SENATE, No. 2374

STATE OF NEW JERSEY

214th LEGISLATURE

INTRODUCED NOVEMBER 8, 2010

Sponsored by:
Senator SEAN T. KEAN
District 11 (Monmouth)
Senator ANDREW R. CIESLA
District 10 (Monmouth and Ocean)

Co-Sponsored by:
Senator Gill

SYNOPSIS

Prohibits siting of industrial wind turbines within 2,000 feet of any residence or residentially zoned property.

CURRENT VERSION OF TEXT

As introduced.

AN ACT concerning wind energy and supplementing Titles 13 and 40 of the Revised Statutes.

BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

1. a. The Legislature finds and declares that industrial-strength wind turbines can be over 400 feet tall and have blades that sweep up to 1.5 acres in area; that, as a result of their size, these machines have the potential to obstruct scenic vistas, create large community eyesores, and reduce property values for nearby residents unless they are sited at appropriate distances from residential areas; that recent developments in the area of wind power production have further indicated that the noise and vibration stemming from the operation of large-scale industrial wind turbines may cause nearby residents to suffer from a health condition known as "wind turbine syndrome," which may result in sleep disturbance, headaches, ringing of the ears, ear pressure, dizziness, vertigo, nausea, visual blurring, racing heartbeat, irritability, problems with memory and concentration, and panic episodes accompanied by internal pulsation or quivering sensations; that people have moved away from their homes to avoid the ill effects associated with "wind turbine syndrome"; and that medical, noise, and acoustics experts, as well as wind energy organizations, have indicated that incidents of "wind turbine syndrome" can be avoided if industrial-strength wind turbines are sited a considerable distance away from residential property.

b. The Legislature therefore finds that, in order to protect the public health and welfare, and in order to preserve the scenic vistas enjoyed by State residents and protect residents from unnecessary reductions in property value, it is both reasonable and necessary to prohibit the siting of industrial-strength wind turbines in or near residential areas.

2. a. No wind energy structure may be erected or installed in the State at a site that is closer than 2,000 feet from any residence or residentially zoned property.

b. No State entity may approve any plan, proposal, or permit application for a wind energy structure if that wind energy structure will be erected or installed at a site that is closer than 2,000 feet from any residence or residentially zoned property.

c. The provisions of this section shall apply only to wind energy structures erected or installed in the State subsequent to the effective date of this act.

d. As used in this section, "wind energy structure" means any on- or off-shore turbine, facility, farm, or other structure that is system," as defined by section 1 of P.L.2009, c.244 (C.40:55D-66.12).

3. a. No municipal agency may approve any plan, proposal, or permit application for a wind energy structure if that wind energy structure will be erected or installed at a site that is closer than 2,000 feet from any residence or residentially zoned property.

b. The provisions of this section shall apply only to wind energy structures erected or installed in the State subsequent to the effective date of this act.

c. As used in this section, "wind energy structure" means any on- or off-shore turbine, facility, farm, or other structure that is designed for the purpose of supplying electrical energy produced from wind technology, but shall not include a "small wind energy system," as defined by section 1 of P.L.2009, c.244 (C.40:55D-66.12).

4. This act shall take effect immediately.

STATEMENT

This bill would prohibit the siting of any industrial-strength wind energy production system within 2,000 feet of any residence or residentially zoned property. It would further prohibit any State entity or local government unit from approving a plan, proposal, or permit application for any industrial wind energy system that will be so sited.

The bill's prohibitions are necessary in order to ensure that the increased use of wind energy in the State will not cause a significant obstruction of scenic views or reduction in home values for New Jersey residents, and, more importantly, will not cause New Jersey residents to suffer from the ill health effects associated with "wind turbine syndrome" – a condition that has been connected with the close placement of industrial-scale wind turbines to residential areas. Symptoms of "wind turbine syndrome" include sleep disturbance, headaches, ringing of the ears, ear pressure, dizziness, vertigo, nausea, visual blurring, racing heartbeat, irritability, problems with memory and concentration, and panic episodes accompanied by internal pulsation or quivering. These symptoms, which are continuing in nature, often force people to move away from their homes. Experts on "wind turbine syndrome," experts in noise and acoustics, and wind energy associations, however, have all indicated that instances of "wind turbine syndrome" can be avoided if industrial wind energy systems are sited a considerable distance away from residential housing industrial wind energy facilities on property values. Consequently, in order to protect the public health and welfare, and preserve the State's scenic vistas and residential property values, it is both reasonable and necessary to prohibit the erection of industrial wind energy facilities within 2,000 feet of any residential property.

It is important to note, however, that this bill would not apply to the siting of small wind energy systems that are used primarily for on-site consumption purposes. "Wind turbine syndrome" has been associated only with the residential placement of large-scale, industrial-strength wind turbines. Moreover, small, personal-use wind energy systems are not likely to cause significant vista obstruction or the reduction of surrounding property values, as is true of their larger, industrial counterparts.

Session 2010 - 11
Internet Publications
Other Bills before Parliament

HOUSE OF LORDS

House of Lords

Wind Turbines (Minimum Distances from Residential Premises) Bill [HL]

Wind Turbines (Minimum Distances from Residential Premises) Bill [HL] 1

A

BILL

TO

Make provision for a minimum distance between wind turbines and residential premises according to the size of the wind turbine; and for connected purposes.

BE IT ENACTED by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

1 Planning permission

(1) No relevant authority may grant planning permission for the construction of a wind turbine generator unless it meets the minimum distance requirement under section 2, subject to the exception in section 3.

(2) "Relevant authority" means the local authority or government department with the power to grant planning permission for a wind turbine generator.

2 Requirements for minimum distance

(1) The "minimum distance requirement" means the necessary minimum distance between the wind turbine generator and residential premises as set out in subsection (4).

(2) "Residential premises" means any premises the main purpose of which is to provide residential accommodation, including farmhouses.

(3) If a number of wind turbine generators are being built as part of the same project the minimum distance requirement applies to each wind turbine generator individually.

(4) If the height of the wind turbine generator is—

(a) greater than 25m, but does not exceed 50m, the minimum distance requirement is 1000m;

(b) greater than 50m, but does not exceed 100m, the minimum distance requirement is 1500m;

(c) greater than 100m, but does not exceed 150m, the minimum distance requirement is 2000m;

(d) greater than 150m, the minimum distance requirement is 3000m.

(5) The height of the wind turbine generator is measured from the ground to the end of the blade tip at its highest point.

(6) There is no minimum distance requirement if the height of the wind turbine generator does not exceed 25m.

(7) If planning permission is granted on the condition that the proposed wind turbine generator meets the minimum distance requirement under subsection (5) the actual height of the wind turbine generator must not exceed the maximum height in relation to that minimum distance.

3 Exception

(1) The local authority may grant planning permission for the construction of a wind turbine generator which does not meet the minimum distance requirement under section 2(4) if the condition under subsection (2) is met.

(2) The condition is that the owners of all residential premises which fall within the minimum distance requirement for the proposed wind turbine generator must agree in writing to the construction of the wind turbine generator.

(3) It is the duty of a relevant authority to ensure that no written agreement is elicited by unlawful means and that all necessary written agreements have been received before planning permission is granted.

4 Short title and extent

(1) This Act shall be known as the Wind Turbines (Minimum Distances from Residential Premises) Act 2010.

(2) This Act extends to England and Wales.

First International Symposium on Adverse Health Effects from Wind Turbines
The Global Wind Industry and Adverse Health Effects: Loss of Social Justice?
Picton, Prince Edward County, Ontario, Canada
October 29-31, 2010

Session I

No Rules, No Caution, No Accountability

Abstract and bio on slide 2 is reproduced from the Symposium Program

First International Symposium on Adverse Health Effects from Wind Turbines
The Global Wind Industry and Adverse Health Effects: Loss of Social Justice?
Picton, Prince Edward County, Ontario, Canada

