1969–1998

Bird species	Frequency[a]	Median (range)[b]	Mean density ± SD (CV)[c]
North temperate residents			
Downy Woodpecker (*Picoides pubescens*)	29	2 (0–6)	1.9 ± 1.4 (74)
Hairy Woodpecker (*Picoides villosus*)	30	2 (>1–3)	1.6 ± 0.7 (43)
White-breasted Nuthatch (*Sitta carolinensis*)	30	2 (>1–6)	1.9 ± 1.4 (71)
Black-capped Chickadee (*Poecile atricapillus*)	29	1 (0–4)	1.1 ± 1.0 (90)
Short distance migrants			
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	30	3 (1–6)	2.8 ± 1.3 (46)
Brown Creeper (*Certhia americana*)	15	>1 (0–2)	0.6 ± 0.8 (140)
Winter Wren (*Troglodytes troglodytes*)	22	1 (0–6)	1.3 ± 1.5 (123)
Hermit Thrush (*Catharus guttatus*)	29	3 (0–8)	3.5 ± 2.1 (61)
Blue-headed Vireo (*Vireo solitarius*)	15	>1 (0–4)	0.6 ± 1.0 (161)
Yellow-rumped Warbler (*Dendroica coronata*)	12	0 (0–5)	0.9 ± 1.3 (133)
Dark-eyed Junco (*Junco hyemalis*)	16	0 (0–8)	1.6 ± 2.7 (167)
Long-distance Neotropical migrants			
Least Flycatcher (*Empidonax minimus*)	17	1 (0–57)	13.0 ± 17.3 (133)
Veery (*Catharus fuscescens*)	30	3 (>1–6)	2.6 ± 1.3 (49)
Swainson's Thrush (*Catharus ustulatus*)	27	3 (0–11)	4.1 ± 3.3 (81)
Wood Thrush (*Hylocichla mustelina*)	22	1 (0–9)	2.9 ± 3.1 (106)
Philadelphia Vireo (*Vireo philadelphicus*)	14	0 (0–8)	1.8 ± 2.3 (129)
Red-eyed Vireo (*Vireo olivaceus*)	30	22 (13–31)	21.7 ± 4.3 (20)
Black-throated Green Warbler (*Dendroica virens*)	30	10 (6–18)	11.2 ± 3.7 (33)
Black-throated Blue Warbler (*Dendroica caerulescens*)	30	11 (4–16)	10.7 ± 2.9 (27)
Blackburnian Warbler (*Dendroica fusca*)	26	2 (0–7)	2.5 ± 2.0 (82)
Ovenbird (*Seiurus aurocapillus*)	30	11 (6–22)	12.5 ± 4.0 (32)
American Redstart (*Setophaga ruticilla*)	30	21 (2–44)	21.9 ± 11.5 (54)
Scarlet Tanager (*Piranga olivacea*)	30	3 (2–8)	3.5 ± 1.8 (52)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	30	4 (>1–10)	4.5 ± 2.4 (54)

[a] Number of years in which one or more individuals (pairs) seen on Hubbard Brook plot.
[b] Median number (and range) of individuals breeding on 10 ha Hubbard Brook plot, 1969–1998.
[c] Mean ± 1 SD of total number of adult birds (males plus females) occupying 10 ha plot 1969–1998. SD and coefficient of variation (CV) are given only as approximate descriptors of variability in numbers of individuals in populations over the 30 year period (see text).

ritories of each species were then determined from those maps, by drawing boundaries encompassing each cluster of observations. These were compared to the number of singing males recorded on the timed censuses and to the number of captures in mist nets (when available), and any discrepancies led to reexamination of all data to determine best estimates of bird abundances. Number of individuals of each species occupying the 10 ha plot was then determined by counting the number of whole or fractional territories, taking into account the mating status of each territorial male. Mating status was determined by the presence of females, nests, or food delivery by males. Data therefore represent total number of adult individuals (males plus females) of each species per 10 ha, and represent best estimates of absolute densities of each species on a 10 ha area of northern hardwood forest (Holmes and Sturges 1975).

For this paper, we consider population trends of the 24 most abundant and regularly occurring breeding species in the northern hardwood forests, grouped by migratory status (see Table 2). We excluded from trend analysis species that occurred sporadically (present in ≤4 of the 30 years of study; e.g. Red-breasted Nuthatch, *Sitta canadensis*; American Robin, *Turdus migratorius*; Black-and-white Warbler, *Mniotilta varia*; Canada Warbler, *Wilsonia canadensis*; and Purple Finch, *Carpodacus purpureus*), as well as those that were regular breeders but present at very low densities (e.g. Ruby-throated Hummingbird, *Archilochus colubris*, Pileated Woodpecker, *Dryocopus pileatus*; Eastern Wood Pewee, *Contopus virens*; and Blue Jay, *Cyanocitta cristata*). Abundances of these species, when present, were included in estimates of total numbers of birds on the study plot (see Fig. 1).

Because some species occurred at very low densities or because their abundances changed markedly over the 30 year study period, no one measure of central tendency or variability adequately described the data. As a result, we present several descriptive measures of the abundance data for each of the 24 species (n = 30 years): median, range, mean (±SD), coefficient of variation (CV = SD × 100/mean), and frequency of years present on the study area. Because SD and CV may not be appropriate for many of the species-specific trends, they are presented here only as approximate descriptors of annual variability

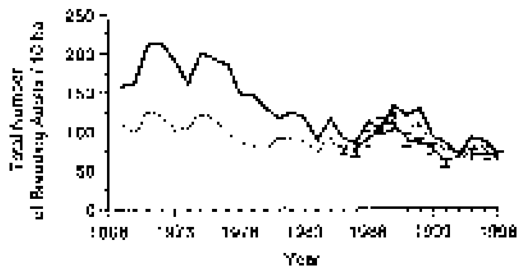

FIG. 1. Total numbers of adult birds (males plus females, all species combined) breeding on the 10 ha study plot at Hubbard Brook, 1969–1998, and on three replicate 10 ha sites (mean ± 1 SE) in nearby parts of the White Mountain National Forest, 1986–1998. Dashed line indicates total numbers of adult birds minus those of Least Flycatcher, Wood Thrush, Philadelphia Vireo, and American Redstart, four species most likely to have declined due to changes related to forest succession (see text).

within each species population. They also allow for comparisons with previous analyses of those data (Holmes et al. 1986, Holmes and Sherry 1988).

Population trends were determined from linear regression models for the abundance of each species over time, following procedures of Holmes and Sherry (1988). Population changes were transformed to units of average percentage annual change: $(t - 1)(100)$, where t = trend. Trends were considered significant when linear regressions had slopes that were statistically different from zero ($P \leq 0.05$), based on F-tests. F-tests are approximate in this case because annual abundance of a species in one year may not be independent among years. Thus, significance levels should be considered as estimates of whether or not slopes differ from zero.

Data on bird abundances from the replicate plots in the nearby White Mountain National Forest were averaged for each year, and are given as means ± 1 SE (n = 3). Those patterns of abundance on nearby sites are presented here only for general comparisons of density levels and abundance trends with the 30 year patterns for each species at Hubbard Brook. More detailed analyses of the similarities and differences in abundance patterns among those replicate plots for individual species will be presented elsewhere (R. T. Holmes and P. J. Doran unpubl. data).

For comparison at the statewide level, we used trends in abundance for the same bird species on the 22–24 BBS routes in New Hampshire for the years 1969 through 1998, obtained from the Patuxent Wildlife Research Center (J. R. Sauer pers. comm.). BBS trends were calculated on the basis of the linear route regression method (Peterjohn et al. 1997), which yielded bootstrap estimates for each species of the median "trend" from which the average percentage annual change was calculated, along with an estimate of variance of these trends among routes for each species. Statistical significance was determined with z tests.

Vegetation on the Hubbard Brook plot was quantified using the point quarter method (Cottam and Curtis 1956) and foliage profiles (MacArthur and Horn 1969). For the former, 40 points were located at 50 m intervals on the census grid, and the nearest tree identified to the point in each of the four quadrants delineated by cardinal compass directions and in each of three size classes: 2–10, 10.1–20, and >20 cm diameter at breast height (DBH). Vegetation was reinventoried at the same points at 5–9 year intervals between 1975–1999. Foliage profile measurements were conducted along six randomly placed sample lines at 23 sites located 100 m apart (in 1973) or at 40 sites located 50 m apart (in 1993) on the census grid. Along each line, six measurements were taken of distances to nearest leaf, both downwards to the ground using a plumb line, and upwards to the canopy using the focusing of a single lens reflex camera to measure distances to intercepting leaves (see MacArthur and Horn 1969). Profiles were calculated using the methods of MacArthur and Horn, and values were averaged for all points on the study area and divided by the height of each stratum. Student's t-tests were used to compare foliage density separately within each stratum between two sampling periods.

RESULTS

Trends in bird community patterns.—Of the 24 relatively common and regularly-occurring species on the study sites, 4 were permanent residents, 7 were short distance migrants, and 13 were long-distance migrants that winter in the Neotropics (Table 2). Only 11 of the 24 species were present as breeders on the Hubbard Brook plot in all 30 years, with the remainder absent in 1 to as many as 18 years. Several species were present and sometimes very abundant during the early years of study but then were absent for a long series of years, leading to wide ranges in abundance and higher mean than median values due to highly skewed frequency distributions in annual abundances (e.g. Least Flycatcher, Wood Thrush, Swainson's Thrush, Philadelphia Vireo, American Redstart, Dark-eyed Junco—Table 2; and see individual species accounts below). Similarly, other species occurred at low densities but fluctuated considerably in abundance from year to year, with low median and mean abundances and high SD and CV (e.g. Black-capped Chickadee, Brown Creeper, Winter Wren, Blue-headed Vireo, Blackburnian Warbler—Table 2).

TABLE 3. Population trends of forest birds on 10 ha study plot in the Hubbard Brook Experimental Forest, New Hampshire and on Breeding Bird Survey (BBS) routes in New Hampshire, grouped by migratory status.

Bird species	Hubbard Brook (1969–1998)		BBS (1966–1998)
	Regression slope[a]	% annual change[b]	% annual change[c]
North temperate residents			
Downy Woodpecker	−0.055***	−5.38	+0.32
Hairy Woodpecker	−0.014	−1.42	−2.40
White-breasted Nuthatch	−0.073*	−2.25	+2.65**
Black-capped Chickadee	−0.014	−1.40	+2.65**
Short distance migrants			
Brown Creeper	+0.013	+1.25	0.75
Winter Wren	−0.012	−1.73	+5.00**
Hermit Thrush	0.017	−1.69	+5.02***
Blue-headed Vireo	−0.002	−0.19	+0.20
Yellow-rumped Warbler	+0.069**	+4.81	+3.47**
Dark-eyed Junco	−0.080***	−8.30	1.49
Long-distance Neotropical migrants			
Yellow-bellied Sapsucker	−0.028	−2.73	+3.07*
Least Flycatcher	−0.188***	−17.17	−4.83***
Veery	−0.009	+0.93	1.90**
Swainson's Thrush	−0.084***	−9.04	NA[d]
Wood Thrush	−0.118***	−12.13	−4.59***
Philadelphia Vireo	−0.222***	8.54	NA
Red-eyed Vireo	−0.010*	−0.56	−1.39***
Black-throated Green Warbler	+0.025***	+2.32	−1.80
Black-throated Blue Warbler	−0.002	+0.19	+0.21
Blackburnian Warbler	−0.055**	−5.45	−4.08
Ovenbird	+0.013*	+1.37	+0.85
American Redstart	−0.050***	−4.85	3.10*
Scarlet Tanager	−0.023**	−2.32	−2.50***
Rose-breasted Grosbeak	−0.052***	−5.08	−7.34*

[a] Regression slope of bird abundance against time (mean ± SE, n = 30 years). Asterisks indicate approximate probability that slopes differ from zero (see text): *P < 0.05, **P < 0.01, ***P < 0.001.

[b] Percentage annual change on Hubbard Brook plot.

[c] Percentage annual change on BBS routes, using route regression method (see text).

[d] New Hampshire BBS data insufficient for trend analysis.

Trends in total abundance.—The total number of adult birds breeding on the 10 ha Hubbard Brook study area (all species combined) declined from a peak of about 210–220 in the early 1970s to 70–90 in the late 1990s (Fig. 1), a highly significant decline ($y = -4.15x - 196.48$, $r^2 = 0.72$, $P < 0.001$). From 1986–1998, mean total abundances of all species on the three replicate plots averaged slightly lower than those at Hubbard Brook, but showed the same temporal pattern, with numbers increasing from 1986 to the early 1990s, decreasing through 1994–1995, and then remaining relatively stable through 1998 (Fig. 1).

Population trends of resident species.—Of the four species that were permanently resident in the study area, two (White-breasted Nuthatch, Downy Woodpecker) declined significantly at Hubbard Brook (Table 3). Nuthatch numbers were high in 1969, the first year of this study, dropping in the two subsequent years, and then remained relatively stable in abundance through 1998 (Fig. 2). Downy Woodpeckers declined more gradually from 2–4 individuals per 10 ha in the early years of the study to <1 individual, on average, in the last 10 years (Fig. 2). During the same period, both Downy Woodpecker and White-breasted Nuthatch increased in abundance statewide in New Hampshire, a trend that was highly significant for the nuthatch (Table 3).

Populations of Hairy Woodpecker and Black-capped Chickadee at Hubbard Brook remained relatively stable between 1969 and 1998 at Hubbard Brook and between 1986–1998 on the replicate plots (Fig. 2, Table 3). On the New Hampshire BBS routes, Hairy Woodpeckers were

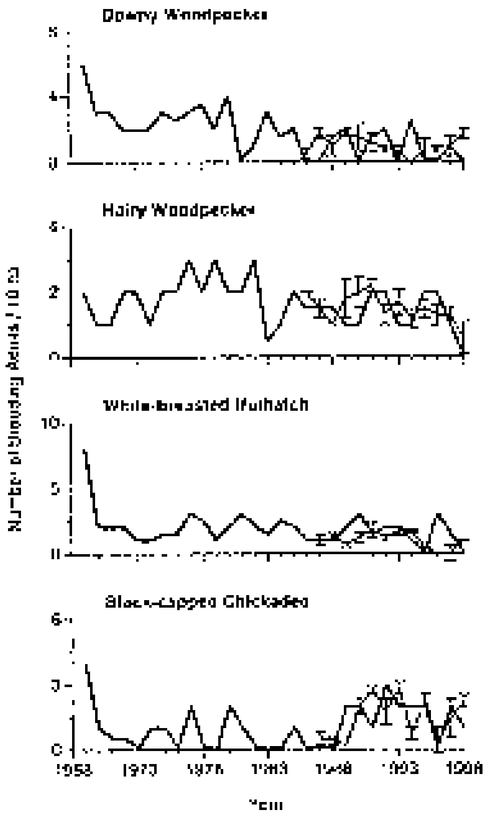

FIG. 2. Population trends of permanently resident species at Hubbard Brook, 1969–1998, and on three replicate sites (mean ± 1 SE), 1986–1998. Note differences in scale on y-axes.

relatively stable, but the chickadee showed a significantly increasing trend (Table 3).