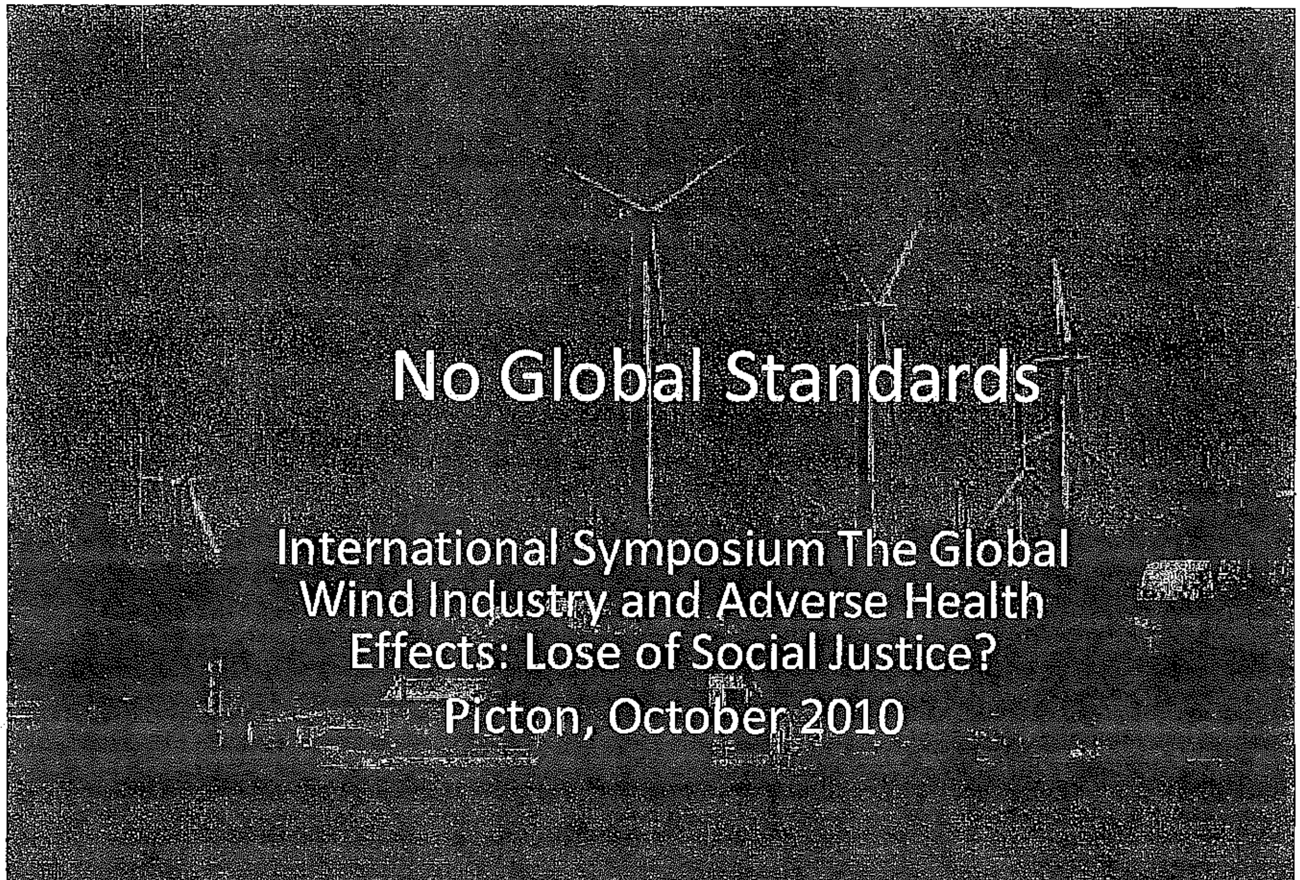
October 29-31, 2010

Orville Walsh, CCSAGE -

NO GLOBAL STANDARDS

Abstract: The rapid expansion of the wind energy industry globally has resulted in governmental authorities at different levels responding to opposing pressures to create or modify regulations and planning guidelines for the siting of utility scale wind turbines. Siting guidelines for health, safety, cultural and natural heritage were reviewed and compared. The results indicate wide ranges of siting standards are being adopted. Government authorities have employed a variety of criteria, resulting in significant variation in the spatial separation between wind turbines and sensitive areas as well as the intensity of the development. Separation distances in many jurisdictions are less than those recommended by health professionals suggesting some in the population are at risk. Current trends in government planning and regulations are discussed.

Bio: Orville Walsh is a resident of Prince Edward County, Ontario and the Chairman of the County Coalition for Safe and Appropriate Green Energy and a board member of the Alliance to Protect Prince Edward County. Walsh held senior management positions with Honda Canada and recently retired after a 30 year career.


No Global Standards
International Symposium The Global Wind Industry and Adverse Health Effects: Lose of Social Justice?
Picton, October 2010
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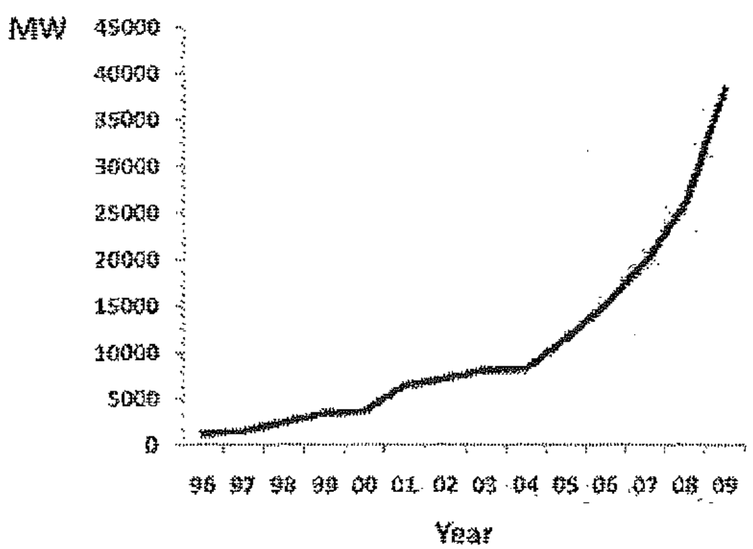
Global Annual Installed Wind Energy Capacity 1996-2009



Growth will continue

- In 2009 38,000MW of wind energy installed.
- Total cumulative installations 158,000MW
- Forecasts indicate over 400,000MW installed by 2014
- Industry driven by:
  - Renewable energy targets
  - National or Provincial/State incentives
  - Economic policy (Green economy)
- Wind energy has wide government and public support.

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Challenging for regulators

In most jurisdictions the final responsibility and decision for the siting industrial development resides with municipal (local) authorities, guided by state or national guidelines or standards.

Crafting bylaws or ordinances to deal with utility scale wind energy developments is challenging;

- It's new
  - Unfamiliar and complex and controversial
- Unique characteristics with scale and operations
  - Large machinery, large unshielded moving components
  - Multiple machines covering a large land area
  - Elevated noise source
  - Operation on a 365/7/24 basis
  - No on-site staff, normally operated from remote locations
  - Located normally in rural and non-industrial locations

Unique areas of concern for wind turbine siting

Health and Safety

- Noise
- Shadow flicker
- Catastrophic failure
- Blade /Ice throw

Natural Environment

- Birds and Bats
- Habitat
- Wetlands, water courses

Cultural and Economic

- Property Rights
- Cultural Heritage
- Tourism
- Viewscape

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Unique areas of concern for wind turbine siting

Health and Safety

- Noise
- Shadow flicker
- Catastrophic failure
- Blade /Ice throw

Noise
Control by dB level or establish distance setbacks

Shadow Flicker
Can be accurately predicted, control exposure

Failure and blade ice throw
Establish safe distance setbacks

Presented at the First International Symposium on Adverse Health Effects from Wind Turbines - October 29-31, 2010

dB Based Standards

World Health Organization Guidelines for Community Noise

Specific environment	Critical health effect(s)	LAeq [dB(A)]	LAmax fast [dB]
Outdoor living area	Serious annoyance, daytime and evening	55	
	Moderate annoyance, daytime and evening	50	
Dwelling, indoors	Speech intelligibility & moderate annoyance, Daytime & evening	35	
Inside bedrooms	Sleep disturbance, night-time	30	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	60

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.

Source: GUIDELINES FOR COMMUNITY NOISE 1999

Distance based recommendations for setbacks from utility scale wind turbines

Researcher	Country	Recommended setback
Pierpont	USA	2.0km
Frey and Hadden	U.K.	2.0km
Harry	U.K.	2.4km
French Academy of Medicin	France	1.5km
U.K. Noise Association	U.K.	1.6km

Method

1. Utilized published comparative reviews
2. Targeted internet search by jurisdiction
   – National/Provincial/State Government Ministries/Departments and National Wind Energy Associations
3. Obtain a copy of the legislation, ordinance, bylaw or guidance documents
4. Limited to utility scale wind turbine facilities (excludes micro, small, medium)
5. Noise limits and setbacks are for rural residential and non-participating properties/dwellings

Limitations
– Difficult to confirm if most current
– Noise penalties (tonality, impulsive) not included
– On-land only

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Sources

Comparative studies
- Noise annoyance from wind turbines – a review- Pedersen 2003
- Wind Turbine Facilities Noise Issues – Ramakrishnan 2007
- Studies for New Brunswick and Nova Scotia municipalities- (Jacques Whitford 2008)

Wind Industry Associations websites
- American Wind Energy Association , Clean Energy Council (Auswind), Canadian Wind Energy Association, Danish Wind Industry Association European Wind Energy Association

Project Environmental assessment documents

Government websites
- Municipal
- Canadian Provincial Ministries
- U.S. State Agencies/Departments
- U.S. Department of Energy, Energy Efficiency and Renewable Energy

Europe Country	Rural Residential Noise Limits dBA				Minimum Setback Distance (m) h=hub height, H=total height D= Rotor diameter		
	Time of day			Comments	Property Line	Dwelling	Roads
	Day	Night	Any				
Belgium	49	39					
Denmark			40			4H	
France	+5	+3		Above ambient, pre-post installation			
Germany	50	40/35					
Ireland	35-40*	43*	L_{90} +5 dBA	Guidelines only	2D		1.1H
Netherlands			40	Interim			
Portugal	55	43					
Spain				Local/Regional			
Sweden			40				
UK	40*	43*	$L_{90,\ 10}$ +5 dBA				

*Values are minimum limits,
i.e. when calculating the limit of ambient plus, it can not go below these established minimums 12

Australia State and New Zealand		Rural Residential Noise Limits dBA		Minimum Setback Distance (m)		
		Anytime of day	Comments	Property Line	Dwelling	Roads
Australia			Draft guidelines being prepared			
	Northern Territory		No specific guidelines			
	New South Wales	$L_{A90,10}$ +5dBA	*35 $L_{Aeq,10}$			
	Queensland		No specific guidance			
	South Australia	L_{90} +5dBA	*35L_{A90}			
	Tasmania		No specific guidance			
	Western Australia	35 L_{A10}			1000	
	Victoria	L_{90} +5dBA	*40L_{A95}			
New Zealand		L_{90} +5dBA	*35-40 L_{90} (10min)			

*Values are minimum limits,
i.e. when calculating the limit of ambient plus, it can not go below these established minimums

USA State Municipality	Rural Residential Noise Limits			Minimum Setback Distance (m) h=hub height, H=total height, D=rotor diameter		
	Any time of day		Comments			
	dB(A)	dB(C)		Property Line	Dwelling	Roads
Wisconsin						
State Model Ordinance	50			1.1H	305	1.1H
Buffalo County	50			H+15		
Door County	50			1.1H	2H/305	1.1H
Town of Magnolia	35 /+5	38		5D/305	805	305
Manitowoc County	+5			305		
Mitchell	50			1.1H	1.1H	1.1H
Morrsion	50			1.1H	305	
New Glarus	45	Yes	By frequency bands			
Town of Rockland	50			1.1H	305	1.1H
Shawano County	+5	Yes		2H/152	4H/305	
Town of Union	+5 & 35	50	Or LeqC-LA90 < +20	5D/305	805	3H