Population trends of short-distance migrants.—Of the seven short-distance migrant species, five (Yellow-bellied Sapsucker, Brown Creeper, Winter Wren, Hermit Thrush, and to an extent Blue-headed Vireo) had stable population trends on the Hubbard Brook plot (Table 3). On the replicate plots, there were generally similar trends in abundance, especially for the creeper, Winter Wren and thrush, but not for the vireo (Fig. 3). On the larger regional scale, the creeper and the vireo also maintained stable or slightly increasing population trends, whereas abundances of the wren, thrush, and sapsucker increased significantly on the New Hampshire BBS routes (Table 3). One short-distance migrant, the Yellow-rumped Warbler, had a significantly increasing trend at Hubbard Brook, but occurred at lower average densities on the replicate plots (Fig. 3). That species increased significantly on BBS counts in New Hampshire between 1969 and 1998 (Table 3). Finally, the Dark-eyed Junco was relatively abundant in the first 10 years of this study, but then declined to local extinction on the Hubbard Brook plot by

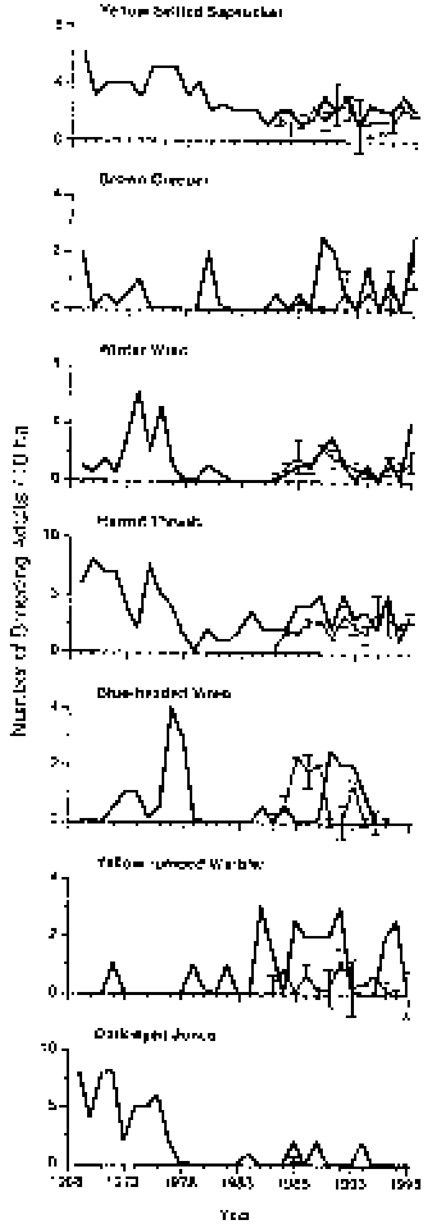

FIG. 3. Population trends of short-distance migrant species at Hubbard Brook, 1969–1998, and on three replicate sites (mean ± 1 SE), 1986–1998. Note differences in scale on y-axes.

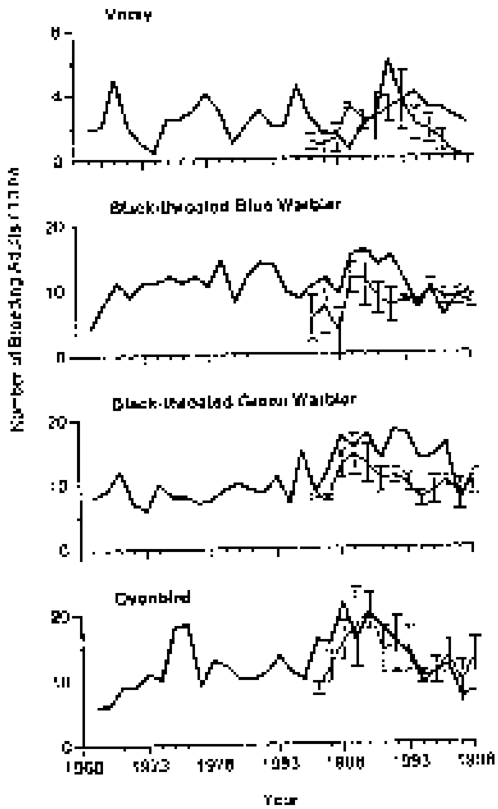

FIG. 4. Population trends of long-distance Neotropical migrants with either constant (Veery, Black-throated Blue Warbler) or significantly increasing (Black-throated Green Warbler, Ovenbird) abundance trends at Hubbard Brook, 1969–1998, and on three replicate sites (mean ± 1 SE), 1986–1998. Note differences in scale on y-axes.

1978. After that time, it was recorded only sporadically, and was essentially absent from the replicate plots between 1986–1998 (Fig. 3). That species exhibited a declining but nonsignificant trend on New Hampshire BBS routes over the 30 year time period (Table 3).

Population trends of long-distance migrants.—Of the 13 Neotropical migrant species, two maintained relatively constant population levels, two increased in abundance, and nine declined (Table 3). Abundance trends for those species are described below and in Figures 4–6, grouped by trend pattern.

Veeries and Black-throated Blue Warblers maintained relatively constant populations at Hubbard Brook between 1969 and 1998 (Table 3) and on the replicate plots since 1986 (Fig. 4). On New Hampshire BBS routes for that same period, the Black-throated Blue Warbler exhibited a stable trend, whereas the Veery declined significantly (Table 3).

In contrast, Ovenbirds and Black-throated Green Warblers increased significantly in abundance at Hubbard Brook between 1969 and 1998 (Table 3), and showed strikingly parallel patterns of population change on the replicate plots since 1986 (Fig. 4). On BBS routes, both species maintained relatively stable abundances between 1969 and 1998 (Table 3).

Of the nine long-distance migrant species that declined, three (Least Flycatcher, Wood Thrush, and Philadelphia Vireo) disappeared entirely from the Hubbard Brook plot by the early 1980s (Fig. 5). For the first 10 years of study, Least Flycatchers were very common, and in fact were the most abundant species in the study area between 1970–1975, reaching a peak of 57 individuals occupying the 10 ha study area in 1973. Though not as numerous, Wood Thrushes were also common in the first 15 years of the study, but dropped in numbers in the late 1970s and then were absent by the late 1980s (Fig. 5). Philadelphia Vireos, though never as numerous as the two preceding species, gradually declined from a maximum of 8 individuals (4 pairs) in 1972 to zero in 1983. Thus, all three species had disappeared entirely from the Hubbard Brook plot by the mid to late 1980s. All three were also rare or absent on the replicate plots for the period 1986–1998 (Fig. 5). On BBS routes in New Hampshire, Least Flycatchers, and Wood Thrushes showed similar highly significant declining trends in abundance (Table 3). Philadelphia Vireos occurred too infrequently on BBS routes for statewide estimates.

Two other long-distance migrants, Swainson's Thrush and American Redstart, also declined significantly in abundance at Hubbard Brook during the first 20 years of the study, but their populations then stabilized at low densities by the mid to late 1980s and remained low thereafter (Fig. 5). The average abundance of redstarts on the replicate plots closely matched those at Hubbard Brook, whereas Swainson's Thrushes were absent from two of the three replicate sites, resulting in lower mean densities on those latter sites (Fig. 5). On BBS statewide estimates, redstart abundances declined significantly between 1969 and 1998 (Table 3). Occurrences of Swainson's Thrush on BBS

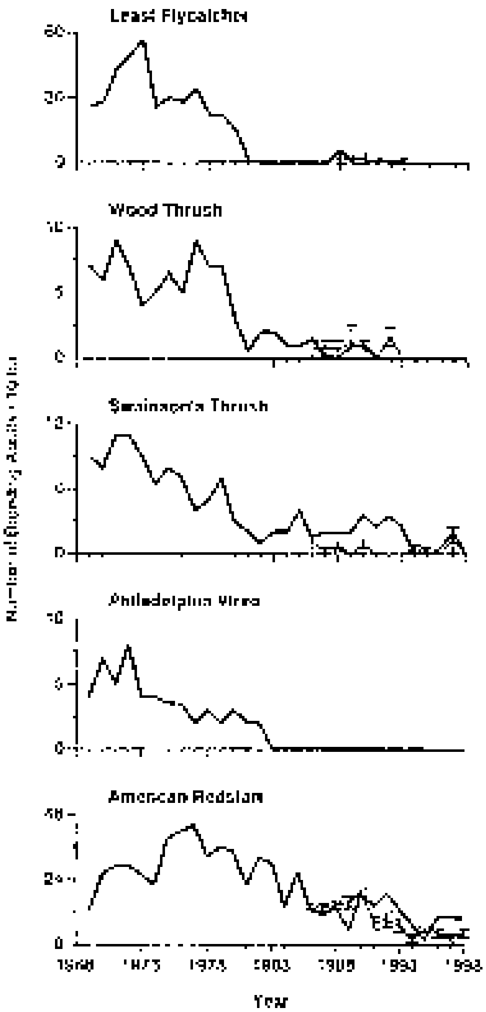

FIG. 5. Population trends of long-distance Neotropical migrant species that exhibited statistically significant and dramatic declines in abundance at Hubbard Brook, 1969–1998, and on three replicate sites (mean ± 1 SE), 1986–1998. Note differences in scale on y-axes.

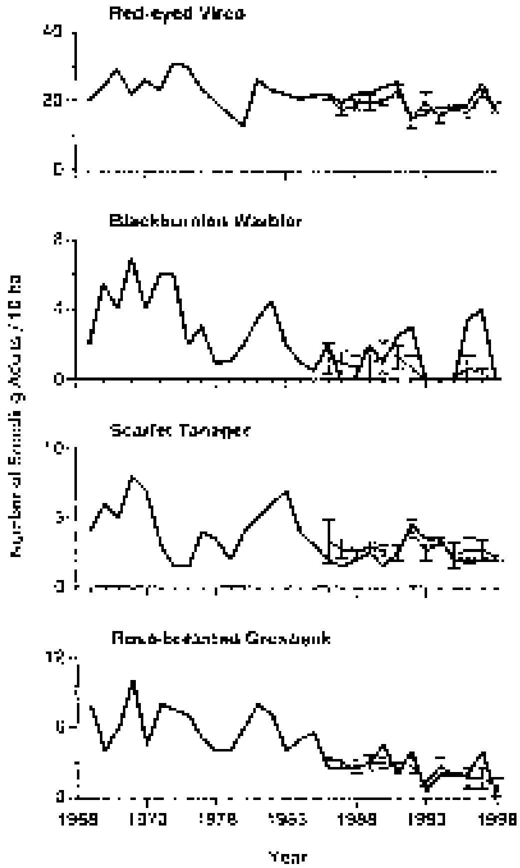

FIG. 6. Population trends of long-distance Neotropical migrant species that exhibited statistically significant but less pronounced declines in abundance at Hubbard Brook, 1969–1998, and on three replicate sites (mean ± 1 SE), 1986–1998. Note differences in scale on y-axes.

routes were too infrequent for statewide estimates.

Finally, four other long-distance migrants (Red-eyed Vireos, Blackburnian Warblers, Scarlet Tanagers, and Rose-breasted Grosbeaks) exhibited significantly declining trends in abundance at Hubbard Brook between 1969–1998 (Fig. 6, Table 3). Similar densities and trends were evident for all four species on the three replicate plots between 1986–1998 (Fig. 6), and BBS trends for all four species on New Hampshire BBS routes were also significantly negative (Table 3).

Overall trends in bird abundances.—To summarize, 12 of the 24 species exhibited significant declines in abundance at Hubbard Brook between 1969–1998 (nine long-distance migrants, one short-distance migrant, two permanent residents). Three species increased significantly (two Neotropical migrants, one short-distance migrant), whereas nine species maintained relatively constant population levels (two resident, five short-distance migrants, and two long-distance migrant species). Mean densities of most species were generally similar on the replicate study sites (Figs. 2–6), suggesting the patterns at Hubbard Brook were

TABLE 4. Summary of population trends for 24 forest bird species at Hubbard Brook (HB) from 1969–1998 and on Breeding Bird Surveys (BBS) in New Hampshire (NH), and their major wintering areas.

	Main winter area
HB steady or increasing, BBS steady or increasing[a]	
Hairy Woodpecker	North Temperate
Yellow-bellied Sapsucker	South Temperate/Caribbean/ Central America
Brown Creeper	South Temperate
Black-capped Chickadee	North Temperate
Winter Wren	South Temperate
Hermit Thrush	South Temperate
Blue-headed Vireo	South Temperate
Black-throated Green Warbler	Central America/Caribbean
Black-throated Blue Warbler	Caribbean
Yellow-rumped Warbler	South Temperate/Caribbean
Ovenbird	Central America/Caribbean
HB steady, BBS decline	
Veery	South America
HB decline, BBS steady or increasing	
Downy Woodpecker	North Temperate
White-breasted Nuthatch	North Temperate
Swainson's Thrush[b]	South America
Philadelphia Vireo[b]	Central America
Blackburnian Warbler	South America
Dark-eyed Junco	South Temperate
HB decline, BBS decline	
Least Flycatcher	Central America
Wood Thrush	Central America
Red-eyed Vireo	South America
American Redstart	Central America/Caribbean
Scarlet Tanager	South America
Rose-breasted Grosbeak	South America

[a] Trends based on linear regression analyses for Hubbard Brook and route regression method for BBS (see Table 2).
[b] Data from New Hampshire BBS routes insufficient for classification, but population trends stable for these two species in continent-wide BBS data (Peterjohn et al. 1995).

representative for those species in that habitat type in central New Hampshire.

Comparisons with New Hampshire BBS data indicate that a majority (17 of 24) of species had similar trends at the local (Hubbard Brook plot) and regional (New Hampshire statewide) scale (Table 4). Of those 17 species, 11 maintained stable or had increasing abundances at both Hubbard Brook and regional levels over the 30 year period, whereas 6 showed strongly significant declines in both data sets. The former group contained species that were permanent residents, short-distance migrants, and Neotropical migrants, but the latter (declining) group consisted exclusively of Neotropical migrants (Table 4). Of those six declining species, three have wintering distributions in South America, two in Central America, and one in both Central America and the Caribbean (Table 4). Conflicting trends between Hubbard Brook and the regional BBS level were found for seven species: six showed declines locally at Hubbard Brook with stable or increasing trends statewide and one (Veery) was stable at Hubbard Brook, but declined statewide (Table 4).