USA State Municipality	Rural Residential Noise Limits dB(A)		Minimum Setback Distance (m) h = hub height, H = total height, D = rotor diameter		
	Any time of day	**Comments**	**Property Line**	**Dwelling**	**Roads**
Michigan					
State Model Ordinance	55	at property line	1.0 -1.5H		
Bank County	60				
Gratiot County	55	at property line	1.5h	2h or 305	
Huron County	50			2h or 305	1.5h
City of Ionia	55	Or +5dBA			
Lodi	55	At project property line	1.5h		
Long Lake Township	+10	Above ambient baseline	2H	1.25H	5H
Manchester Township	55		1.5H		1.5H
Ostego County	+10	At project property line	381		381
Ottawa County	+5		1.5H	1.5H	1.5H
City of Portland	+5	At project property line	1.5H	2H or 305	

USA **State** Municipality	**Rural Residential Noise Limits dBA**			**Minimum Setback Distance (m)** h = hub height, H = total height, D = rotor diameter		
	Time of day		**Comments**	**Property Line**	**Dwelling**	**Roads**
	Day	**Night**				
Minnesota						
State Model Ordinance	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		3D-5D (based on cardinal direction)	152+noise	76
Big Stone County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.1H	229	1.1H
Browns County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.5H	229	1.5H
Cooks County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		H		
Fillmore County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.1H	229	
Lyon County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.1H	305	H
Martin County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		H	229	
Nicollet County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.1H	229	1.1H
Swift County	L_{10} 65 L_{50}60	L_{10} 55 L_{50}50		1.1H	229	H

USA State	Rural Residential Noise Limits dBA				Minimum Setback Distance (m)		
	Time of day			Comments	Property Line	Dwelling	Roads
	Day	Night	Any				
Oregon	L_{50} 55 L_{10} 60 L_1 75	L_{50} 50 L_{10} 55 L_1 60	36	+10 over ambient assumed to be 26 In any one hour		1000	

USA State Municipality	Rural Residential Noise Limits			Minimum Setback Distance (m) h = hub height, H = total height, D = rotor diameter		
	Any time of day		Comments	Property Line	Dwelling	Roads
	dB(A)	dBC				
New York						
State Model Ordinance	50			1.5H	457	1.5H
Fenner	50		Property line	1.5H	1.5H	
Hamlin	+6		Above ambient	183	366	183
Martinsburg				91	457	
St. Lawrence County	50			152	305	152
North Carolina						
State Model Ordinance	55			1.5H	2.5H	1.5H
Ashe County	45			305		1.5H
Camden County	None			1H	2H	
Currituck County				1.5H	2.5H	1.5-2.5H
Hyde County	55			1.1H	2.5H	1.5H
Kill Devil	60					
Tyrell County	55			1.5H	2.5H	1.5H
Watuga County					1.5H	18

USA State Municipality	Rural Residential Noise Limits					Minimum Setback Distance (m) h = hub height, H = total height, D = rotor diameter		
	dBA			dBC	Comments	Property Line	Dwelling	Roads
	Day	Night	Any					
Maine								
State Model Ordinance	55	45						
Town of Buckfield			+5	Max 50		Larger of 13H or 1609		4H
Dixmont*	50	40		+20 Max 50-55	$L_{eq}C_{(post)}$ - $L_{90}A_{(pre)}$<20 dB	762	1609	457
Town of Montville			+5	+20 Max 50		Larger of 13H or 1609		4H
Massachusetts								
State Model Ordinance			+10		At property line and dwelling	30	1.5H	1.5H
Salem			+10			0.75H	H	

* Sound limits apply when within 0-1609m of non-participating property, lower limits apply for those greater than 1609m

Canada **Province** Municipality	**Rural Residential Noise Limits dBA**				**Minimum Setback Distance (m)** h =hub height, H=total height, b=blade length		
	Time of day			**Comments**	**Property Line**	**Dwelling**	**Roads**
	Day	**Night**	**Any**				
British Columbia			40				
Alberta	50	40		40 dBA at 1.5km if no receptor			
Pincher Creek MD	50	40	45	At project boundary	1.1H		1.1H
Manitoba*				Guidance document only	1.5H	500-550	1.5H
Ontario				Number of turbines⇨ +SPL (40dBA is target)	h or can be reduced to b+10	550-1500	b+10
			40	Target for predictive modeling		550	
			40-51	for compliance			
Québec			40				
New Brunswick*			40-53	wind speed, guidance only			
Nova Scotia*			40-53	wind speed, guidance only			
Prince Edward Island				45 dBA applied	H	4H	

* Manitoba, New Brunswick and Nova Scotia appear to be utilizing the non-current Ontario regulations for guidance

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Ontario, Canada Noise Distance Setbacks

Number of Turbines (within 3km)	Total distance from wind turbine to nearest noise receptor of the wind turbine by Sound power level of wind turbine (expressed in dBA)			
	102	103-104	105	106-107
1-5	550	600	850	950
6-10	600	700	1000	1200
11-25	750	850	1250	1500

•Proponents in Ontario have the option of using the noise setback matrix (above) or to conduct a noise study (predictive). The noise study uses 40dBA as the maximum noise level permitted at a receptor.

•For compliance, it is not clear if the noise levels over 40dBA that are permissible in Ontario <u>Noise Guidelines for Wind Farms</u> 2008 (up to 51dBA) may be allowed.

http://www.e-laws.gov.on.ca/html/source/regs/english/2009/elaws_src_regs_r09359_e.htm#BK71

Safety

- The noise setback requirements are assumed to provide sufficient protection to dwellings from catastrophic turbine failure, blade and ice throw.
- The majority of jurisdictions provide some protection to personal property by establishing a fall zone, specifying setbacks equal to and greater than the total height of the turbine. The majority of setback distances are between 1.1 and 1.5 times the total height of the turbine.
- Few jurisdictions provide a high level of safety for blade/ice throw near roads and property.
- Ontario Canada is the only senior government which does not specify a setback from property lines and roads that is greater than the turbine total height.

Noise

- Most rely on noise modeling prior to construction for establishing distance from dwellings and/or properties.
  - A-scale for noise used, a few using C-scale
  - Only a few jurisdictions used a fixed setback distance
- Maximum permissible noise levels varied:
  - Above ambient limits ranged from +3 to +10 dBA
  - dBA limits range from 35 to 60
  - Incremental limits with wind speed
  - Different decibel measurements used
- Definition of noise measuring point varied:
  - Project property line
  - Non-participating property line
  - Fixed distance from dwelling

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Noise

1. Only a few jurisdictions have established noise distance setbacks approaching those recommended by researchers.
2. The noise limits based on decibels are close to those noise levels where negative health impacts can be expected.

- This suggests that some in the population are at risk.

Guidelines and Regulations

- Reacting to local governments, senior levels of Government establishing siting regulations or guidelines and authority.
  - Ontario, Canada and Green Energy Act
- Will result in more wind turbines sited at maximum limits.

Balance or Compromise

"A balanced assessment of wind energy proposals requires that these benefits be weighed against any possible negative effects on recognised environmental and cultural values."

Policy and planning guidelines for development of wind energy facilities in Victoria - Sustainable Energy Authority Victoria

"There will be individuals who live close to existing and future wind farms who will disagree with these standards we set. As I do in all siting decisions, I feel for these people, but I believe we will treat them fairly and balance their concerns with the state's real and important drive to advance clean energy projects."

Wisconsin PSC Chairman - Eric Callisto

"An appropriate balance must be achieved between power production and noise impact"

Planning Guidelines - Ireland

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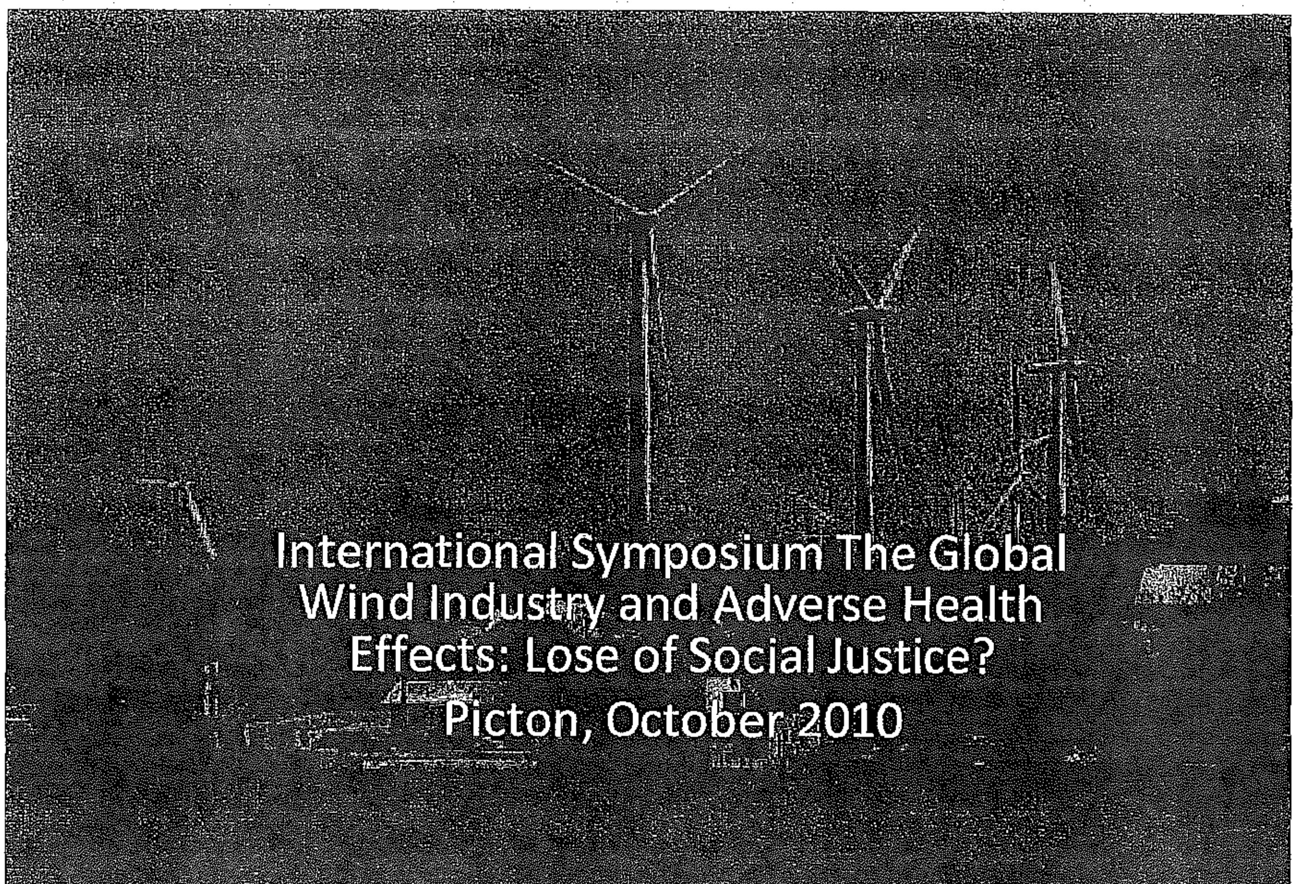
International Symposium The Global
Wind Industry and Adverse Health
Effects: Lose of Social Justice?
Picton, October 2010

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GE
Energy

Ice Shedding and Ice Throw – Risk and Mitigation

David Wahl
Philippe Giguere
Wind Application Engineering

GE Energy
Greenville, SC

Ice Shedding and Ice Throw – Risk and Mitigation

Introduction

As with any structure, wind turbines can accumulate ice under certain atmospheric conditions, such as ambient temperatures near freezing (0°C) combined with high relative humidity, freezing rain, or sleet. Since weather conditions may then cause this ice to be shed, there are safety concerns that must be considered during project development and operation. The intent of this paper is to share knowledge and recommendations in order to mitigate risk.

The Risk

The accumulation of ice is highly dependent on local weather conditions and the turbine's operational state.[2,4] Any ice that is accumulated may be shed from the turbine due to both gravity and the mechanical forces of the rotating blades. An increase in ambient temperature, wind, or solar radiation may cause sheets or fragments of ice to loosen and fall, making the area directly under the rotor subject to the greatest risks[1]. In addition, rotating turbine blades may propel ice fragments some distance from the turbine—up to several hundred meters if conditions are right.[1,2,3] Falling ice may cause damage to structures and vehicles, and injury to site personnel and the general public, unless adequote measures are put in place for protection.

Risk Mitigation

The risk of ice throw must be taken into account during both project planning and wind farm operation. GE suggests that the following actions, which are based on recognized industry practices, be considered when siting turbines to mitigate risk for ice-prone project locations:

- **Turbine Siting:** Locating turbines a safe distance from any occupied structure, road, or public use area. Some consultant groups have the capability to provide risk assessment based on site-specific conditions that will lead to suggestions for turbine locations. In the absence of such an assessment, other guidelines may be used. Wind Energy Production in Cold Climate[6] provides the following formula for calculating a safe distance:

  $$1.5 * (\text{hub height} + \text{rotor diameter})$$

  While this guideline is recommended by the certifying agency Germanischer Lloyd as well as the Deutsches Windenergie-Institut (DEWI), it should be noted that the actual distance is dependant upon turbine dimensions, rotational speed and many other potential factors. Please refer to the *References* for more resources.

- **Physical and Visual Warnings:** Placing fences and warning signs as appropriate for the protection of site personnel and the public.[4]

- **Turbine Deactivation:** Remotely switching off the turbine when site personnel detect ice accumulation. Additionally there are several scenarios which could lead to an automatic shutdown of the turbine:
  - Detection of ice by a nacelle-mounted ice sensor which is available for some models (with current sensor technology, ice detection is not highly reliable)
  - Detection of rotor imbalance caused by blade ice formation by a shaft vibration sensor; note, however, that it is possible for ice to build in a symmetric manner on all blades and not trigger the sensor[2]
  - Anemometer icing that leads to a measured wind speed below cut-in

- **Operator Safety:** Restricting access to turbines by site personnel while ice remains on the turbine structure. If site personnel absolutely must access the turbine while iced, safety precautions may include remotely shutting down the turbine, yawing to place the rotor on the opposite side of the tower door, parking vehicles at a distance of at least 100 m from the tower, and restarting the turbine remotely when work is complete. As always, standard protective gear should be worn.

References

The following are informative papers that address the topic of wind turbine icing and safety. These papers are created and maintained by other public and private organizations. GE does not control or guarantee the accuracy, relevance, timeliness, or completeness of this outside information. Further, the order of the references is not intended to reflect their importance, nor is it intended to endorse any views expressed or products or services offered by the authors of the references.

[1] *Wind Turbine Icing and Public Safety – a Quantifiable Risk?:* Colin Morgan and Ervin Bossanyi of Garrad Hassan, 1996.

[2] *Assessment of Safety Risks Arising From Wind Turbine Icing:* Colin Morgan and Ervin Bossanyi of Garrad Hassan, and Henry Seifert of DEWI, 1998.

[3] *Risk Analysis of Ice Throw From Wind Turbines:* Henry Seifert, Annette Westerhellweg, and Jürgen Kröning of DEWI, 2003.

[4] *State-of-the-Art of Wind Energy in Cold Climates:* produced by the International Energy Agency, IEA, 2003.

[5] *On-Site Cold Climate Problems:* Michael Durstewitz, Institut fur Solare Energieversorgungstechnik e.V. (ISET), 2003.

[6] *Wind Energy Production in Cold Climate:* Tammelin, Cavaliere, Holttinen, Hannele, Morgan, Seifert, and Säntti, 1997.

16. Precautions in Case of Fire

At any type of fire in or near a turbine, the power to the turbine must always be disconnected at the main high voltage circuit breaker. To disconnect supply, switch off by pushing the red button (marked TRIP F60) on the nacelle controller in the nacelle. In the tower bottom the power supply is switched off by pushing the red button situated on the breaker in the high voltage section. If it is impossible to get to the main circuit breaker, contact the power station for a disconnection of the grid.

In case of a fire during an uncontrolled operation, do under no circumstances approach the turbine. Evacuate and rope off the turbine in a radius of minimum 400m (1300ft). In case of a fire in a non-operating turbine, the fire can be put out by means of a powder extinguisher.

⚠ CAUTION **Use of a CO2 extinguisher in a closed room can result in lack of oxygen.**

17. Directions for Use of Rotor Lock

To avoid accidents and near-accidents, which can be prevented via mechanical locking of the rotor, the following guidelines must be followed:

IN GENERAL:
Besides following the requirements listed in this document, it is important also to use ones common sense and assess the specific situations.

When the wind speed exceeds the values of the mechanical design of the locking system, it is not allowed to work in a turbine as listed below.

A technical solution must be prepared before starting work on a turbine that cannot be locked mechanically.

The work listed below must not be carried out before the turbine has been mechanically locked.

Mechanical rotor locking must be used in connection with:

1. Hub and blades:
   a. stay in hub and nose cone
   b. stay on/near the blade is not allowed unless both the rotor and the blade has been locked

2. Work on gearbox and gear oil system if this involves:
   a. disassembly and adjustment of mechanical parts
   b. tensioning
   c. activation of shrink disc
   d. internal inspection – unless it is a visual inspection

3. Work on coupling and braking system if this involves:
   a. disassembly and adjustment of mechanical parts

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 izontally 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:

s= v times t + 1/2 g times t squared.

3 .=140 t + 16 t**2

Solving for t, we get about 2.5 seconds. In 2.5 seconds the increase in the range is:

~'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. Interestingly, when the chunks become larger, the Reynolds number increases, and viscosity becomes less important. What this means is that the larger, more dangerous chunks will tend to travel further than small ones.

Moreover, the study of "harvested" ice that is subjected to wind tunnel testing is likewise demonstrably without merit. The procedure is to 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 efficient = 1.0 This is close to the drag that a half a tennis ball (say) would esent 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 m 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).

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 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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Professor Terry Matilsky
Department of Physics and Astronomy
Rutgers University
Piscataway, N. J. 08854
http://xray.rutgers.edu/~matilsky

matilsky@physics.rutgers.edu
Tel: 1-732-445-5500 ext. 3876
Fax: 1-732-445-4343

THE MORNING JOURNAL

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News

Blade comes off wind turbine at Perkins High School

Published: Wednesday, December 01, 2010

By RICHARD PAYERCHIN
rpayerchin@MorningJournal.com

PERKINS TOWNSHIP — Wind turbines that power Perkins High School are shut down after a blade detached from one of the machines on Monday evening.

No one was hurt when the blade came off the rotating hub of the northernmost turbine, one off three at the school at 3714 Campbell St.

This was the second time in two years the school district had a wind turbine fail due to a problem with blades. The turbine that failed this week was not the one that had earlier problems, officials said.

"At this point we're going to take a step back, find out what happened and make decisions from there," P[illegible]ns school Superintendent Jim Gunner said.

:n this week's incident, the blade did not break when it hit the ground, said Gunner and David L. Rengel, /ice president of Wilkes & Co., which also operates energy consultant Engineered Process Systems Ltd. of Huron. The company installed the turbines, which are manufactured by ReDriven Power Inc. of Iroquois, Ontario.

'One of the blades fell off the attachment bolts," Rengel said. "It appeared to be sheared off. How it ıappened, what caused it, I have really no idea."

A technician from ReDriven was on the way to Erie County yesterday to examine what went wrong, Rengel said.

'They're the experts," Rengel said. "We're installers, but they are the experts on their equipment."