Vegetation changes at Hubbard Brook.—Inventories of woody plants on the Hubbard Brook census plot indicate that although some components of the forest remained relatively constant, other aspects changed markedly. The density and relative importance of the large (>20 cm DBH) canopy tree species remained relatively constant over the course of the study, with only a slight increase in sugar maple and a decrease in American beech (Table 5). In the 10–20 cm DBH tree size class, yellow birch declined in frequency and importance value, beech increased in relative importance, and sugar maple remained relatively constant (Table 5). The most striking changes were in the density and species composition of the smallest (2–10 cm DBH) size class of trees, with sugar maple and yellow birch declining sharply both in density and relative importance values,

TABLE 5. Density and relative importance values of trees on the Hubbard Brook study area between 1973 and 1999, as measured by the point-quarter method (Cottam and Curtis 1956).

Size class/tree species	Number of stems/ha (importance value,[a] %)				
	1973	1982	1987	1993	1999
2–10 cm DBH[b]					
Sugar maple	154 (42.8)	135 (42.5)	126 (32.8)	92 (24.9)	78 (14.5)
American beech	150 (37.2)	178 (44.4)	262 (53.4)	334 (55.6)	655 (69.7)
Yellow birch	16 (7.2)	0 (0.0)	5 (1.4)	5 (1.8)	4 (0.7)
Striped maple	14 (4.0)	20 (7.2)	48 (11.0)	61 (12.3)	121 (13.7)
Red spruce	5 (1.9)	9 (3.3)	9 (2.4)	13 (3.8)	8 (0.9)
Others	28 (6.7)	3 (2.6)	9 (2.0)	6 (1.6)	9 (0.5)
10.1–20 cm DBH					
Sugar maple	55 (36.5)	67 (48.6)	54 (45.1)	53 (44.4)	51 (39.3)
American beech	39 (27.5)	42 (36.7)	48 (40.1)	47 (38.9)	65 (48.5)
Yellow birch	34 (25.3)	12 (13.7)	8 (9.2)	9 (9.4)	8 (7.3)
White ash	1 (0.6)	0 (0.0)	1 (0.6)	0 (0.0)	0 (0.0)
Striped maple	10 (7.3)	3 (3.9)	2 (1.7)	2 (2.2)	5 (4.3)
Red spruce	2 (1.8)	3 (3.9)	2 (1.7)	2 (2.2)	0 (0.0)
Others	1 (0.7)	3 (3.6)	4 (4.5)	4 (3.9)	1 (0.6)
>20 cm DBH					
Sugar maple	66 (38.4)	91 (39.8)	92 (39.7)	75 (39.4)	102 (44.7)
American beech	55 (26.8)	53 (29.6)	60 (25.6)	44 (24.6)	51 (28.9)
Yellow birch	62 (27.4)	41 (21.2)	49 (22.5)	48 (26.9)	50 (23.3)
White ash	18 (5.9)	13 (8.0)	15 (10.4)	12 (6.9)	15 (9.4)
Other	3 (1.5)	3 (1.5)	4 (1.8)	5 (2.7)	3 (1.7)

[a] Importance value = 100 (relative basal area + relative density + relative frequency)/3.
[b] DBH = diameter at breast height.

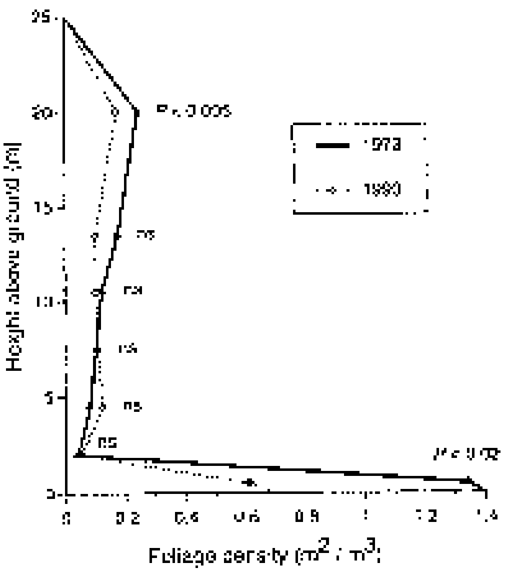

FIG. 7. Foliage density profile (leaf area per unit volume) for the Hubbard census plot in 1972–1973 (solid line) and in 1993 (broken line), as measured by methods of MacArthur and Horn (1969). Units represent projected leaf surface area per cubic meter. Results of *t*-tests for differences between means at each of seven height intervals are indicated (NS = nonsignificant, $P > 0.05$).

whereas striped maple and especially beech increased dramatically (Table 5). The decline, absence, or both of yellow birch and white ash in the smaller size classes is consistent with the shade-intolerance of seedlings and the special germination requirements of these midsuccessional tree species (Forcier 1975). Changes also occurred in the distribution of foliage over the vertical profile of the forest (Fig. 7). Between 1973 and 1993, foliage density was significantly reduced in both canopy and low shrub strata, resulting in a more equal vertical distribution of foliage (Fig. 7, see also Holmes et al. 1986). The forest therefore changed from one characterized by a dense, fairly closed canopy, with an open subcanopy and a low, dense shrub layer in the late 1960s to one with a more open and patchy canopy, a denser and taller shrub/subcanopy layer composed disproportionately of beech thickets, and a more sparse, low shrub layer in the 1990s.

DISCUSSION

In this study, we have shown that the bird community of an undisturbed, unfragmented, and relatively mature deciduous forest in New Hampshire changed dramatically over a 30 year period between 1969 and 1998. Total number of individuals, all species combined, occupying the 10 ha study area declined by ~60%, from a peak of about 210–220 in the early 1970s to 70–90 in the late 1990s. Twelve species exhibited long-term, statistically significant declines. Several of those disappeared entirely from the study area, including one (Least Flycatcher) that in 1970–1975 had been the most abundant species there (see Fig. 3, Holmes et al. 1986). Three species increased significantly in abundance, whereas nine others fluctuated in numbers but with no long-term positive or negative trend. These findings, which were largely corroborated by similar patterns at larger regional scales on replicate study sites in nearby sections of the White Mountains and from BBS routes located across the state of New Hampshire, demonstrate that bird abundances in those intact, relatively mature northern hardwood forests do not (necessarily) remain stable over time. Indeed, the longer our study has continued the more evident such fluctuations have become, indicating the value and necessity of long-term continuous studies for detecting and measuring population trends and variability. That is important for two reasons. First, investigators comparing bird populations or communities on the same site separated by long time intervals should not assume stasis or any other pattern for the intervening years. In particular, attempts to deduce long-term population changes from a simple repeat census after a long interval should be done with great caution. Secondly, the different population trajectories occurring on different time scales among cooccurring species suggest that no single common factor or event can account for the observed changes and that generalizations from one species to another are tenuous at best (see also Holmes et al. 1986, Taper et al. 1995).

Given such caveats and the fact that causes of population changes, especially when based on correlational evidence, are often difficult to identify (Wilcove and Terborgh 1984, Sauer et al. 1996), below we consider and evaluate possible explanations for the population changes observed at Hubbard Brook, specifically the effects of (1) habitat change in the breeding area, (2) summer food availability, (3) interspecific competitive interactions, (4) nest predators and brood parasites, and (5) nonbreeding season mortality.

Effects of habitat change.—Bird species have long been known to vary in abundance along successional (Johnston and Odum 1956, Martin 1960, Shugart and James 1973, Morgan and Freedman 1986, Thompson and Capen 1988) and environmental (Bond 1957, Smith 1977) gradients, often in accordance with changes in habitat structure (Wiens and Rotenberry 1981, James and Wamer 1982). Bird-species composition and abundance also change with forestry practices and management, most of which involve alterations in habitat structure (e.g. DeGraaf et al. 1998). Even though the forest at Hubbard Brook was considered to be relatively mature at the start of our study (see above), changes in vegetation structure did occur during the subsequent 30 years (see below). Those changes were mostly due to normal processes of natural succession (e.g. increasing frequency of treefall gaps associated with a more even vertical distribution of foliage, Aber 1979), sometimes in combination with local disturbances, for instance due to storm damage or disease. Damage due to high winds or to heavy icing during the winter sometimes topple large trees (especially those weakened by disease, see below) or result in broken tree crowns and branches, thus creating gaps and other changes in the structure of the forest canopy (Ireland 1998, R. T. Holmes pers. obs.). Perhaps the most important disturbance factor in the last 30 years has been the occurrence of beech bark disease (*Nectria coccinea*), first detected at Hubbard Brook in the 1970s (T. G. Siccama pers. comm.). That fungal pathogen not only results in weakening and eventual death of large beeches (Shigo 1977, Twery and Patterson 1984), but also leads to a subsequent release of beech sprouts or suckers from the roots of the dying trees (Houston 1975, E. Hane and T. G. Siccama pers. comm.). With increased light admitted through the more open canopy, those beech suckers (and some other understory shrubs such as striped maple) grow rapidly, and produce dense shrub-layer thickets. Such dense stands, dominated by beech saplings, were prevalent in our study area in the late 1980s (see Table 5), and by the mid to late 1990s, those young beeches had grown 3–8 m tall (but many still <5 cm DBH), forming a tall, dense shrub and subcanopy layer in parts of the study area. At that time, the ground cover beneath those beech thickets, although containing herbs, ferns, and other low-lying vegetation, had fewer other woody plants, such as hobblebush or small tree seedlings, which in the earlier years of this study had formed dense patches at the low (<3 m) shrub level (R. T. Holmes pers. obs.). A recent experimental manipulation at Hubbard Brook indicates that the proliferation of small beech negatively affects the growth and survival of sugar maple seedlings and saplings (E. Hane unpubl. data), which may explain the observed decline in small sugar maples (see Table 5). A similar interspecific competitive effect may have also resulted in a reduction in hobblebush in some parts of the study area (R. T. Holmes pers. obs.). Thus, even though the forest at Hubbard Brook has remained free of logging and other direct human influences since the early 1900s, it has continued to change in diverse and substantial ways even during the last 30 years when it appeared to be a relatively mature forest. As indicated above, the most noticeable changes during the period were in its physical structure, particularly the openness of the canopy and the distribution of foliage among strata.

To what degree can these changes in habitat structure account for the trends in bird abundances that we have documented? Four of the five species that have shown the most dramatic declines in abundance or have disappeared from the forest at Hubbard Brook (Least Flycatcher, Wood Thrush, American Redstart, and Philadelphia Vireo) are most strongly associated with midsuccessional forests. If the abundances of those four strongly declining species are removed from the community totals, the overall decline in total bird numbers at Hubbard Brook is less dramatic (see Fig. 1), although still significantly declining ($y = -1.13x + 2310.6$, $R^2 = 0.35$, $P < 0.001$). Below, we review the evidence, most of which is correlational, for succession and other vegetation change as the cause of population trends for those and other Hubbard Brook species.

Least Flycatchers are often locally abundant in well-stratified forests, with a relatively open subcanopy beneath a dense upper canopy (Breckenridge 1956, Sherry 1979, Briskie 1994). In northern hardwood succession, that structure is characteristic of 40–60 year old forests, whereas the canopy in older stands becomes opened by tree falls and other forms of disturbance, resulting in a greater variety of tree ages, sizes, and shapes (Aber 1979). Similarly, Bond (1957) in his ordination of birds among plant communities in Wisconsin forests found that Least Flycatchers reached greatest abundance midway along the vegetation (partly a successional) gradient. At Hubbard Brook, Least Flycatchers disappeared from the census plot in the late 1970s, but they continued to occur in other nearby parts of the forest through the late 1980s to early 1990s (Sherry and Holmes 1985, T. W. Sherry and R. T. Holmes pers. obs.). The areas where they persisted were at elevations and on slopes that had been most severely damaged by a major hurricane in 1938. That storm had blown down many trees in those areas, creating patches of earlier successional forests (Merrens and Peart 1992, R. T. Holmes pers. obs.), which were in effect 40–50 years of age in the 1980s when they were still occupied by the flycatchers. That species disappeared from even those areas by the mid 1990s, and it was recorded only once during systematic censuses of all bird species in the 3000 ha Hubbard Brook valley in 1999–2000 (P. J. Doran unpubl. data). Thus, by the late 1990s, the Least Flycatcher no longer occurred in that forest. We hypothesize that is due to an increase in canopy gaps and other changes in vegetation structure that have occurred in the last 20–30 years in that forest, making that site unsuitable for that species, and that maturing of the forests in New Hampshire and perhaps New England as a whole (see Litvaitis 1993, Hunt 1998) may account for the Least Flycatcher's regional decline in recent years.

Wood Thrushes are typically a species of mesic deciduous and mixed deciduous–coniferous forests. They are also found commonly along edges, in suburban areas, and in fragmented forest patches (Dilger 1956, James et al. 1984, Roth et al. 1996), which suggests extensive use of disturbed and human-modified woodlands. Wood Thrushes occur at highest densities in forests with tall canopies, few small trees, a well-developed but sparse understory shrub layer, and a fairly open forest floor (James et al. 1984, Roth et al. 1996), characteristics that correspond to midsuccessional northern hardwood forests in New England (Aber 1979). Similarly, in Bond's (1957) ordinations, Wood Thrush abundance peaked in midsuccessional plant communities. Like Least Flycatchers, Wood Thrushes disappeared from the Hubbard Brook census plot in the late 1970s, but remained in areas that had been severely affected by a hurricane in 1938 for 10–15 years after they had disappeared from the census plot (R. T. Holmes pers. obs.). Thus, the gradual decline of the Wood Thrush on the Hubbard Brook plot could have been expedited, if not caused, by subtle forest changes associated with secondary succession (but see below for an alternative explanation).

American Redstarts have been shown through both empirical and modeling studies to occur more frequently in early and midsuccessional forest habitat (Hunt 1996, 1998). Hunt showed that redstart abundance was positively correlated with amount of early successional habitat and that their decline in recent decades in New England was coincident with forest maturation in the region. In addition, a greater proportion of older, presumably more experienced redstarts were found in early successional sites, and individuals in those sites had smaller territories and higher mating success (Hunt 1996). These findings suggest that early successional forests are more suitable for this species in terms of reproduction and probably survival.

Philadelphia Vireos are also a species primarily of early to midsuccessional woodlands, aspen parklands, and shrub thickets (Moskoff and Robinson 1996). Their disappearance from Hubbard Brook seems consistent with the hypothesis that forest maturation has decreased the suitability of the forest.

Finally, habitat change can also improve conditions for some species. At Hubbard Brook, abundance of Ovenbird, Black-throated Green and Yellow-rumped warblers have gradually increased over the last 30 years as the forest has become older. All three species are typically found in structurally diverse, mature forests. The Ovenbird is typically found in deciduous forests with relatively open understories (Van Horn and Donovan 1994), and the data from Hubbard Brook suggest that the shrub layer has become less dense in recent years (see Fig. 7, and above). The Black-throated Green and Yellow-rumped warblers are most common in mature coniferous or mixed deciduous–coniferous stands (Morse 1993, Hunt and Flaspohler 1998).