The wind turbines had been operating as expected, and there were no signs of a strong wind gust or severe veather on Monday evening, Rengel said.

School was not in session when the blade came off about 5:30 p.m., Gunner said. A few students were at the chool for swim practice and a parent there first noticed the blade came off, Gunner said. The parent began alling Perkins school board members, and board President Dr. Brian Printy quickly called Gunner.

'he blade is part of the third set of blades to be on the turbines, Rengel said.

'erkins schools gained national attention in 2008 when the district and consultant Honeywell Inc. unveiled n energy-saving plan that included three wind turbines to generate electric power for the high school and earby Briar Middle School on South Avenue.

'he three turbines were installed in January 2009, and the district made headlines again the next month vhen three of the blades came off one of the turbines. The blades broke apart while spinning and the berglass pieces sailed up to 40 yards away from the turbine's monopole tower.

'he turbines were stopped, but began spinning again with replacement blades. Finally, ReDriven provided a ıird set of reinforced blades and those were installed and remained in place until Monday's incident, Rengel said.

:e emphasized the wind turbine industry has a good record of safety and the incident Monday did not ıclude flying fiberglass.

Pieces didn't go flying and the wind turbine blade didn't go flying," Rengel said. "The blade dropped at the ase of the tower.

- Return to Paging Mode

Fallen turbine

More information needed on collapses

WEDNESDAY, DECEMBER 30, 2009

ARTICLE OPTIONS

SHARE

New Yorkers need to understand why a 300-foot tall wind turbine weighing 187 tons collapsed in a Madison County cornfield.

The collapse is not an isolated incident. However just because such a failure is uncommon provides no excuse not to aggressively pursue the reasons why. All across the state communities are facing pressure to site wind turbines. As these local governments proceed they must know why the turbine fell.

The turbine near Fenner in northern Madison County came crashing to the ground Sunday before sunrise. Less than 10 years old, the structure fell more than 1,000 feet away from a house or road. That is fortunate.

The owners of the 20-turbine wind farm, Canastota Windpower LLC., a subsidiary of Enel North America Inc. based in Andover, Mass., were investigating the circumstances earlier this week. Such an investigation by the owner is certainly necessary but is not adequate.

Besides the Fenner site, which can produce as much as 30 megawatts of electricity, the company operates a 6.6 megawatt facility in Gainesville, Wyoming County, and owns wind farms in Minnesota, Kansas, Texas and Newfoundland.

Another industrial turbine toppled in New York earlier this year — in Altona, Franklin County. There the blades of a 392-foot-tall turbine spun out of control after the braking system malfunctioned, causing a fire and a partial collapse of the structure.

The collapses and malfunctions of wind turbines do not disqualify the technology from being used. But ɼind turbines are like any evolving technology — nowledge and higher degrees of safety are developed y a thorough analysis of the causes of every failure.

Independent engineers need to determine ɼhether soil conditions, design flaws, construction hort cuts, poor manufacturing or lack of maintenance ontributed to the failure.

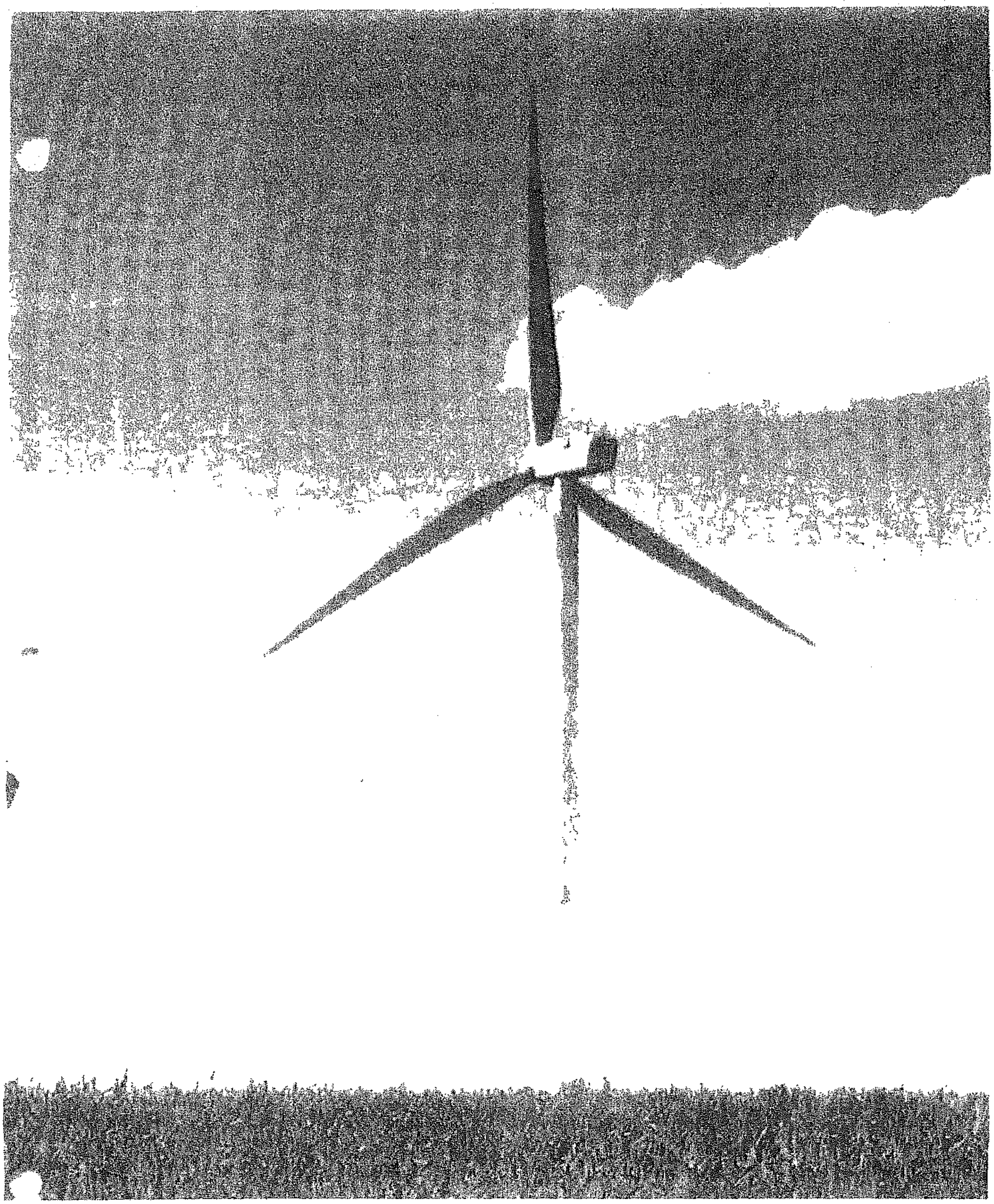
Given the vast economic and political interest in xploiting the wind to create electricity, New York tate should immediately take control of this ıvestigation with a goal of providing improved uilding code standards for any turbine built in New 'ork. The investigation should also include rigorous ıspection criteria for existing wind turbines to etermine any potential flaws.

Attorney General Andrew M. Cuomo's office is ɼell suited to execute this independent appraisal. It as the expertise, the authority and the credibility to eliver a report and recommend new design and onstruction requirements, which will assure New 'orkers that the burgeoning wind generation business ; not a threat to their safety. Mr. Cuomo should take ontrol and initiate the required investigation nmediately.

HOW COMMENTS (14)

NOISE

Noise from modern wind turbines is not known to cause hearing loss, but the low-frequency noise and vibration emitted by wind turbines may have adverse health effects on humans and may become an important community noise concern.

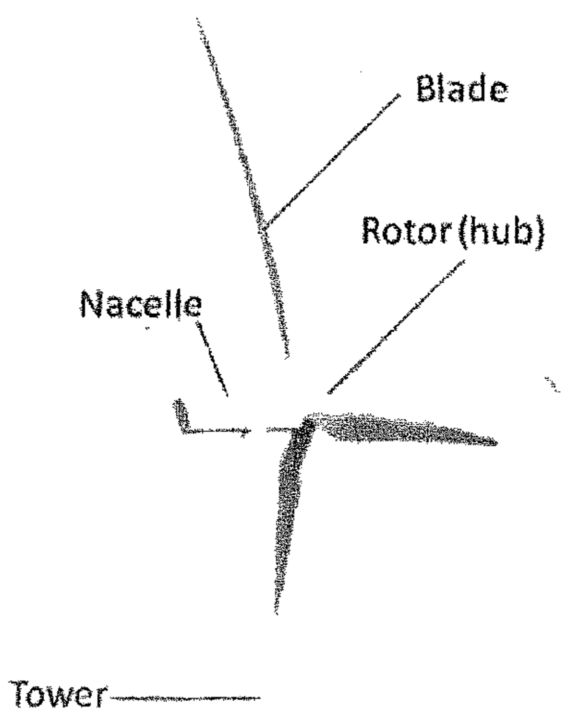


Most of us would agree that the modern wind turbine is a desirable alternative for producing electrical energy. One of the most highly touted ways to meet a federal mandate that 20 percent of all energy must come from renewable sources by 2020 is to install large numbers of utility-scale wind turbines. Evidence has been mounting over the past decade, however, that these utility-scale wind turbines produce significant levels of low-frequency noise and vibration that can be highly disturbing to nearby residents.

None of these unwanted emissions, whether audible or inaudible, are believed to cause hearing loss, but they are widely known to cause sleep disturbances. Inaudible components can induce resonant vibration in solids, liquids, and gases—including the ground, houses, and other building structures, spaces within those structures, and bodily tissues and cavities—that is potentially harmful to humans. The most extreme of these low-frequency (infrasonic) emissions, at frequencies under about 16 Hz, can easily penetrate homes. Some residents perceive the energy as sound, others experience it as vibration, and others are not aware of it at all. Research is beginning to show that, in addition to sleep disturbances, these emissions may have other deleterious consequences on health. It is for these reasons that wind turbines are becoming an important community health issue, especially when hosted in quiet rural communities that have no prior experience with industrial noise or urban hum.