Most of the above discussion about effects of habitat change has relied on correlational evidence, and points to the fact that we know very little about how changes in vegetation structure influence habitat choice and hence local abundance patterns. Do these population changes relate in some way to the structure of the habitat per se, or to associated changes in food abundance or availability (Robinson and Holmes 1982, Parrish 1995), predation risk to adults or to young, microclimate, availability of nest sites, or other factors that determine habitat suitability that influence reproductive success and survival? Identifying such mechanisms and processes, which involves behavioral, ecological and demographic studies, is essential for understanding how habitat change affects these species and their population trends, as well as being critical for developing scientifically based management plans.

Effects of summer food availability.—Studies at Hubbard Brook have shown that fluctuations in the availability of food, specifically Lepidoptera larvae, influence the reproductive success of several bird species (Holmes 1988, Holmes et al. 1991, 1992; Rodenhouse and Holmes 1992, Sillett et al. 2000). In turn, for American Redstarts and Black-throated Blue Warblers, the mean number of young fledged annually per female correlates with the number of yearlings recruited into populations in the following season (Sherry and Holmes 1991, Holmes et al. 1992, Sillett et al. 2000), illustrating the importance of breeding-ground events in maintaining local breeding populations of those species.

In the first three years of this study, caterpillars were unusually abundant on the Hubbard Brook study area due to a broad, regional irruption of a defoliating caterpillar, the saddled prominent (*Heterocampa guttivitta*, Notodontidae, Lepidoptera). The maximum bird numbers on the study area (see Fig. 1) were coincident with, or lagged slightly after, that irruption, suggesting that food abundance influenced population sizes of many forest-bird species (Holmes and Sturges 1975, Holmes et al. 1986, Holmes and Sherry 1988). In addition, several species bred on the study area only during those years (e.g. American Robin, Purple Finch), and others typically found in more coniferous habitat (e.g. Swainson's Thrush, Dark-eyed Junco), may have increased in our study area due to the locally high abundance of food in those years. There has been no other major irruption of any defoliating caterpillar since the early 1970s, although small, localized outbreaks of a looper (*Alsophila pometaria*, Geometridae) occurred in 1977, 1981–1983, and 1991–1992 (Holmes et al. 1986, R. T. Holmes unpubl. data). Those small eruptions were all short term, occurred early in the breeding season, and appeared to have relatively little effect on bird reproductive output. Therefore, during most years since 1972, Lepidoptera larvae have been low in abundance, averaging 3–5 caterpillars per 1,000 leaves (all Lepidoptera species combined; R. T. Holmes unpubl. data). That level could represent limiting conditions for many forest birds (Holmes et al. 1991, Rodenhouse and Holmes 1992).

Additional evidence that food abundance can influence forest-bird populations comes from the association of reproductive success of Black-throated Blue Warblers at Hubbard Brook with El Niño Southern Oscillation (ENSO; Sillett et al. 2000). From 1986 to 1999, warbler reproductive output was higher during the La Niña phase of ENSO, as was mass of young at fledging and the abundance of Lepidoptera larvae. Thus, changes in food abundance related to global climate events appear to affect bird reproduction, and those in turn influence recruitment into winter and subsequent breeding populations (Sillett et al. 2000). However, the extent to which those climate-mediated changes in reproductive parameters contributed to the long-term population changes of any species we studied, is unknown. For example, the population of Black-throated Blue Warblers, the subject of the above-cited study, has shown no net change in abundance at Hubbard Brook in the last 30 years (see Fig. 4), and the Black-throated Green Warbler, another species that depends extensively on caterpillars for food (Morse 1993), significantly increased in abundance at Hubbard Brook during the course of this study. Finally, with the available data, we can not rule out the possibility that declines in those species that we have attributed to habitat change were not exacerbated by low food supply following the major caterpillar irruption in the early 1970s. For example, the abrupt decline in caterpillar abundance in 1972 following the collapse of the defoliator outbreak could have contributed to the subsequent decline of the Least Flycatcher and Philadelphia Vireo. The degree or extent to which food determines habitat quality and influences local densities of those forest bird species requires further study.

Effects of interspecific competitive interactions.—Studies at Hubbard Brook have shown that competitive interactions between certain pairs of bird species influence local patterns of distribution and abundance of other species (Sherry 1979, Robinson 1981, Sherry and Holmes 1988). That was most evident when American Redstarts shifted their distribution in response to the presence and then absence of Least Flycatchers, a pattern that was verified through experimental manipulations (Sherry and Holmes 1988). This interspecific effect could have contributed to the increase in redstart abundance in the mid 1970s as Least Flycatchers declined (see Fig. 3), but does not account for either the disappearance of the flycatcher, nor the subsequent decline of the redstart. It is important to consider such competitive interactions, however, because they can affect local patterns of abundance and thus be important when assessing short-term changes in abundance at the local scale.

Effects of nest depredation and brood parasitism.—Depredation of eggs and nestlings is the major factor affecting nesting success for birds at Hubbard Brook (Sherry and Holmes 1991, Holmes et al. 1992, Sloan et al. 1998) and for most passerine birds (Martin 1993). Nest depredation also has been shown to increase when habitats are fragmented or disturbed, and has been cited as a major factor influencing breeding success and ultimately the abundances of songbirds (Wilcove and Robinson 1990). At Hubbard Brook, annual nesting success, as measured by the Mayfield method, has varied 20–74% ($n = 9$ years) for American Redstarts (Sherry and Holmes 1992) and 46–79% ($n = 12$ years) in Black-throated Blue Warblers (Holmes et al. 1992, 1996; R. T. Holmes unpubl. data). Such variation in nest survival among years is related largely to differences in the abundance of major nest predators (e.g. Eastern chipmunks, *Tamias striatus*, and red squirrels, *Tamiasciurus hudsonicus*), which in turn is related to the intermittent but highly synchronous production of seeds by forest trees (Ostfeld and Keesing 2000, R. T. Holmes pers. obs.). The result is a highly variable pattern of nest predation from year to year, but not one that shows either an increasing or decreasing trend over long time intervals (R. T. Holmes unpubl. data).

Thus, it seems unlikely that nest depredation over this 30 year period could be a factor responsible for long-term increases or declines in the abundances of any particular bird species in this unfragmented forest.

Brood parasitism has been proposed as a major factor contributing to declines of Neotropical migrants (e.g. Brittingham and Temple 1983, Robinson et al. 1995a). Brood parasitism, however, was not a factor affecting bird populations at Hubbard Brook during this 30 year study. Even though cowbirds occur in agricultural areas within several kilometers of our study area, they have rarely been seen within the extensive forest where our study plots are located, and only then in mid and late summer in the early 1970s during the defoliator irruption (Holmes and Sturges 1975, Holmes 1990). In 30 years of intensive field work, only one sighting of a cowbird fledgling has been made within the forest at Hubbard Brook (S. K. Robinson pers. comm., Holmes 1990) and none on the replicate plots (R. T. Holmes unpubl. data). Similarly, in bird censuses covering the entire Hubbard Brook valley in 1999 and 2000, only one cowbird was recorded in more than 1,000 point counts each season (P. J. Doran unpubl. data). This lack of cowbirds in these New Hampshire forests contrasts sharply with the situation in woodlots and forest edges in the midwestern United States and other areas where cowbirds are abundant and frequently parasitize bird nests (Brittingham and Temple 1983, Robinson et al. 1995a,b; Smith 2000), even penetrating many kilometers into the forest (Morse and Robinson 1999).

Effects of events during the nonbreeding period.—Another possible cause of bird-population changes observed at Hubbard Brook is mortality occurring in the nonbreeding season. The best evidence for winter limitation from Hubbard Brook comes from data early in our study on species permanently resident at Hubbard Brook (e.g. woodpeckers, chickadees) and on short-distance migrants that winter in the southern United States (e.g. Hermit Thrushes and Dark-eyed Juncos). For both sets of species during the late 1960s to mid 1970s, abundances in summer at Hubbard Brook declined following severe winters in the northeastern and southeastern United States (Holmes et al. 1986, Holmes and Sherry 1988).

For long-distance Neotropical migrants, it is more difficult to identify changes in abundance that could be attributed to events in their wintering areas (Wilcove and Terborgh 1984, Holmes et al. 1986, Rappole and McDonald 1994, Sherry and Holmes 1996), partly because individuals from local breeding areas apparently scatter widely through the species' winter quarters (Chamberlain et al. 1997), making the effects of local winter events on breeding populations difficult to detect. However, survivorship analyses incorporating recapture and resighting probabilities for Black-throated Blue Warblers in both breeding and wintering areas suggest that increased mortality resulting from El Niño conditions during the winter affects survival and subsequent recruitment of individuals into breeding populations (Sillett et al. 2000, T. S. Sillett and R. T. Holmes unpubl. data). Similarly, Marra et al. (1998), using a habitat-specific isotope tracer, showed that winter-habitat quality lowered overwinter body condition and delayed spring departure schedules of American Redstarts, influencing in turn arrival times and, potentially, reproductive output. Those latter two studies suggest that winter habitat conditions affect migrant bird demography that have carryover effects into the breeding season. They also highlight the need for the development of new methods and approaches for assessing the effects of events in different seasons and places on the abundances of these long-distance migrant species.

With respect to winter habitat loss causing population declines, it could be argued that migrant species that commonly inhabit second-growth and other disturbed habitats in winter should not be affected (or should at least be less affected) by winter habitat loss than those species utilizing tropical forests. By this line of reasoning, the declines at Hubbard Brook of Least Flycatcher, American Redstart, and Philadelphia Vireo, all of which winter commonly in second-growth and edge habitats in Central America, the Caribbean, or both (Holmes et al. 1989, Greenberg 1992, Moskoff and Robinson 1996, Greenberg et al. 1997) do not seem to be ascribable to availability of their habitats in the winter areas. As a caveat to that argument, however, we note that just because those species are found in second-growth habitats in winter does not mean that those habitats are necessarily of the highest quality; that is, those most suitable for maintaining body condition and survival over the winter period. In Jamaica, for instance, American Redstarts compete for high quality habitats that are the more heavily forested ones. For that species, the more subordinate individuals are forced into second-growth scrub where they are less able to maintain body condition and survive less well compared to the more dominant birds occupying forested sites (Marra and Holberton 1998, Marra and Holmes 2001). In this case, it is possible that the conversion of tropical forest to second-growth habitats over recent decades may have resulted in an overall decline in both quantity and quality of habitat for wintering redstarts (and perhaps other migrants), and that could have contributed to its general population decline. No comparable habitat-specific demographic data are available from the winter grounds for Least Flycatchers or Philadelphia Vireos or for most other Neotropical migrant songbirds. Such information is needed before discounting the winter period as being unimportant in affecting migratory bird populations.

Species of long-distance migratory songbirds that depend more exclusively on mature forests in the Neotropics could be affected by the loss or degradation of those habitats through deforestation. The Wood Thrush is a good example of such a species (Roth et al. 1996), and it is at least plausible to hypothesize that winter habitat loss could be a cause for its population decline (Rappole et al. 1992, Morton 1992). However, the alternative hypothesis that population decline of Wood Thrushes is due to the loss of suitable breeding sites due to forest succession (see above) or to effects of fragmentation (Robinson et al. 1995a) seems equally likely, and of course, both may be occurring simultaneously. This illustrates the difficulty of identifying the factors limiting those populations and the need for understanding the influence of factors operating at different parts of the annual cycle.

Correspondence of trends at different spatial scales.—For many of the species studied, we identified similar trends at three different spatial scales: local (Hubbard Brook Experimental Forest; Table 3, Figs. 2–6), regional (southwestern White Mountains of New Hampshire, on the basis of three replicate plots; Figs. 2–6), and statewide (on the basis of BBS surveys, see Tables 3 and 4). Thus, similar population trends for a species occurring at the local level tended to be representative of those at larger scales. That may be related to the general maturing of forest habitat in New England as a whole during the last 30 years (Irland 1982, Litvaitis 1993, Hunt 1995), providing an increasingly forested landscape, which provides increasingly favorable habitat for some species but negatively affects others. For species declining within that region, the lack of recruitment of new individuals into those more mature habitats or even into local patches of suitable habitat within the more mature habitat matrix could be affected by the absence of nearby source areas (see Robinson et al. 1995b, Simons et al. 2000). The landscape context, coupled with dispersal abilities and habitat preferences of each species, may be important in determining whether populations increase or decrease within a given area.

Finally, the lack of congruence in trends between the local Hubbard Brook plot and larger scale BBS trends for several species (see Tables 3 and 4) may be an artifact of sampling, especially because most of those species were represented in the Hubbard Brook study plot and often in the BBS data set by a very small number of individuals. Also, for four of those seven species (Swainson's Thrush, Philadelphia Vireo, Blackburnian Warbler, Dark-eyed Junco), northern hardwood probably represents marginal breeding habitat, where populations may fluctuate more.

In conclusion, our long-term data from Hubbard Brook demonstrate that bird populations within that unfragmented and largely undisturbed forest fluctuate widely in abundance and that those fluctuations are evident at local and often regional (statewide) spatial scales. Our focus in this paper has been on the factors causing local changes in abundances, which are shown to be multiple and complex, to vary among species, and to operate at different temporal and spatial scales. We have shown those factors to include forest history (e.g. timing and intensity of logging), natural successional processes, disturbances such as pathogens (beech-bark disease), and climatic events such as wind and ice storms that affect forest structure. We identified structural changes in the forest over time, especially those related to natural forest succession, as particularly important in affecting bird-population changes at Hubbard Brook. This latter finding, in particular, implies that studies examining causes of bird-population change, including those concerned with the effects of habitat fragmentation, cowbird parasitism, etc., need to control for concomitant changes in habitat quality due to succession and other factors.

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Data on bird abundances at Hubbard Brook (1969–1998) and on three replicate plots (1986–1998) are available online at www.hbrooks.sr.unh.edu/data/animal.

LITERATURE CITED

AREF, J. D. 1979. Foliage-height profiles and succession in northern hardwoods forests. Ecology 60:18–23.

AMBUEL, B., AND S. A. TEMPLE. 1982. Songbird populations in southern Wisconsin forests: 1954 and 1979. Journal of Field Ornithology 53:149–158.

ASKINS, R. A. 2000. Restoring North America's Birds: Lessons from Landscape Ecology. Yale University Press, New Haven, Connecticut.

ASKINS, R. A., J. F. LYNCH, AND R. GREENBERG. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7:1–57.

BOHNING-GAESE, K., M. L. TAPER, AND J. H. BROWN. 1993. Are declines in North American insectivorous songbirds due to causes on the breeding range? Conservation Biology 7:76–86.

BOND, R. R. 1957. Ecological distribution of birds in the upland forests of southwestern Wisconsin. Ecological Monographs 27:351–384.

BORMANN, F. H., AND G. E. LIKENS. 1979. Pattern and Process in a Forested Ecosystem. Springer-Verlag, New York.

BORMANN, F. H., T. G. SICCAMA, G. E. LIKENS, AND R. H. WHITTAKER. 1970. The Hubbard Brook ecosystem study: Composition and dynamics of the tree stratum. Ecological Monographs 40:373–388.

BRECKENRIDGE, W. J. 1956. Measurements of the habitat niche of the Least Flycatcher. Wilson Bulletin 68:47–51.

BRISKIE, J. V. 1994. The Least Flycatcher (*Empidonax minimus*). *In* The Birds of North America, no. 99 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

BRITTINGHAM, M. C., AND S. A. TEMPLE. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31–35.

CHAMBERLAIN, C. P., J. D. BLUM, R. T. HOLMES, X. FENG, T. W. SHERRY, AND G. R. GRAVES. 1997. The use of isotope tracers for identifying populations of migratory birds. Oecologia 109:132–141.

COTTAM, G., AND J. T. CURTIS. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451–460.

DEGRAAF, R. M., J. B. HESTBECK, AND M. YAMASAKI. 1998. Association between breeding bird abundance and stand structure in the White Mountains, New Hampshire and Maine, USA. Forest Ecology and Management 103:217–233.

DILGER, W. C. 1956. Adaptive modifications and ecological isolating mechanisms in the thrush genera *Catharus* and *Hylocichla*. Wilson Bulletin 68:171–199.

DONOVAN, T. M., R. H. LAMBERSON, A. KIMBER, F. R. THOMPSON III, AND J. FAABORG. 1995. Modeling the effects of habitat fragmentation on source and sink demography of Neotropical migrant birds. Conservation Biology 9:1396–1407.

ENEMAR, A., B. CAVALLIN, E. NYHOLM, I. RUDEBECK, AND A. M. THORNER. 1994. Dynamics of a passerine bird community in a small deciduous wood, S Sweden, during 40 years. Ornis Svecica 4:65–104.

FAUTH, P. T. 2000. Reproductive success of Wood Thrushes in forest fragments in northern Indiana. Auk 117:194–204.

FORCIER, L. K. 1975. Reproductive strategies and the co-occurrence of climax tree species. Science 189:808–810.

GREENBERG, R. 1992. Forest migrants in non-forest habitats on the Yucatan Peninsula. Pages 273–286 *in* Ecology and Conservation of Neotropical Migrant Landbirds (J. M. Hagan III and D. W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

GREENBERG, R., P. BICHIER, AND J. STERLING. 1997. Acacia, cattle and migratory birds in southeastern Mexico. Biological Conservation 80:235–247.

HAGAN, J. M. III, AND D. W. JOHNSTON, EDS. 1992. Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institution Press, Washington, D.C.

HOLMES, R. T. 1988. Community structure, population fluctuations, and resource dynamics of birds in temperate deciduous forests. Pages 1318–1327 *in* Acta XIX Congressus Internationalis Ornithologici (H. Ouellet, Ed.). National Museum of Natural Sciences, Ottawa, Ontario.

HOLMES, R. T. 1990. The structure of a temperate deciduous forest bird community: Variability in time and space. Pages 121–139 *in* Biogeography and Ecology of Forest Bird Communities (A. Keast, Ed.). SPB Academic Publishing, The Hague.

HOLMES, R. T., P. P. MARRA, AND T. W. SHERRY. 1996. Habitat-specific demography of breeding Black-throated Blue Warblers (*Dendroica caerulescens*): Implications for population dynamics. Journal of Animal Ecology 65:183–195.

HOLMES, R. T., AND T. W. SHERRY. 1988. Assessing population trends of New Hampshire forest birds: Local versus regional patterns. Auk 105:756–768.

HOLMES, R. T., T. W. SHERRY, P. P. MARRA, AND K. E. PETIT. 1992. Multiple-brooding and productivity of a Neotropical migrant, the Black-throated Blue Warbler (*Dendroica caerulescens*), in an unfragmented temperate forest. Auk 109:321–333.

HOLMES, R. T., T. W. SHERRY, AND L. R. REITSMA. 1989. Population structure, territoriality, and overwinter survival of two migrant warbler species in Jamaica. Condor 91:545–561.

HOLMES, R. T., T. W. SHERRY, AND F. W. STURGES. 1986. Bird community dynamics in a temperate deciduous forest: Long-term trends at Hubbard Brook. Ecological Monographs 56:201–220.

HOLMES, R. T., T. W. SHERRY, AND F. W. STURGES. 1991. Numerical and demographic responses of temperate forest birds to annual fluctuations in their food resources. Pages 1559–1567 *in* Acta XX Congressus Internationalis Ornithologici (B. D. Bell, Ed.). New Zealand Ornithological Congress Trust Board, Christchurch.

HOLMES, R. T., AND F. W. STURGES. 1975. Avian community dynamics and energetics in a northern hardwoods ecosystem. Journal of Animal Ecology 44:175–200.

HOUSTON, D. R. 1975. Beech bark disease: The aftermath forests are structured for a new outbreak. Journal of Forestry 73:660–663.

HUNT, P. D. 1996. Habitat selection by American Redstarts along a successional gradient in northern hardwoods forest: Evaluation of habitat quality. Auk 113:875–888.

HUNT, P. D. 1998. Evidence from a landscape population model of the importance of early successional habitat to the American Redstart. Conservation Biology 12:1377–1389.

HUNT, P. D., AND D. J. FLASPOHLER. 1998. Yellow-rumped Warbler (*Dendroica coronata*). *In* The Birds of North America, no. 376 (A. Poole and F. Gill, Eds.). The Birds of North America, Inc., Philadelphia.

IRLAND, L. C. 1982. Wildlands and Woodlots: The Story of New England's Forests. University Press of New England, Hanover, New Hampshire.

IRLAND, L. C. 1998. Ice storm 1998 and the forests of the Northeast: A preliminary assessment. Journal of Forestry 96:32–40.

JAMES, F. C., R. F. JOHNSTON, N. O. WAMER, G. J. NIEMI, AND W. J. BOECKLEN. 1984. The Grinnellian niche of the Wood Thrush. American Naturalist 124:17–30.

JAMES, F. C., C. E. MCCULLOCH, AND D. A. WIEDENFELD. 1996. New approaches to the analysis of population trends in land birds. Ecology 77:13–27.

JAMES, F. C., AND N. O. WAMER. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63:159–171.

JOHNSTON, D. W., AND E. P. ODUM. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. Ecology 37:50–62.

KEAST, A., AND E. S. MORTON, EDS. 1980. Migrant Birds in the Neotropics: Ecology, Behavior, Distribution and Conservation. Smithsonian Institution Press, Washington, D.C.

KENDEIGH, S. C. 1982. Bird populations in east central Illinois: Fluctuations, variations, and development over a half-century. Illinois Biological Monographs, no. 52.

KIRK, D. A., T. W. DIAMOND, A. R. SMITH, G. E. HOLLAND, AND P. CHYTYK. 1997. Population change in boreal forest birds in Saskatchewan and Manitoba. Wilson Bulletin 109:1–27.

LATTA, S. C., AND M. E. BALTZ. 1997. Population limitation in Neotropical migratory birds: Comments on Rappole and McDonald (1994). Auk 114:754–762.

LEAK, W. B., AND M. L. SMITH. 1996. Sixty years of management and natural disturbance in a New England forested landscape. Forest Ecology and Management 81:63–73.

LECK, C. F., B. G. MURRAY, JR., AND J. SWINEBROAD. 1988. Long-term changes in the breeding bird populations of a New Jersey forest. Biological Conservation 46:145–157.

LIKENS, G. E., C. T. DRISCOLL, AND D. C. BUSO. 1996. Long-term effects of acid rain: Response and recovery of a forested ecosystem. Science 272:244–246.

LITVAITIS, J. A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7:866–873.

MacArthur, R. H., and H. S. Horn. 1969. Foliage profiles by vertical measurement. Ecology 50:802–804.

Marra, P. P., K. A. Hobson, and R. T. Holmes. 1998. Linking winter and summer events in a migratory bird by using stable-carbon isotopes. Science 282:1884–1886.

Marra, P. P., and R. L. Holberton. 1998. Corticosterone levels as indicators of habitat quality: Effects of habitat segregation in a migratory bird during the non-breeding period. Oecologia 116:284–292.

Marra, P. P., and R. T. Holmes. 2001. Demographic consequences of sexual habitat segregation in a migrant passerine bird during the non-breeding season. Auk 118:94–106.

Marshall, J. T. 1988. Birds lost from a giant sequoia forest during fifty years. Condor 90:359–372.

Martin, N. D. 1960. An analysis of bird populations in relation to forest succession in Algonquin Provincial Park, Ontario. Ecology 41:126–140.

Martin, T. E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecological Monographs 65:101–127.

Martin, T. E., and D. M. Finch, Eds. 1995. Ecology and Management of Neotropical Migratory Birds. Oxford University Press, New York.

Merrens, E. J., and D. R. Peart. 1992. Effects of hurricane damage on individual growth and stand structure in a hardwood forest in New Hampshire, USA. Journal of Ecology 80:787–795.

Morgan, K., and B. Freedman. 1986. Breeding bird communities in a hardwood forest succession in Nova Scotia. Canadian Field-Naturalist 100:506–519.

Morse, D. H. 1993. Black-throated Green Warbler (*Dendroica virens*). *In* The Birds of North America, no. 55 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Morse, S. F., and S. K. Robinson. 1999. Nesting success of a Neotropical migrant in a multiple-use forested landscape. Conservation Biology 13:327–337.

Morton, E. S. 1992. What do we know about the future of migrant landbirds? Pages 579–589 *in* Ecology and Conservation of Neotropical Migrant Landbirds (J. M. Hagan III and D. W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Moskoff, W., and S. K. Robinson. 1996. Philadelphia Vireo (*Vireo philadelphicus*). *In* The Birds of North America, no. 214 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Ostfeld, R. S., and F. Keesing. 2000. Pulsed resources and community dynamics of consumers in terrestrial ecosystems. Trends in Ecology and Evolution 15:232–238.

Parrish, J. D. 1995. Effects of needle architecture on warbler habitat selection in a coastal spruce forest. Ecology 76:1813–1820.

Peterjohn, B. G., J. R. Sauer, and W. A. Link. 1997. The 1994 and 1995 summary of the North American breeding bird survey. Bird Populations 3:48–56.

Peterjohn, B. G., J. R. Sauer, and C. S. Robbins. 1995. Population trends from the North American breeding bird survey. Pages 3–39 *in* Ecology and Management of Neotropical Migratory Birds (T. E. Martin and D. M. Finch, Eds.). Oxford University Press, New York.

Rappole, J. H., E. S. Morton, and M. A. Ramos. 1992. Density, philopatry, and population estimates for songbird migrants wintering in Veracruz. Pages 337–344 *in* Ecology and Conservation of Neotropical Migrant Landbirds (J. M. Hagan III and D. W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Rappole, J. H., and M. V. McDonald. 1994. Cause and effect in population declines of migratory birds. Auk 111:652–660.

Rappole, J. H., and M. V. McDonald. 1998. Response to Latta and Baltz (1997). Auk 115:246–251.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences USA 86:7658–7662.

Robinson, S. K. 1981. Ecological relations and social interactions of Philadelphia and Red-eyed vireos. Condor 83:16–26.

Robinson, S. K., and R. T. Holmes. 1982. Foraging behavior of forest birds: The relationships among search tactics, diet, and habitat structure. Ecology 63:1918–1931.

Robinson, S. K., S. I. Rothstein, M. C. Brittingham, L. J. Petit, and J. A. Grzybowski. 1995a. Ecology and behavior of cowbirds and their impact on host populations. Pages 428–460 *in* Ecology and Management of Neotropical Migratory Birds (T. E. Martin and D. M. Finch, Eds.). Oxford University Press, New York.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995b. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987–1990.

Rodenhouse, N. L., and R. T. Holmes. 1992. Effects of experimental and natural food reductions for breeding Black-throated Blue Warblers. Ecology 73:357–372.

Roth, R. R., M. S. Johnson, and T. J. Underwood. 1996. Wood Thrush (*Hylocichla mustelina*). *In* The Birds of North America, no. 246 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Sauer, J. R., G. W. Pendleton, and B. G. Peterjohn. 1996. Evaluating causes of population change in North American insectivorous songbirds. Conservation Biology 10:465–478.

Schmidt, K. A., and C. J. Whelan. 1999. Effects of exotic *Lonicera* and *Rhamnus* on songbird nest predation. Conservation Biology 13:1502–1506.

Sherry, T. W. 1979. Competitive interactions and adaptive strategies of American Redstarts and Least Flycatchers in a northern hardwoods forest. Auk 96:265–283.

Sherry, T. W., and R. T. Holmes. 1985. Dispersion and habitat responses of birds in northern hardwoods forest. Pages 283–309 *in* Habitat Selection in Birds (M. Cody, Ed.). Academic Press, New York.

Sherry, T. W., and R. T. Holmes. 1988. Habitat selection by breeding American Redstarts in response to a dominant competitor, the Least Flycatcher. Auk 96:350–364.

Sherry, T. W., and R. T. Holmes. 1991. Population age structure of long-distance migratory passerine birds: Variation in time and space. Pages 1542–1556 *in* Acta XX Congressus Internationalis Ornithologici (B. D. Bell, Ed.). New Zealand Ornithological Congress Trust Board, Christchurch.

Sherry, T. W., and R. T. Holmes. 1992. Population fluctuations in a long-distance Neotropical migrant: Demographic evidence for the importance of breeding season events in the American Redstart. Pages 431–442 *in* Ecology and Conservation of Neotropical Migrant Landbirds (J. M. Hagan III and D. W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Sherry, T. W., and R. T. Holmes. 1995. Summer versus winter limitation of populations: Conceptual issues and evidence. Pages 85–120 *in* Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues (T. E. Martin and D. M. Finch, Eds.). Oxford University Press, New York.

Sherry, T. W., and R. T. Holmes. 1996. Winter habitat quality, population limitation, and conservation of Neotropical-Nearctic migrant birds. Ecology 77:36–48.

Shigo, A. L. 1972. The beech bark disease today in the northeastern U.S. Journal of Forestry 70:286–289.

Shugart, H. H., Jr., and D. A. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62–77.

Sillett, T. S., R. T. Holmes, and T. W. Sherry. 2000. Impacts of a global climate cycle on population dynamics of a migratory songbird. Science 288:2040–2042.

Simons, T. R., G. L. Farnsworth, and S. A. Shriner. 2000. Evaluating Great Smoky Mountains National Park as a population source for the Wood Thrush. Conservation Biology 14:1133–1144.

Sloan, S. S., R. T. Holmes, and T. W. Sherry. 1998. Depredation rates and predators at artificial bird nests in an unfragmented northern hardwood forest. Journal of Wildlife Management 62:529–539.

Smith, K. G. 1977. Distribution of summer birds along a forest moisture gradient in an Ozark watershed. Ecology 58:952–961.

Taper, M. L., K. Böhning-Gaese, and J. H. Brown. 1995. Individualistic responses of bird species to environmental change. Oecologia 101:478–486.

Thompson, F. R., III, and D. E. Capen. 1988. Avian assemblages in seral stages of a Vermont forest. Journal of Wildlife Management 52:771–777.