The people most susceptible to disturbances caused by wind turbines may be a small percentage of the total exposed population, but for them the introduction of wind turbines in their communities is not something to which they can easily become acclimated. Instead, they become annoyed, uncomfortable, distressed, or ill. This problem is increasing as newer utility-scale wind turbines capable of generating 1.5-5 MWatts of electricity or more replace the older turbines used over the past 30 years, which produced less than 1 MWatt of power. These large wind turbines can have hub heights that span the length of a football field and blade lengths that span half that distance. The increased size of these multi-MWatt turbines, especially the blades, has been associated with complaints of adverse health effects (AHEs) that cannot be explained by auditory responses alone.

For this article, we reviewed the English-language peer-reviewed literature from around the world on the topic of wind-turbine noise and vibration and their effects on humans. In addition, we used popular search engines to locate relevant online trade journals, books, reference sources, government regulations, and acoustic and vibration standards. We also consulted professional engineers and psychoacousticians regarding their unpublished ideas and research.



Major components of a modern wind turbine.

Physically, a modern wind turbine consists of a tower; a rotor (or hub); a set of rotating blades—usually three, located upwind to the tower; and a nacelle, which is an enclosure containing a gearbox, a generator, and computerized controls that monitor and regulate operations (FIGURE 1). Wind speed can be much greater at hub level than at ground level, so taller wind towers are used to take advantage of these higher wind speeds. Calculators are available for predicting wind speed at hub height, based on wind speeds at 10 meter weather towers, which can easily be measured directly.

Mechanical equipment inside the nacelle generates some noise, but at quieter levels than older turbines. This mechanical sound is usually considered of secondary importance in discussions of annoyance from today's turbines. The main cause of annoyance is an aerodynamic source created by interaction of the turning blades with the wind. With optimal wind conditions, this aerodynamic noise is steady and commonly described as an airplane overhead that never leaves.

When wind conditions are not optimal, such as during turbulence caused by a storm, the steady sounds are augmented by fluctuating aerodynamic sounds. Under steady wind conditions, this interaction generates a broadband whooshing sound that repeats itself about once a second and is clearly audible. Many people who live near the wind turbine find this condition to be very disturbing.

The whooshing sound comes from variations of air turbulence from hub to blade tip and the inability of the turbine to keep the blades adjusted at an optimal angle as wind direction varies. The audible portion of the whoosh is around 300 Hz, which can easily penetrate walls of homes and other buildings. In addition, the rotating blades create energy at frequencies as low as 1–2 Hz (the blade-passage frequency), with overtones of up to about 20 Hz. Although some of this low-frequency energy is audible to some people with sensitive hearing, the energy is mostly vibratory to people who react negatively to it.

Hubbard and Shepherd (1990), in a technical paper written for the National Aeronautics and Space Administration (NASA), were the first to report in depth on the noise and vibration from wind turbines. Most of the relevant research since that time has been conducted by European investigators, as commercial-grade (utility-scale) wind turbines have existed in Europe for many decades. Unfortunately, the research and development done by wind-turbine manufacturers is proprietary and typically has not been shared with the public, but reports of the distressing effects on people living near utility-scale wind turbines in various parts of the world are becoming more common.

Studies carried out in Denmark, The Netherlands, and Germany (Wolsink and Sprengers, 1993; Wolsink et al, 1993), a Danish study (Pedersen and Nielsen, 1994), and two Swedish studies (Pedersen and Persson Waye, 2004, 2007) collectively indicate that wind turbines differ from other sources of community noise in several respects. These investigators confirm the findings of earlier research that amplitude-modulated sound is more easily perceived and more annoying than constant-level sounds (Bradley, 1994; Bengtsson et al, 2004) and that sounds that are unpredictable and uncontrollable are more annoying than other sounds (Geen and McCown, 1984; Hatfield et al, 2002).

Annoyance from wind-turbine noise has been difficult to characterize by the use of such psychoacoustic parameters as sharpness, loudness, roughness, or modulation (Persson Waye and Öhrström, 2002). The extremely low-frequency nature of wind-turbine noise, in combination with the fluctuating blade sounds, also means that the noise is not easily masked by other environmental sounds.

Pedersen et al (2009), in a survey conducted in The Netherlands on 725 respondents, found that noise from wind turbines is more annoying than transportation or industrial noises at comparable levels, measured in dBA. They noted that annoyance from turbine sounds at 35 dBA corresponds to the annoyance reported for other common community-noise sources at 45 dBA. Higher visibility of the turbines was associated with higher levels of annoyance, and annoyance was greater when attitudes toward the visual impact of the turbines on the landscape were negative. However, the height of wind turbines means that they are also most clearly visible to the people closest to them and those who also receive the highest sound levels. Thus, proximity of the receiver to wind turbines makes it difficult to determine whether annoyance to the noise is independent of annoyance to the visual impact. Pedersen et al (2009) also found that annoyance was substantially lower in people who benefitted economically from having wind turbines located on their property.

Among audiologists and acousticians, it has been understood for many decades that sufficiently intense and prolonged exposure to environmental noise can cause hearing impairment, annoyance, or both. In essence, the view has been *what* you can hear can hurt you. In the case of wind turbines, it seems that *what* you can't hear can also hurt you. Again, there is no evidence that noise generated by wind turbines, even the largest utility-scale turbines, causes hearing loss. But there is increasingly clear evidence that audible and low-frequency acoustic energy from these turbines is sufficiently intense to cause extreme annoyance and inability to sleep, or disturbed sleep, in individuals living near them.

Jung and colleagues (2008), in a Korean study, concluded that low-frequency noise in the frequency range above 30 Hz can lead to psychological complaints and that infrasound in the frequency range of 5–8 Hz can cause complaints due to rattling doors and windows in homes.

The energy generated by large wind turbines can be especially disturbing to the vestibular systems of some people, as well as cause other troubling sensations of the head, chest, or other parts of the body. Dr. Nina Pierpont (2009), in her definitive natural experiment on the subject, refers to these effects as Wind-Turbine Syndrome (WTS). TABLE 1 lists the symptoms that, in various combinations, characterize WTS. Although hearing impairment is not one of the symptoms of WTS, audiologists whose patients report these symptoms should ask them if they live near a wind turbine.

It is well known that sleep deprivation has serious consequences, and we know that noncontinuous sounds and nighttime sounds are less tolerable than continuous and daytime sounds. Somewhat related effects, such as cardiac arrhythmias, stress, hypertension, and headaches have also been attributed to noise or vibration from wind turbines, and some researchers are referring to these effects as Vibroacoustic Disease, or VAD (Castelo Branco, 1999; Castelo Branco and Alves-Pereira, 2004). VAD is described as occurring in persons who are exposed to high-level (>90 dB SPL) infra- and low-frequency noise (ILFN), under 500 Hz, for periods of 10 years or more. It is believed to be a systemic pathology characterized by direct tissue damage to a variety of bodily organs and may involve abnormal proliferation of extracellular matrices.

Alves-Pereira and Castelo Branco (2007) reported on a family who lived near wind turbines and showed signs of VAD. The sound levels in the home were less than 60 dB SPL in each 1/3–octave band below 100 Hz. We have measured unweighted sound levels ranging from 60 to 70 dB Leq (averaged over 1 minute) in these low-frequency bands in Ontario homes of people reporting AHEs from wind turbines. A spectral analysis of sounds emitted at a Michigan site revealed that unweighted peak levels at frequencies under 5 Hz exceeded 90 dB SPL (Wade Bray, pers. comm., 2009).

Table 1. Core Symptoms of Wind-Turbine Syndrome

Sleep disturbance
Headache
Visceral Vibratory Vestibular Disturbance (VVVD)
Dizziness, vertigo, unsteadiness
Tinnitus
Ear pressure or pain
External auditory canal sensation
Memory and concentration deficits
Irritability, anger
Fatigue, loss of motivation

Source: Pierpont, 2009

Similar observations have been made in studies of people who live near busy highways and airports, which also expose people to low-frequency sounds, both outdoors and in their homes. Evidence is insufficient to substantiate that typical exposures to wind-turbine noise, even in residents who live nearby, can lead to VAD, but early indications are that there are some more-vulnerable people who may be susceptible. Because ILFN is not yet recognized as a disease agent, it is not covered by legislation, permissible exposure levels have not yet been established, and dose-response relationships are unknown (Alves-Pereira, 2007).

As distinguished from VAD, Pierpont's (2009) use of the term Wind-Turbine Syndrome appears to emphasize a constellation of symptoms due to stimulation, or overstimulation, of the vestibular organs of balance due to ILFN from wind turbines (see TABLE 1). One of the most distinctive symptoms she lists in the constellation of symptoms comprising WTS is Visceral Vibratory Vestibular Disturbance (VVVD), which she defines as "a sensation of internal quivering, vibration, or pulsation accompanied by agitation, anxiety, alarm, irritability, rapid heartbeat, nausea, and sleep disturbance" (p. 270).

Drawing on the recent work of Balaban and colleagues (i.e., Balaban and Yates, 2004), Pierpont describes the close association between the vestibular system and its neural connections to brain nuclei involved with balance processing, autonomic and somatic sensory inflow and outflow, the fear and anxiety associated with vertigo or a sudden feeling of postural instability, and aversive learning. These neurological relationships give credence to Pierpont's linkage of the symptoms of VVVD to the vestibular system.