Twery, M. J., and W. A. Patterson. 1984. Variations in beech bark disease and its effects on species composition and structure of northern hardwood stands in central New England. Canadian Journal of Forest Research 14:565–574.

Van Horn, M. A., and T. M. Donovan. 1994. Ovenbird (*Seiurus aurocapillus*). *In* The Birds of North America, no. 88 (A. Poole and F. Gill, Eds.). Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Wesolowski, T., and L. Tomialojc. 1997. Breeding bird dynamics in a primaeval temperate forest: Long-term trends in Bialowieza National Park (Poland). Ecography 20:432–453.

Whittaker, R. H., F. H. Bormann, G. E. Likens, and T. G. Siccama. 1974. The Hubbard Brook ecosystem study: Forest biomass and production. Ecological Monographs 44:233–254.

Wiens, J. A., and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51:21–41.

Wilcove, D. S. 1988. Changes in the avifauna of the Great Smoky Mountains: 1947–1983. Wilson Bulletin 100:256–271.

Wilcove, D. S., and S. K. Robinson. 1990. The impact of forest fragmentation on bird communities in eastern North America. Pages 319–331 *in* Biogeography and Ecology of Forest Bird Communities (A. Keast, Ed.). SPB Academic Publishing, The Hague.

Wilcove, D. S., and J. W. Terborgh. 1984. Patterns of population decline in birds. American Birds 38:10–13.

Associate Editor: A. [illegible]

CHILLING STATISTICS

Large wind turbines being built today have a "swept area" nearly the size of a football field. Their arms reach high in the sky, affecting birds that used to fly beyond reach of the older models. The rotors appear to turn slowly, but the blades travel at 150 to 300 Km/h at the tip, surprising the birds.

They are deadly to anything that flies, including birds, bats, and insects. In Cordelia, California, a single turbine erected in a low avian activity area was estimated to have killed 54 birds in one year [11]. This invalidates the idea that turbines having ample space between them will cause insignificant mortality (an argument presented by the promoters of the Chautauqua project in New York State, for instance).

The Cordelia results also fly in the face of the contention that American windfarms have lower birdkill rates than European ones.

Because of scavengers, searches for dead birds and bats are often unsuccessful. This is because they occur at intervals ranging from twice a week to once every 3 months, which leaves plenty of time for coyotes, foxes, and other animals to take away the remains.

In the Cordelia study, *"dead bird searches were conducted five days a week during nocturnal migration monitoring and once a week thereafter."* Daily searches, and a single turbine to look after: these could be the reasons for the relative efficiency of that particular mortality survey.

Except for certain species, like diurnal raptors, most casualties occur at night. So it is important to conduct the search at dawn, before scavengers find the bodies with their acute sense of smell. But it is clear that if one or two field workers must search an entire windfarm, or even half of it, the portion they will be able to cover at dawn will be tiny.

And ideally, in the case of diurnal raptors, two searches a day should be performed: in the late morning, and before sunset.

In view of this, there is an easy recipe for finding a low mortality rate at any windfarm:

1) An insufficient budget, limiting the number of searches to an inadequate frequency.

2) An excessive number of turbines to cover, and an inadequate number of searchers.

3) Poorly planned and inadequately performed scavenger-removal and searcher-efficiency tests.

In addition, the windfarm keeper could be asked to remove the most visible and embarrassing evidence, like dead eagles, swans, storks etc.

Bird mortality at windfarms is a burning subject. The stakes are high. After initial studies evidenced alarming levels of mortality, money is now being spent on new field surveys. Their purpose is to convince the public that bird populations will not be affected in a "significant" manner. And this may be achieved following the above recipe - with or without added ingredients.

As a result, inadequate studies are now the rule. They are sometimes voluminous and obfuscating, sometimes short and to the point, but mendacious always, minimizing the avian impact. And they serve the purpose that is assigned to them: permit the erection of windfarms where the promoters want them - like Smola island, Norway, sanctuary of the white-tailed sea eagle; Beinn an Tuirc, Scotland, on the home range of a breeding pair of golden eagles; Edinbane, Scotland, on a ridge where young eagles from two different species come to soar daily.

Such widespread use of pseudo-science and misleading conclusions renders precious the few reports that do not attempt to minimize survey results and mortality estimates. They are briefly summarized in this paper.

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PRELIMINARY CONSIDERATIONS ON AVIAN MORTALITY:

Large turbines of the latest technology may have blades that rotate more slowly than those of older types; but they are much longer - 35 to 40 meters

- and sweep much larger areas. They also reach higher in the sky, up to 125 meters high, affecting more species of birds and bats [1].

Furthermore, in spite of their slower rotation, speed at the tip is very high. Their increased length accounts for that. To give an example: General Electric model 1.5S has a rotor 70.5-meter-wide (diameter), and a generating rotor-speed varying between 11 and 22 rpm [2].

It is simple to calculate the tip-speed from this data:

70.5 meters x 3.14 (π R2) = 221.37meters circumference x 11rpm = 2435meters per minute x 60 minutes = **146 km/h**

At 22 rpm (revolutions per minute), the tips go twice as fast:

70.5 meters x 3.14 (π R2) = 221.37meters circumference x 22rpm = 4870meters x 60 minutes = **292km/h**

Large, fast moving blades that appear to turn slowly are a deadly trap to birds and bats, as shown by evidence provided below.

It is a known fact that intelligent animals like dogs can easily misjudge the time needed to cross the road safely. And the higher the speed of approaching cars, the greater the chances of miscalculation.

As a matter of fact, children, and even grown men, happen to err in their appreciation of speed and distances. Many accidents on our roads attest to the fact. And there is an aggravating factor: unlike cars, blade-tips travel on an orbit. Birds crossing the swept area would not always see them coming.

Why should birds, which some people regard as stupid, know better than people the speed at which the blade-tips are travelling? Hired consultants often claim that all but a few birds do see and avoid the blades. - The statistics below will show that this is hardly the case.

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BIRD MORTALITY ESTIMATES FROM EARLIER REPORTS.

1) Altamont Pass.

Several studies evidenced an on-going massacre at this very large windfarm near San Francisco. Golden eagles are being killed there at the rate of 40 to 60 per annum [3]. - A yearly average of 50 eagles, if we apply it from when the farm became operative about 20 years ago, represents 1,000 dead eagles.

The same windfarm also kills about 500 other raptors each year: hawks, owls, falcons, harriers and kites [4]. Cumulatively, that's 10,000 "protected" raptors over 20 years.
Other victims include doves, larks, ducks, blackbirds, gulls, swallows, herons, ravens, passerines, and bats [5].

For all birds inclusive, Dr. Smallwood gives us an estimate of 25,000 to 50,000 specimens killed at Altamont over 20 years [5] - bats excluded.

2) Strait of Gibraltar.

In 1995, SEO/Birdlife [6] evidenced that 14 species enjoying protected status were being killed at two windfarms in Tarifa. Short-toed eagles, griffon vultures, eagle owls, kestrels, kites, egrets are included in the list.

Yet, *"The scarce effect of both windfarms studied on migration of soaring birds in 1994 is attributed to the fact that, although most birds have followed routes very near the windfarms, the location of the turbines are such that they do not interfere with these routes"* [6]

So, in spite of being located off the migration corridor, these two windfarms kill migrating as well as local birds. How many? This remains undetermined for sure, because the report was trying to minimize the results. In an earlier analysis, I tried to expose this lack of objectivity:

"Here, the actual body count was: 65 large or medium-size birds for 34% of the 256 turbines surveyed "generally twice a week", and 54% of the tension lines surveyed once a week. Two short-toed eagles were among them, as well as 30 griffon vultures, 15 kestrels (3 of them on the endangered list), 2 eagle owls, 1 black kite, 1 "unidentified raptor" (it could be an endangered imperial eagle, for all we know) and one egret. Based on this, the summary estimates total mortality to be: 89 large and medium size birds - whereas a weighted extrapolation from 64 bodies on

34% of the windfarm area, and 1 on 34% of the tension lines area, would yield 190 bird carcasses for 100% of the area.
So, in effect, we are asked to believe that the estimated mortality is less than half the estimated body count." [7]

Other irregularities included the fact that, although small bird mortality was not surveyed, it was easy for the superficial reader to think all birds were included. Another was that scavenger and searcher-efficiency factors were only applied to kestrels [7].

But in spite of under-valuating bird mortality at the Strait of Gibraltar, the SEO report did create waves in the ornithological community. After Altamont Pass, it had evidenced that windfarms were particularly dangerous for raptors.

However, the wind industry, and accommodating bird societies, decided to treat the Altamont and Tarifa examples as "exceptions". They still do, in spite of the rest of the evidence below, which is simply ignored.

3) San Gorgonio, California.

Raptors were the main concern. But a study by Mccrary (1986)evidenced that passerines were also being killed in numbers: "an overall estimate of as many as 6,800 birds killed per year, most of them nocturnal passerine migrants." [8]
Many waterbirds are on the list as well.

But 6,800 birds out of millions were said to be "biologically insignificant".

No one bothered to ask what the cumulative effect would be, over thousands of future windfarms, over time, and over bird mortality from other causes. Instead, the wind industry and their followers take the minimizing approach: what's 10,000-40,000 birds killed by windfarms in the US compared to millions killed by cats, cars, windows etc.!

Notes: a) 10,000-40,000 is "their" estimate,
b) it does not consider the ever-expanding number of windfarms,
c) cats and windows do not kill eagles, storks, swans etc.
d) more windfarms mean more power lines, another bird killer,
e) saturation of the airspace with obstacles is likely to increase the overall bird mortality rate,
f) the cumulative effect of all mortality causes is what is worrying,

g) cynically, what is actually being said is: one bird massacre justifies another. In the Chautauqua report, they call it the "real life" approach.

4) Navarra, Spain.

In 2001, a report commissioned by the local government gave evidence that one third of the wind turbines in the region had made 7,150 victims in one year, including 409 griffon vultures, 24 eagles and other raptors, 650 bats and over 6,000 small birds, 40% of them migrants. [9]

A deceitful summary was added to the 150-page document, disclosing only 0.03 victims/turbine/mo; and the report was shelved. This falsification* of the results did not cause the Spanish ornithological society to come out in the press, let alone take legal action. Not even when an employee with a conscience leaked out the report to GURELUR, a local association, or when it was published on Internet by IBERICA 2000.org.

> *0.03 x 368 turbines = 11 victims/mo
> And the true mortality of 7,150 had to be reconstructed from various tables in the report.

7,150 / 368 turbines = 20 victims/turbine/year
Dr. Lekuona, biologist and author of the field study, stresses that his mortality estimates are conservative.

5) Flanders, Belgium.

"At 12 sea-directed wind turbines on the 'East dam' in the port of Zeebrugge the mean number was 39 birds/wind turbine/year." [10]

The overall bird-kill average for the Flanders windfarms studied by biologist Joris Everaert in 2001-2002 comes to 20 birds per turbine/year. The author adds that his figures are conservative.

Yet, when this study was mentioned by a comprehensive Birdlife report, only the bird species were mentioned, not the figures. The protest of a few concerned individuals made them rectify in a subsequent edition.

6) Cordelia, Solano County, California.

S. Byrne monitored a solitary wind turbine for one year, starting in 1992: *"The mortality adjusted for scavenger removal and detectability suggests an actual mortality during the study as high as 54 birds."*

"Findings indicated relatively low rates of waterfowl movements and nocturnal songbird migration over the wind turbine site". And the author adds: *"Migration rates were considerably lower than those recorded in the eastern United States."* [11]

This example is remarkable on various counts:

A) Searches were conducted 5 days a week during nocturnal migrations - once a week thereafter.
Too many studies are based on weekly, half-monthly, monthly, and sometimes quarterly searches. This allows for most dead birds and bats to disappear. Besides, scavenger-removal tests are not an exact science. Some biologists use road-kills that have been frozen for months; but well-fed scavengers patrolling the windfarm daily may show a preference for freshly killed victims bearing no human or road scent. - This could distort the results significantly.

Daily searches are crucial when rare species are at stake. For example: let us suppose three Bonelli´s eagles are killed at a given windfarm in a given year, and their bodies are removed by foxes (or windfarm employees) between the weekly searches. - The study will show zero Bonelli's eagles among the victims, even if scavenger-removal tests were conducted: a correction factor applied to a zero body-count comes out as nought.

Hence the importance of daily searches.

B) Being a solitary rotor, it should be easy for birds to avoid it - easier than a long string of turbines barring a migration flyway, like the Chautauqua project for instance. But the high mortality evidenced by Byrne shows that even a single machine is not so easy to avoid.

Moving blades, at night, are difficult to see - worse still in overcast conditions. Rain, wind are aggravating factors for visibility and avoidance action. And during the day, raptors are not deterred but attracted by the wind turbines, because of the mice, rabbits, or ground-squirrels that proliferate under them. Freshly-moved topsoil makes for easy burrowing around the concrete bases, and cleared woodlands turn into grasslands - i.e. rodent habitat. This has been amply demonstrated at Altamont [5].

The Chautauqua avian risk assessment pretends that wind turbines having ample space between them will cause insignificant mortality. - The Byrne study of a solitary turbine invalidates that prediction.

C) The Byrne survey yielded the highest-known bird-kill rate in the United States. Yet, it was promptly shelved and forgotten - evidencing a will to downplay the negative effects of windfarms on birdlife.

It is also in line with European findings (20 to 60 birds/turbine/year), whereas the US wind industry pretends that American windfarms only kill about 2 birds/turbine/year.

Unchallenged as they are by bird societies, wind promoters are able to go to extremes on the deception scale. Such is the case of the avian risk assessment of the Chautauqua project: here the consultant pretends that a string of 34 turbines on a ridgetop across a well-known migration flyway will kill a "maximum" of 110 birds/y. This compares with 54 birds killed by the single turbine studied by Byrne, which was located in a relatively low avian activity area.

If we applied the Byrne findings to the Chautauqua project:

34 x 54 = 1,836 dead birds/year

But at Cordelia, *"Migration rates were considerably lower than those recorded in the eastern United States."*

This is not the case for Chautauqua: the consultant estimates that 100,000 raptors fly over the wind resource area (WRA) each spring, 16,000 of which at an altitude agl* below 125 meters, which is the height of the turbines. Landfalls occur, so do local flights, and so does soaring and circling within the WRA. *above ground level

Waterbirds, bats and cranes also use the flyway. As for night migrating songbirds, the consultant estimates them at 3 million/year over the WRA, 118,000 of which fly below 125 meters agl and within the WRA.

It is clear that the figure of 1,836 - our birdkill extrapolation from the low bird activity area of Cordelia, is inadequate to estimate mortality at Chautauqua. A number in the five figures would be more likely, not including exceptional massacres due to poor weather conditions.

Yet the consultant predicts 110 dead birds/year. - The gap is that of two orders of magnitude!

7) The Netherlands.

In the ornithology profession, the highest reference when it comes to evaluating windfarm survey results is Dutch biologist J.E. Winkelman. She gave her name to the "Winkelman formula", which permits to extrapolate body-counts into estimated yearly mortality. This is done through applying a number of factors - scavenger removal, searcher efficiency, etc. which are to be established for each windfarm by rigorously conducted tests.

In her 1992 study at Urk and Oosterbierum, she estimated mortality to be somewhere between 33,500 and 195,500 birds per 1,000MW [(12)].

If we were to apply these estimates to the 50 MW Chautauqua project, we would obtain 1,675 to 9,775 dead birds a year. But Chautauqua is well-known for being a migration hotspot, so this extrapolation would be conservative.

What is more, the Dutch biologist emphasizes that her numbers are non-yearly figures: no observations were made during the summer period for both windfarms under study, nor during the winter period at Oosterbierum. More victims undoubtedly fell during those periods, so the "yearly" figures are underestimates, she notes.

She also wrote (translation): "*From the night-research at Oosterbierum it became clear that the real number of victims lies between the average calculated and maximum number of victim.*" - i.e. somewhere between 33,500 and 195,500 dead birds per 1,000 MW. Conservatively, colleagues in the profession use the figure of 46,000 - i.e. 46 birds per turbine/year.

8) Sweden.

From the PIER Study of the California Energy Commission (2002) [(8)]:

"In a summary of avian impacts at wind turbines by Benner et al. (1993) bird deaths per turbine per year were as high as 309 in Germany and 895 in Sweden."

These may be maxima, as opposed to averages; they are nevertheless staggering. Even if they occurred in bad weather conditions, or because a light attracted the birds at night, or whatever the reason: they illustrate the fact that these mishaps are likely to occur at windfarms, as they occur with obstacles as obvious and still as are smokestacks:

"On 23 September 1982, 1,265 birds (30 species from an estimated kill of 3,000) were collected below chimneys at the Crystal River Generating Facility, Citrus County, Florida.... On 24 September, an estimated 2,000 birds were involved in chimney collisions". Maehr, D.S., A.G. Spratt, and D.K. Voigts. 1983. Bird casualties at a central Florida power plant. Florida Field Naturalist 11:45-68.

As windfarms do not replace conventional plants, which are needed to back up the random intermittency of wind-produced electricity, the birds killed by windfarms will be added to those killed by smokestacks.

9) Germany.

Bernd Koop estimated there would be 60,000 to 100,000 annual bird collisions per 1,000 megawatt installed capacity in his country [13]. That's 60 to 100 birds/turbine/year.

If we apply his estimate to 15,000 MW of presently installed capacity in Germany, that's 900,000 to 1,500,000 bird collisions per annum. And the closer we are getting to territorial saturation, the lower the chances for the birds to find safe routes through the maze, especially if we add the deadly power lines. Such high mortality rates will be surpassed as more windfarms are built.

Birds in Germany die in great numbers from collision with 70,000 km of high-tension lines that criss-cross the country - 30 million birds per year is an extrapolation found in Hoerschelmann, Haack & Wohlgemuth, based on a study along 4.5 km of power lines - electrocutions excluded [14].
But windfarms need more power lines, so this kind of bird mortality will increase as well.

The cumulative effect of existing tension lines, plus tens of thousands of wind turbines, and yet more power lines to connect the windfarms to the grid, will be severe. And the killing of migrating birds on continental Germany, over the Baltic and the North Sea, and in Scandinavia, will be felt in other parts of Europe as well as Africa.

Reports of monitoring studies on German windfarms have not been made public as yet. It is most regrettable. In any event, the political importance of the birdkill figures to be released is paramount for the survival of the coalition government, which includes the Green party; so the pressure to minimize them will be very strong.

DISCUSSION

Much effort was made to put a lid on the above statistics. The Winkelman yearly figures, for instance, were converted into daily rates per turbine in order to mask their magnitude [15]. In the Lekuona study, a summary was added that showed 11 victims *per month*, whereas the body of the report established annual mortality at 7,150 bird and bats, including 409 griffon vultures [16]. These, and other examples of deception, have been analysed and published [17]. More will be very soon: the Chautauqua and De Lucas studies are among them.

The studies concerning Altamont, and the SEO/Birdlife report on Tarifa (Strait of Gibraltar) did reach some notoriety because of the high visibility of the raptors being victimized. But the wind industry chose to pretend they were exceptions that confirmed the rule, and ignored the rest of the evidence. Bird societies, who support that industry, by and large acted likewise.

And today we are facing a well-financed disinformation campaign. Non-objective, unscientific studies are being released to promote windfarm projects in areas that are vital to birdlife. For people with little time to read them - everybody really - an abstract is added, which states what the sponsor wants them to believe.

For example, in the executive summary to the De Lucas study on a windfarm overlooking the Strait of Gibraltar, we read: " *wind farms have shown a spectacular growth because they have reduced the costs of energy production. This phenomenon has resulted in a proliferation of wind farms around the world (Germany, Holland, Spain, United States, etc.) (Osborn et al. 2000).* " [18]

Why would ornithologists dabble in electricity production costing? Do the promoters dictate what the report must say - in this case a lie? Or are the consultants outdoing themselves to try and please their sponsors?

For the record, here is what the RAE has to say about the true cost of windpower:

"According to research carried out by the Royal Academy of Engineering (RAE), the cheapest electricity, costing just 2.3 pence per unit, will be generated from gas turbines and nuclear power stations, compared with 3.7p for onshore wind and 5.5p for offshore. The Academy also emphasised the need to provide backup for wind energy to cover periods when the wind doesn't blow. The study assumed the need for about 65% backup from conventional sources, adding 1.7p to the cost of wind power, bringing its price up to two and a half times that of gas or nuclear power."

Yet, this very report by De Lucas, biased as it is, is the cornerstone of a drive to place windfarms on migration hotspots in the State of New York (Chautauqua and others) [(18)].

In the same vein of deceipt, we are being asked to believe that wind turbines pose "insignificant" threat to eagle populations, even when placed on their hunting territory - home range or dispersion area. On the basis of this untruth*, which is based on statistical manipulation and disregard for cumulative impacts, windfarm projects have, or will soon be approved, at Edinbane, Ben Aketil, Beinn an Tuirc and Beinn Mholach, Scotland - Smola island, Norway - sierras of Almudaina and Alfaro, Spain - Starfish Hill, South Australia - Slovenia - Panama - and more eagle habitats.

* Explaining "untruth": Scientists have established that about 1,000 eagles have died so far at the Altamont Pass windfarm. At German windpower plants, the bodies of 13 rare white-tailed sea eagles were found by members of the public. In Spain, eagles are being killed by windfarms in the provinces of Navarre, Aragon, and Andalusia - that we know of. At Starfish Hill, South Australia, 2 eagles were killed practically as soon as the turbines became operative [(19)]. - As monitoring remains the exception, the total eagle-take worldwide is likely to be in the thousands.

Eagles are slow to reproduce. It is clear that, if more windfarms are built on eagle territories throughout the world, their cumulative impact will not be "biologically insignificant".

There is no limit to this line of dishonesty: industry followers now pretend that it is acceptable to place 300 wind turbines in a bird sanctuary of international importance, protected by the RAMSAR convention and the European network of natural reserves NATURA 2000: the Lewis peatlands SPA, in the Western Isles, Scotland. It is home to seven listed species, some of them in numbers constituting a high percentage of the total UK or European populations. It is also an important migration stopover for many other species - including whooper and bewick's swans, barnacle geese, white-fronted geese, etc. - being their first and last landfall on their route to and from Greenland and Iceland.

And they get away with it: witness the approval of a windfarm in South Gippsland* last month - in spite of the parrots, of the eagles, and the opposition of its people. * Victoria, Australia.

CONCLUSION

Deceitful studies, irregular and faulty surveys*, untruthful statements* permit the violation of conservation laws that took 2 centuries to establish.

> * the case of Scottish Natural Heritage in removing their objection to the siting of a windfarm in the Lewis peatlands SPA [21].

Yet bird societies, who are de-facto watchdogs for the respect of such laws regarding birdlife, remain very quiet. The Royal Society for the Protection of Birds, for instance, refused to mediatize its mild written objection to the Beinn Mholach windfarm project in the Natura 2000/RAMSAR Lewis peatlands SPA. And the project was subsequently approved.

They equally fail to publicize the studies and statistics presented in this paper, and keep pretending stubbornly that Altamont and Tarifa are "exceptions", when evidence is to the contrary.

The Bulgarian Society for the Protection of Birds is the exception that confirms the rule: they did launch a petition to save their migrating birds from a windfarm project. Who would have thought that Bulgarian ornithologists would give a lesson to the rest of the world in conservation ethics?

The question remains: how do other bird societies justify the installation of controversial and deadly windfarms in listed-raptor habitat, on migration flyways, or in bird sanctuaries? Given the chilling statistics presented herein, it is hard to understand. - After all, is there no room elsewhere?

And what about bats?

The effect of windfarms on bats deserves another paper. Suffice to say here that a windfarm on the Backbone Mountain in West Virginia is estimated to have killed 2,000 to 4,000 bats in one year [20].

That's 45 to 90 dead bats per turbine/year.

And the world is heading for one million wind turbines, in a first phase of windpower development.

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(documents & pictures)
http://www.iberica2000.org/documents/EOLICA/PHOTOS (pictures)

REFERENCES

(1) - Birdlife/Bern report - section
http://www.coe.int/t/e/Cultural_Co-operation/Environment/Nature_and_biological_diversity/Nature_protection/sc23_inf12e.pdf?L=E

(2) - General Electric webpage:
http://www.gepower.com/dhtml/wind/en_us/products/15/15specs.jsp

(3) - W. Grainger Hunt et al., Golden Eagles in a Perilous Landscape: Predicting The Effects Of Mitigation For Wind Turbine Blade-Strike Mortality, University of California, Santa Cruz. California Energy Commission Report, 2002.
http://www.energy.ca.gov/reports/2002-01-10_600-00-030.PDF

(4) - K. Shawn Smallwood, Carl Thelander, and Linda Spiegel
Raptor Mortality at the Altamont Pass Wind Resource Area
Research funded by the National Renewable Energy Laboratory.
http://www.iberica2000.org/documents/EOLICA/ALTAMONT/Dr.Smallwood_presentation.pdf

(5) - Thelander, C. G,Smallwood, K.S., Rugge, L. - Bird Risk Behaviors and Fatalities at the Altamont Pass Wind Resource Area - March 1998-December 2000, National Renewable Energy Laboratory Report SR-500-33829, December 2003. http://www.nrel.gov/docs/fy04osti/33829.pdf , www.nationalwind.org/events/wildlife/20031117/presentations/Smallwood

(6) - SEO/Birdlife International: Effects of wind turbine power plants on the avifauna in the Campo de Gibraltar region (1995) - 4. conclusions) by L. B. Jaque and R. M. Montes.
http://www.iberica2000.org/documents/EOLICA/SEO_Birdlife_report.pdf

(7) - M. Duchamp (2003): Critical Analysis of Four Reports on Bird Mortality at Windfarm Sites - section 2.
http://www.iberica2000.org/Es/Articulo.asp?Id=1223

(8) - D. Sterner, for the California Energy Commision (Dec. 2002)
A Roadmap for PIER Research on Avian Collisions with Wind Turbines in California
http://www.iberica2000.org/documents/EOLICA/6800_bird_fatalities.doc

(9) - J.M. Lekuona report:
http://www.iberica2000.org/Es/Articulo.asp?Id=1188

(10) - J. Everaert report: Wind Turbines and Birds in Flanders: preliminary study results and recommendations (2003) - Joris Everaert, biologist, Institute of Nature Conservation (IN). Scientific Institute of the Flemish Community.
http://www.iberica2000.org/documents/EOLICA/Everaert_report.pdf

(11) - Byrne, S. 1983. Bird movements and collision mortality at a large horizontal axis wind turbine. Cal-Neva Wildlife Transactions: 76-83. This study was conducted as a part of Pacific Gas and Electric Company's performance monitoring program for a Boeing MOD-2 wind turbine.

(12) - Winkelman J.E., 1992a - De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr) op
vogels - aanvaringsslachtoffers - section 5.6.8.
De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr) op
Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Arnhem.

(13) - Koop B., 1997. Vogelzug und Windenergieplanung. Beispiele für Auswirkungen aus dem Kreis Plön (Schleswig-Holstein). Naturschutz und Landschaftsplanung 29 (7): 202-207.
http://www.1-tra.de/Weiperfelden/windkraftanlagen_oder_voegel.htm

(14) - Hoerschelmann, Haack & Wohlgemuth (Ecol. Birds 10, 1988: 85-103; German text, English summary)

(15) - M. Duchamp (2003) Critical Analysis of Four Reports on Bird Mortality at Windfarm Sites
www.iberica2000.org/Es/Articulo.asp?Id=1223 - section 4.

(16) - M. Duchamp (2003) Critical Analysis of Four Reports on Bird Mortality at Windfarm Sites
www.iberica2000.org/Es/Articulo.asp?Id=1223 - section 1.

(17) - M. Duchamp (2003) Critical Analysis of Four Reports on Bird Mortality at Windfarm Sites
www.iberica2000.org/Es/Articulo.asp?Id=1223 - all four sections.

- M. Duchamp (2003) Red Energy
www.iberica2000.org/Es/Articulo.asp?Id=1227

(18) - M. de Lucas, Janss & Ferrer (2002-2003): The effects of a wind farm on birds in a migration point: the Strait of Gibraltar. Department of Applied Biology, Estacion Biologica de Donana (CSIC) Seville, Spain. (Received 10 July 2002; accepted in revised form 20 January 2003)
- critique of this report, and of the Chautauqua avian risk assessment, available upon request.

(19) - A. Chapman (2003) - Renewable Energy Industry Environmental Impacts: *"I recently received the following information from members of the*

Eaglehawk Conservation Group in South Australia about the Starfish Hill wind farm, a facility developed by Starfish Hill Wind Farm Pty Ltd, a wholly owned subsidiary of Tarong Energy, based in Queensland.

- *On 22 September 2003 the group said a Wedge-tailed Eagle had been killed at the Starfish Hill wind farm. This kill occurred before it was officially opened by Premier Mike Rann on Saturday 4 October 03.*
- *During the first week in October 2003 a second eagle was found dead under one of the turbines by the Tarong Energy Site Manager.*

At least four months after the first turbine commenced operating and even after the last kill there was no official bird kill monitoring procedure in place. These two eagle kills are known only because members of the public have stumbled across them.

(20) - Merlin Tuttle, director of Bat Conservation International in Austin, Texas www.friendsofthealleghenyfront.org/newsdown14.htm

(21) - M. Duchamp (2004), Objection to the Beinn Mholach (aka Pentland Road windfarm) - Section E: Objection hastily removed by SNH http://www.iberica2000.org/documents/eolica/Objection_Lewis_SPA.doc

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Do wind turbines kill birds?
The answer is Yes, but how many and what species vary significantly from site to site. When many people think about wind turbines and birds, they envision birds colliding with monopoles or turbine blades. While direct collisions do occur [1], turbines can also have unseen effects on bird populations where the turbines fragment bird habitat and interfere with migratory pathways.