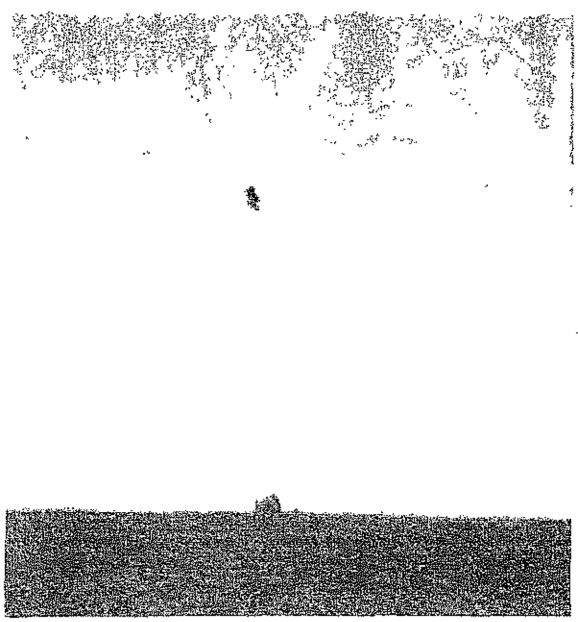
Todd et al (2008) demonstrated that the resonant frequency of the human vestibular system is 100 Hz, concluding that the mechano-receptive hair cells of the vestibular structures of the inner ear are remarkably sensitive to low-frequency vibration and that this sensitivity to vibration exceeds that of the cochlea. Not only is 100 Hz the frequency of the peak response of the vestibular system to vibration, but it is also a frequency at which a substantial amount of acoustic energy is produced by wind turbines. Symptoms of both VAD and VVVD can presumably occur in the presence of ILFN as a result of disruptions of normal paths or structures that mediate the fine coordination between living tissue deformation and activation of signal transducers; these disruptions can lead to aberrant mechano-electrical coupling that can, in turn, lead to conditions such as heart arrhythmias (Ingber, 2008). Ultimately, further research will be needed to sort out the commonalities and differences among the symptoms variously described in the literature as VAD, VVVD, and WTS.

Dr. Geoff Leventhall, a British scientist, and his colleagues (Waye et al, 1997; Leventhall, 2003, 2004) have documented the detrimental effects of low-frequency noise exposure. They consider it to be a special environmental noise, particularly to sensitive people in their homes. Waye et al (1997) found that exposure to dynamically modulated low-frequency ventilation noise (20–200 Hz)—as opposed to midfrequency noise exposure—was more bothersome, less pleasant, impacted work performance more negatively, and led to lower social orientation.

Leventhall (2003), in reviewing the literature on the effects of exposure to low-frequency noise, found no evidence of hearing loss but substantial evidence of vibration of bodily structures (chest vibration), annoyance (especially in homes), perceptions of unpleasantness (pressure on the eardrum, unpleasant perception within the chest area, and a general feeling of vibration), sleep disturbance (reduced wakefulness), stress, reduced performance on demanding verbal tasks, and negative biological effects that included quantitative measurements of EEG activity, blood pressure, respiration, hormone production, and heart rate.

Regarding work performance, reviewed studies indicated that dynamically modulated low-frequency noise, even when inaudible to most individuals, is more difficult to ignore than mid- or high-frequency noise and that its imperviousness to habituation leads to reduced available information-processing resources. Leventhall hypothesized that low-frequency noise, therefore, may impair work performance. More recently, as a consultant on behalf of the British Wind Energy Association (BWEA), the American Wind Energy Association (AWEA), and the Canadian Wind Energy Association (CANWEA), Leventhall (2006) changed his position, stating that although wind turbines do produce significant levels of low-frequency sound, they do not pose a threat to humans—in effect reverting to the notion that *what* you can't hear can't hurt you.

According to the World Health Organization guidelines (WHO, 2007), observable effects of nighttime, outdoor wind-turbine noise do not occur at levels of 30 dBA or lower. Many rural communities have ambient, nighttime sound levels that do not exceed 25 dBA. As outdoor sound levels increase, the risk of AHEs also increases, with the most vulnerable being the first to show its effects. Vulnerable populations include elderly persons; children,



Utility-scale wind turbines located in Huron County, Michigan

especially those younger than age six; and people with pre-existing medical conditions, especially if sleep is affected. For outdoor sound levels of 40 dBA or higher, the WHO states that there is sufficient evidence to link prolonged exposure to AHEs. While the WHO identifies long-term, nighttime audible sounds over 40 dBA outside one's home as a cause of AHEs, the wind industry commonly promotes 50 dBA as a safe limit for nearby homes and properties. Recently, a limit of 45 dBA has been proposed for new wind projects in Canada (Keith et al, 2008).

Much of the answer as to why the wind industry denies that noise is a serious problem with its wind turbines is because holding the noise to 30 dBA at night has serious economic consequences. The following quotation by Upton Sinclair seems relevant here: "It is difficult to get a man to understand something when his salary depends upon his not understanding it" (Sinclair, 1935, reprinted 1994, p. 109).

In recent years, the wind industry has denied the validity of any noise complaints by people who live near its utility-scale wind turbines. Residents who are leasing their properties for the siting of turbines are generally so pleased to receive the lease payments that they seldom complain. In fact, they normally are required to sign a leasing agreement, or gag clause, stating they will not speak or write anything unfavorable about the turbines. Consequently, complaints, and sometimes lawsuits, tend to be initiated by individuals who live near property on which wind turbines are sited, and not by those who are leasing their own property. This situation pits neighbor against neighbor, which leads to antagonistic divisions within communities.

It is important to point out that the continued use of the A-weighting scale in sound-level meters is the basis for misunderstandings that have led to acrimony between advocates and opponents of locating wind turbines in residential areas. The dBA scale grew out of the desire to incorporate a function into the measurement of sound pressure levels of environmental and industrial noise that is the inverse of the minimum audibility curve (Fletcher and Munson, 1933) at the 40-phon level. It is typically used, though, to specify the levels of noises that are more intense, where the audibility curve becomes considerably flattened, obviating the need for A-weighting. It is mandated in various national and international standards for measurements that are compared to damage-risk criteria for hearing loss and other health effects. The A-weighted scale in sound-level meters drastically reduces sound-level readings in the lower frequencies, beginning at 1000 Hz, and reduces sounds at 20 Hz by 50 dB.

For wind-turbine noise, the A-weighting scale is especially ill-suited because of its devaluation of the effects of low-frequency noise. This is why it is important to make C-weighted measurements, as well as A-weighted measurements, when considering the impact of sound from wind turbines. Theoretically, linear-scale measurements would seem superior to C-scale measurements in wind-turbine applications, but linear-scale measurements lack standardization due to failure on the part of manufacturers of sound-level meters to agree on such factors as low-frequency cutoff and response tolerance limits. The Z-scale, or zero-frequency weighting, was introduced in 2003 by the International Electro-technical Commission (IEC) in its Standard 61672 to replace the flat, or linear, weighting used by manufacturers in the past.

Michigan's siting guidelines (State of Michigan, 2008) will be used as an example of guidelines that deal only in a limited way with sound. These guidelines refer to earlier, now outdated, WHO and Environmental Protection Agency (EPA) guidelines to support a noise criterion that SPLs cannot exceed 55 dBA at the adjacent property line. This level is allowed to be exceeded during severe weather or power outages, and when the ambient sound level is greater than 55 dBA, the turbine noise can exceed that higher background sound level by 5 dB. These levels are about 30 dB above the nighttime levels of most rural communities. When utility-scale turbines were installed in Huron County, Michigan, in May 2008, the WHO's 2007 guidelines that call for nighttime, outside levels not to exceed 30 dBA were already in place. Based on measurements made by the authors, these turbines produce 40–45 dBA sound levels at the perimeter of a 1,000 ft radius under typical weather conditions, and the additive effects of multiple turbines produce higher levels. Many of the turbines have been located close enough to homes to produce very noticeable noise and vibration.

Kamperman and James (2009) have offered recommendations for change in the State of Michigan guidelines (2008) for wind turbines. Some of the more pertinent details of the Michigan siting guidelines are shown in the left-hand column of TABLE 2. The state of Michigan permits sound levels that do not exceed 55 dBA or L90 + 5 dBA, whichever is greater, measured at the property line closest to the wind-energy system. These guidelines make no provisions to limit low-frequency sounds from wind-turbine operations.

In consideration of the current WHO guidelines (2007), measurements made by the authors in Huron County, Michigan, indicate that the current Michigan guidelines do not appear adequate to protect the public from the nuisances and known health risks of wind-turbine noise. In fact, these guidelines appear to be especially lenient

Table 2. Current and Proposed Wind-Turbine Siting Guidelines

Sound level cannot exceed 55 dBA or L90 + 5 dBA, whichever is greater.	Operating LAeq is not to exceed the background LA90 +5 dBA, where LA90 is measured during a preconstruction noise study at the quietest time of night. Similar dBC limits should also be applied.
Limits apply to sound levels measured at homes (as stated in Huron County Ordinance).	Limits apply to sound levels measured at property lines, except that turbine sounds cannot exceed 35 dBA at any home.
No provisions are made for limiting low-frequency sounds from wind-turbine operations.	LCeq-LA90 cannot exceed 20 dB at receiving property, e.g., LCeq (from turbines) minus (LA90 [background] + 5) < 20 dB; and is not to exceed 55 LCeq from wind turbines (60 LCeq for properties within one mile of major heavily trafficked roads).

*Source State of Michigan, 2008

**Source Kamperman and James, 2009

in terms of tolerable sound levels. Sound levels that approach 20 dBA higher than natural ambient levels are considered unacceptable in most countries; Michigan permits 30 dBA increases.

In considering the health and well-being of people living near wind-turbine projects, the changes recommended by Kamperman and James (2009) would abandon the 55 dBA limit in favor of the commonly accepted criteria of L90 + 5 dBA, for both A- and C-scale readings, where L90 is the preconstruction ambient level. These recommendations also include a prohibition against any wind-turbine-related sound levels exceeding 35 dBA on receiving properties that include homes or other structures in which people sleep. Additional protections against low-frequency sound are given in the right-hand column of TABLE 2. These recommended provisions would protect residents by limiting the difference between C-weighted

> People living near wind turbines may experience sleep disturbance.