All energy production comes at a cost. Carbon dioxide, sulfur dioxide, and nitrogen oxide emissions from fossil fuels are all significantly harmful to human health, wildlife, and the environment, as are oil spills. Offshore wind farms and similar marine-based energy facilities, however, may also pose significant risks to wildlife, and they don't guarantee that fossil fuel plants will close.

What kind of risks do wind turbines pose to birds?
In addition to the danger of birds colliding with turbines, other problems can arise, depending on the location and size of an offshore wind energy site. For example, the Federal Aviation Administration requires that tall offshore wind turbines have lights for pilot safety. There are no such lighted arrays of structures anywhere in United States coastal waters [2]. We know very little about the effects of lighting at these altitudes on night migrating songbirds and other species, especially during adverse weather [3], but preliminary research suggests that lights paired with dense fog or low clouds may disorient night migrating songbirds and some pelagic birds [4]. Migrating birds function on a limited energy supply, and it is well documented that birds pushed off course (in storms, for example) may never be able to recoup lost calories [5]; therefore, the alteration of migratory pathways may cause death in some birds of certain species.

Large wind farms may also displace birds by fragmenting habitat. This concern is greatest for those bird species that have been pushed to the brink of extinction by other human activities that limit their habitat resources, such as dense coastal development, human traffic on beaches, and coastal pollution. The greatest risks are to beach-nesting birds such as roseate terns and piping plovers [6]. Likewise, construction could potentially force migratory birds to move resting or foraging activities to more marginal habitat and could interfere with the passage or feeding activities of nesting shorebirds. The nature of the risk depends on when and how birds use a particular habitat.

How can you predict whether a particular site is a risky one for birds?
It's key to collect information about avian activity in an area prior to deciding whether large structures, such as wind turbines, are appropriate. To date, very little data have been collected about the potential impacts of marine-based wind farms on birds, and groups such as the National Wind Coordinating Committee Avian Subcommittee caution that land-based data do not apply to marine-based sites and that some findings from previous research "may need to be revised for wind farms with tower heights in excess of 300 feet" [7]. At the very least, it is important to know the species of birds that transit or reside in the area of the proposed construction and how they use that site. The degree of risk posed by any site (on land or offshore) depends on both the number and types of birds that may be affected, as some species are more vulnerable than others.

Are there any examples we can look to for guidance in designing research to assess a project's risk to birds?
The proposal by Cape Wind Associates to construct a wind farm in Nantucket Sound is the marine-based project furthest along in the review process. Nantucket Sound is an important area for migrating, overwintering, and nesting birds. According to the estimates of biologist Dr. Ian Nisbet, tens of millions of birds fly through the Sound every year, with many migrating at night

Do offshore wind farms harm marine life?

Frequently Asked Questions: Do turbines kill birds?

Offshore wind farms and the public trust

Frequently Asked Questions: Do turbines kill bats?

Harm to birds from wind farms can be minimized

Questions and answers about wind farms, wildlife and global warming

Thirty songbirds die at a single turbine in one night

[8] Specific information about the numbers, species, and activities of birds that use the site, however, is unavailable.

When asked to identify concerns and ways to identify risks, the Massachusetts Division of Fisheries and Wildlife and the U.S. Fish and Wildlife Service provided comments to the U.S. Army Corps of Engineers, the permitting agency. Both agencies called for a thorough environmental review.

The Division of Fisheries and Wildlife expressed particular concern for adverse impacts to rare species, wintering seabirds and seaducks, and migrating shorebirds and songbirds [9]. The U.S. Fish and Wildlife Service stated that it is absolutely necessary to extensively utilize remote radar and acoustic sensing technologies to identify the critical areas and key times during which sensitive bird species would be impacted. The agency also stated that the preferred study plan would consist of three years of avian field studies using a combination of horizontal and vertical radar, acoustic detection, direct field sampling, and visual observation by boat, barge, and aircraft [10].

These recommendations have been supported by representatives of The Humane Society of the United States, the Ornithological Council, the Sierra Club, the International Wildlife Coalition, the International Fund for Animal Welfare, the Massachusetts Society for the Prevention of Cruelty to Animals, and Three Bays Preservation [11], as well as the Massachusetts Audubon Society [12] and the Association to Preserve Cape Cod [13]. To date, the developer has not conducted the studies recommended by federal and state wildlife agencies.

What do you recommend?
Many prestigious wildlife and environmental organizations and avian biologists insist that developers conduct adequate avian studies prior to constructing wind turbines in marine waters. To insist on a proper environmental review does not imply either endorsement for or opposition to a certain project. Instead, it demonstrates a concern for the environment and a desire to get things right the first time around. Proactive study is always better than retrospective regret.

CITATIONS:
[1] "Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons of Avian Collision Mortality in the United States," a resource document of the National Wind Coordinating Committee from 2001, states that "Data collected to date indicate an average of 2.19 avian fatalities per turbine per year in the U.S." available at http://www.nationalwind.org/pubs/avian_collisions.pdf

[2] "Analysis of Legal and Scientific Deficiencies in the Analysis of Adverse Impacts to Birds and Bird Habitat Caused by the Proposed Cape Wind Energy Plant," submitted to the U.S. Army Corps of Engineers by the Alliance to Protect Nantucket Sound, March 11, 2003, available at http://safewind.info/articles/LSE.htm.

[3] "Avian/ Wind Turbine Interaction: A Short Summary of Research Results and Remaining Questions – Fact Sheet," National Wind Coordinating Committee.

[4] "Bird Kills at Towers and Other Human-Made Structures: An Annotated Partial Bibliography (1960-1998)," U.S. Fish and Wildlife Service, available at http://safewind.info/pdf/bird_kills.pdf

[5] "Migration of birds," Circular 16, 1998. U.S. Fish and Wildlife Service. Available at the Northern Prairie Wildlife Research Center Home Page: http://www.npwrc.usgs.gov/resource/othrdata/migratio/migratio.htm

[6] Letter to Robert Durand, Executive Office of Environmental Affairs, from Bradford G. Blodget, State Ornithologist, Massachusetts Division of Fisheries and Wildlife, December 20, 2001, available at http://safewind.info/pdf/ornithologist_letter.pdf

[7] "Avian/ Wind Turbine Interaction: A Short Summary of Research Results and Remaining Questions – Fact Sheet," National Wind Coordinating Committee

[8] Letter to Karen Adams, U.S. Army Corps of Engineers, from Dr. Ian Nisbet, March 26, 2002, available at http://safewind.info/pdf/nisbet.pdf

[9] Letter to Robert Durand, Executive Office of Environmental Affairs, from Bradford G. Blodget, Massachusetts Division of Fisheries and Wildlife.

December 20, 2001, available at
http://www.safewind.info/pdf/ornithologist_letter.pdf

[10] Letter to Chris Godfrey, U.S. Army Corps of Engineers, from Michael J. Bartlett, U.S. Fish and Wildlife Service, May 8, 2002, available at
http://safewind.info/pdf/3yrstudy.pdf

[11] Letter to Colonel Thomas L. Koning, U.S. Army Corps of Engineers, from The Humane Society of the United States, the Ornithological Council, the Sierra Club, the International Wildlife Coalition, the International Fund for Animal Welfare, the Massachusetts Society for the Prevention of Cruelty to Animals, and Three Bays Preservation, March 19, 2003, available at
http://safewind.info/articles/avian_studies_letter_031903.htm

[12] Massachusetts Audubon Society, "Position Statement on The Proposed Cape Wind Project, Nantucket Sound, May 12, 2003," available at
http://safewind.info/articles/Mass_Audubon_Statement.htm

[13] Personal communication with Maggie Geist, APCC executive director, March 21, 2003

... wind company distorts bat research in its reports. Bat Conservation guru, Ed Arnett, responds in letter, below.

Calvin Luther Martin

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5 June 2005

To whom it may concern,

I was asked to review sections of a DEIS (see below) prepared by a developer on bat interaction with wind turbines, in which portions of my research were cited. I have provided technical comments regarding statements in these sections, as well as some clarification on citation from my work.

The report section reads as follows:

"The numbers of migrating bats crossing the Project area are probably far lower than in the forested Appalachian ridge tops of West Virginia, Tennessee and southern Pennsylvania. The geography and latitude of the Project area are significantly different. The Project area is located in the Finger Lakes region of the glaciated Allegany Plateau physiographic province. The region is characterized by hills and valleys quilted with farmland and wooded hillside tracts. The broad Lake Ontario Plain lies directly north between the Project area and Lake Ontario. As during bird migration, migrating bats may fly through the region along a broad front in low densities. Migrating bats may show a tendency to avoid crossing the approximately 50-mile width of Lake Ontario (north of the Project area). Bats migrating south from Canada may tend to swing to the east around Lake Ontario and concentrate along the prominent Appalachian Mountain ridgeline. Based on bat study mortality data, the low levels of collision mortality in northeast wind farms (away from the Appalachian ridgeline) compared with high levels along Appalachian ridgeline wind farms offers support for this hypothesis. Impacts to resident bats would also be expected to be low in the Project area. Numerous studies have shown a wide range of resident bat activity at wind farms and very little corresponding collision mortality (Proceedings 2004). Recent thermal imaging conducted at the Backbone Mountain, WV wind farm in the late summer of 2004 indicated that bats often flew through the blade sweep zone and actively avoided moving blades and occasionally even investigated moving blades (NWCC 2004). Low levels of resident bat activity were recorded during the mid and late summer 2004 mist-netting and vocalization monitoring studies in the Project area. John Chenger of Bat Conservation and Management, Inc. (pwers. com), the bat specialist who conducted the Project bat surveys, offered that resident bat densities are typically highest around water bodies and streams and lowest over open farmland. A comparison of the Emerson Road farmland site with the 4 creek sampling sites indicates a higher level of bat activity at the creek sites. In the July 5-11 sampling there were a total of 34 bats netted at the creek sites and 2 bats collected at the Emerson Road site. During the August 22-26 sampling there were 53 bats netted at the creek sites versus 10 netted at Emerson Road. Eight of the netted bats at Emerson were northern long-eared bats. Because this species reportedly prefers wooded hillsides and hibernates near the summer range, the netted bats were probably local residents."

<u>Comments:</u>

"The numbers of migrating bats crossing the Project area are probably far lower than in the forested Appalachian ridge tops of West Virginia, Tennessee and southern Pennsylvania. The geography and latitude of the Project area are significantly different. The Project area is located in the Finger Lakes region of the glaciated Allegany Plateau physiographic province. The region is characterized by hills and valleys quilted with farmland and wooded hillside tracts. The broad Lake Ontario Plain lies directly north

between the Project area and Lake Ontario. As during bird migration, migrating bats may fly through the region along a broad front in low densities. Migrating bats may show a tendency to avoid crossing the approximately 50-mile width of Lake Ontario (north of the Project area). Bats migrating south from Canada may tend to swing to the east around Lake Ontario and concentrate along the prominent Appalachian Mountain ridgeline.

- This appears to be purely speculative with no cited empirical evidence.

Based on bat study mortality data, the low levels of collision mortality in northeast wind farms (away from the Appalachian ridgeline) compared with high levels along Appalachian ridgeline wind farms offers support for this hypothesis.

- I am not aware of the data referenced here, nor has it been cited. Perhaps these reports are being held in confidence, but the author should at least offer a citation or a "personal communication" when referencing an actual body of work. However, even if the data are available, it wouldn't seem to support the suggested hypothesis. Low levels of fatality has nothing to do with how bats move through the air space of a proposed wind farm.

Impacts to resident bats would also be expected to be low in the Project area. Numerous studies have shown a wide range of resident bat activity at wind farms and very little corresponding collision mortality (Proceedings 2004).

- What kind of citation is "Proceedings"? Proceedings of what? Prior to the study I coordinated in West Virginia and Pennsylvania, only 12 efforts have attempted to quantify bat fatality (see the presentation by Greg Johnson posted on the NWCC website from the November 2004 Wildlife working group meeting; this perhaps is the "proceedings" the author references. That presentation points out that reported fatality from the few efforts in open prairie and farmland from the west and upper Midwest report relatively low fatality. One must keep in mind that all of these studies are conditioned on the assumptions and sampling efforts, and it is clear that searcher efficiency and scavenger removal of bat carcasses has been poorly accounted for by all efforts prior to our study (again, see the Johnson presentation for the "rest" of the story.

Recent thermal imaging conducted at the Backbone Mountain, WV wind farm in the late summer of 2004 indicated that bats often flew through the blade sweep zone and actively avoided moving blades and occasionally even investigated moving blades (NWCC 2004).

- This statement is true, but there is no context and that's not the entire story from our thermal work. If the author is trying to suggest that "impacts to resident bats would also be expected to be low in the project area" by saying that bats are fully capable of flying through the rotor-swept zone and actively avoiding blades, then they are completely out of line and have misrepresented the context of this information. Bats flying through the rotor-swept area, whether actively avoiding blades or not, says NOTHING about impacts or relative risk to bats in any area, let alone a completely different site. The author seems to have forgotten to mention that we found hundreds of dead bats and have now estimated roughly 1,500-3000 were killed in just 6-weeks that didn't seem to actively avoid the blades.

Low levels of resident bat activity were recorded during the mid and late summer 2004 mist-netting and vocalization monitoring studies in the Project area. John Changer of Bat Conservation and Management, Inc. (peers. com.), the bat specialist who conducted the Project bat surveys, offered that resident bat densities are typically highest around water bodies and streams and lowest over open farmland.

- Mist net and acoustic surveys DO NOT yield densities of bats…period! Nor do they reflect habitat preference. This perhaps is simply an issue with terminology as much as anything, but it's critical to make this clear. Mist nets give you a species list of bats present, but do not confirm absence. Nor do they reflect activity or preference. Without mark-recapture data, estimates of populations (thus, densities) are not possible. If designed very rigorously, mist net data could be used to compare relative capture rates among habitats, but not habitat preference, which requires a different type of data from marked individuals that includes their residence time in habitats. Detectors give you relative activity rates for comparison, but again do not reflect preference, as residence time among habitats by individuals is required for such an analysis and inference.

A comparison of the Emerson Road farmland site with the 4 creek sampling sites indicates a higher level of bat activity at the creek sites. In the July 6-11 sampling there were a total of 34 bats netted at the creek sites and 2 bats collected at the Emerson Road site. During the August 22-26 sampling there were 55 bats netted in the creek sites versus 10 netted at Emerson Road. Eight of the netted bats at Emerson were northern long-eared bats. Because this species reportedly prefers wooded hillsides and hibernates near the summer range, the netted bats were probably local residents."

- Seems like a reasonable conclusion.

Respectfully,

Edward B. Arnett, Conservation Scientist
Bat Conservation International