Leq during turbine operation and the quietest A-weighted pre-operation background sound levels, plus 5 dB, to no more than 20 dB at the property line. This level should not exceed 55 dB Leq on the C scale, or 60 dB Leq for properties within one mile of major heavily trafficked roads, which sets a higher tolerance for communities that tend to experience slightly noisier conditions.

Implementation of the recommendations of Kamperman and James would result in siting wind turbines differently than what is currently planned for future wind-turbine projects in Michigan. This change would result in sound levels at nearby properties that are much less noticeable, and much less likely to cause sleep deprivation, annoyance, and related health risks. These sound-level measurements should be made by independent acoustical engineers or knowledgeable audiologists who follow ANSI guidelines (1993, 1994) to ensure fair and accurate readings, and not by representatives of the wind industry.

People living within a mile of one or more wind turbines, and especially those living within a half mile, have frequent sleep disturbance leading to sleep deprivation, and sleep disturbances are common in people who live up to about 1.25 miles away. This is the setback distance at which a group of turbines would need to be in order not to be a nighttime noise disturbance (Kamperman and James, 2009). It is also the setback distance used in several other countries that have substantial experience with wind turbines, and is the distance at which Pierpont (2009) found very few people reporting AHEs.

A study conducted by van den Berg (2003) in The Netherlands demonstrated that daytime levels cannot be used to predict nighttime levels and that residents within 1900 mile (1.18 mile) of a wind-turbine project expressed annoyance from the noise. Pierpont (2009) recommends baseline minimum setbacks of 2 kilometers (1.24 mile) from residences and other buildings such as hospitals, schools, and nursing homes, and longer setbacks in mountainous terrain and when necessary to meet the noise criteria developed by Kamperman and James (2009).

In a panel review report, the American Wind Energy Association (AWEA) and Canadian Wind Energy Association (CANWEA) have objected to setbacks that exceed 1 mile (Colby et al, 2009). A coalition of independent medical and acoustical experts, the Society for Wind Vigilance (2010), has provided a recent rebuttal to that report. The society has described the panel review as a typical product of industry-funded white papers, being neither authoritative nor convincing. The society accepts as a medical fact that sleep disturbance, physiological stress, and psychological distress can result from exposure to wind-turbine noise.

Wind turbines have different effects on different people. Some of these effects are somewhat predictable based on financial compensation, legal restrictions on free speech included in the lease contracts with hosting landowners, and distance of the residence from wind projects, but they are sometimes totally unpredictable. Planning for wind projects needs to be directed not only toward benefitting society at large but also toward protecting the individuals living near them. We believe that the state of Michigan, and other states that have adopted similar siting guidelines for wind turbines, are not acting in the best interest of all their citizens and need to revise their siting guidelines to protect the public from possible health risks and loss of property values, as well as reduce complaints about noise annoyance.

Wind-utility developers proposing new projects to a potential host community are often asked if their projects will cause the same negative community responses that are heard from people living in the footprint of operating projects. They often respond that they will use a different type of wind turbine or that reports of complaints refer to older-style turbines that they do not use. In our opinion, these statements should usually be viewed as diversionary.

Finally, it is important to note that there is little difference in noise generated across makes and models of modern utility-scale, upwind wind turbines once their power outputs are normalized. Kamperman (pers. comm., 2009), after analyzing data from a project funded by the Danish Energy Authority (Søndergaard and Madsen, 2008), has indicated that when the A-weighted sound levels are converted to unweighted levels, the low-frequency energy from industrial wind turbines increases inversely with frequency at a rate of approximately 3 dB per octave to below 10 Hz (the lowest reported frequency). Kamperman has concluded that the amount of noise generated at low frequencies increases by 3–5 dB for every MW of electrical power generated. Because turbines are getting larger, this means that future noise problems are likely to get worse if siting guidelines are not changed.

Our purpose in this article has been to provide audiologists with a better understanding of the types of noise generated by wind turbines, some basic considerations underlying sound-level measurements of wind-turbine noise, and the adverse health effects on people who live near these turbines. In future years, we expect that audiologists will be called upon to make noise measurements in communities that have acquired wind turbines, or are considering them. Some of us, along with members of the medical profession, will be asked to provide legal testimony regarding our opinions on the effects of such noise on people. Many of us will likely see clinical patients who are experiencing some of the adverse health effects described in this article.

As a professional community, audiologists should become involved not only in making these measurements to corroborate the complaints of residents living near wind-turbine projects but also in developing and shaping siting guidelines that minimize the potentially adverse health effects of the noise and vibration they generate. In these ways, we can promote public health interests without opposing the use of wind turbines as a desirable and viable alternative energy source.

[illegible] PhD, [illegible] James, INCE, and Dan Pabst, BS, are with the Department of Communicative Sciences and Disorders, Michigan State University, East Lansing, MI

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References

Alves-Pereira M, Castelo Branco NAA. (2007) In-home wind-turbine noise is conducive to Vibroacoustic Disease. Paper presented at Second International Meeting on Wind-Turbine Noise, Lyon, France.

American National Standards Institute (ANSI) (1993) *ANSI Standard S12.9, Part 3—1993 (R 2008).* Quantities and procedures for description and measurement of environmental sound. Part 3: Short-term measurements with an observer present. New York: American National Standards Institute.

American National Standards Institute (ANSI) (1994) *ANSI Standard S12.18—1994 (R 2009).* Outdoor measurement of sound pressure level. New York: American National Standards Institute.

Balaban CD, Yates BJ. (2004) The vestibuloautonomic interactions: a teleologic perspective. In: Highstein SM, Fay RR, Popper AN, eds. *The Vestibular System.* New York: Springer-Verlag, 286–342.

Bengtsson J, Persson Waye K, Kjellberg A. (2004) Sound characteristics in low frequency noise and their relevance for the perception of pleasantness. *Acta Acust* 90:171–180.

Bradley JS. (1994) Annoyance caused by constant-amplitude and amplitude-modulated sound containing rumble. *Noise Control Eng J* 42:203–208.

Castelo Branco NAA. (1999) The clinical stages of vibroacoustic disease. *Aviat Space Environ Med* 70(3):32–39.

Castelo Branco NAA, Alves-Pereira M. (2004) Vibroacoustic disease. *Noise Health* 6(23):3–20.

Colby WD, Dobie R, Leventhall G, Lipscomb DM, McCunney RJ, Seilo MT. (December 2009) "Wind-Turbine Sound and Health Effects: An Expert Panel Review." Prepared for the American Wind Energy Association and Canadian Wind Energy Association.

Fletcher H, Munson WA. (1933) Loudness, its definition, measurement and calculation. *J Acoust Soc Am* 5:82–108.

Geen RG, McCown EJ. (1984) Effects of noise and attack on aggression and physiological arousal. *Motivat Emot* 8:231–241.

Hatfield J, Job RF, Hede AJ, Carter NL, Peploe P, Taylor R, et al. (2002) Human response to environmental noise: the role of perceived control. *J Behav Med* 9:341–359.

Hubbard HH, Shepherd KP. (1990) Wind Turbine Acoustics. NASA Technical Paper 3057 DOE/NASA/20320-77. National Aeronautics and Space Administration.

Ingber DE. (2008) Tensegrity-based mechanosensing from macro to micro. *Prog Biophys Molec Biol* 97:163–179.

Kamperman G, James R. (2009) Guidelines for selecting wind turbine sites. *J Sound Vib* 43(7):8–12.

Keith SE, Michaud DS, Bly SHP. (2008) A proposal for evaluating the potential health effects of wind-turbine noise for projects under the Canadian Environmental Assessment Act. *J Low Freq Noise Vib and Active Control* 27:253–265.

Jung SS, Cheung W, Cheong C, Shin S. (2008) Experimental identification of acoustic emission characteristics of large wind turbines with emphasis on infrasound and low-frequency noise. *J Korean Phys Soc* 53:1897–1905.

Leventhall G. (2003) A Review of Published Research on Low Frequency Noise and its Effects. Defra Report. London: Department for Environment, Food and Rural Affairs.

Leventhall G. (2004) Low frequency noise and annoyance. *Noise Health* 6(23):59–72.

Leventhall G. (2006) Infrasound from wind turbines—fact, fiction or deception. *Canad Acoust* 34(2):29–36.

Pedersen E, Persson Waye K. (2004) Perception and annoyance due to wind turbine noise—a dose–response relationship. *J Acoust Soc Am* 116:3460–3470.

Pedersen E, Persson Waye K. (2007) Wind turbine noise, annoyance and self-reported health and wellbeing in different living environments. *Occup Env Med* 64:480–486.

Pedersen E, van den Berg F, Bakker R, Bouma J. (2009) Response to noise from modern wind farms in The Netherlands. *J Acoust Soc Am* 126:634–643.

Pedersen TH, Nielsen KS. (1994) Genvirkning af støj fra vindmøller (Annoyance by noise from wind turbines). Report No. 150, DELTA Acoustic and Vibration, Lydteknisk Institute, Copenhagen.

Persson Waye K, Öhrström E. (2002) Psycho-acoustic characters of relevance for annoyance of wind turbine noise. *J Sound Vib* 250(1):65–73.

Pierpont, N. (2009) Wind-Turbine Syndrome: a report on a natural experiment. Santa Fe, NM: K-Selected Books.

Sinclair U. (1935) I, candidate for governor: and how I got licked. New York: Farrar and Rinehart. (Reprinted, Berkeley, CA University of California Press, 1994.)

Sondergaard B, Madsen KD. (2008) Low frequency noise from large wind turbines: summaries and conclusions on measurements and methods. EFP-06 Project, DELTA Danish Electronics, Light and Acoustics.

State of Michigan. (2008) Sample zoning for wind energy systems. http://www.michigan.gov/documents/dleg/WindEnergySampleZoning_236105_7.pdf (accessed December 2, 2009).

The Society for Wind Vigilance. (2010) An Analysis of the American/Canadian Wind Energy Association Sponsored "Wind-Turbine Sound and Health Effects: An Expert Panel Review, December 2009." http://windconcernsontario.wordpress.com/2010/01/10/media-release-the-society-for-wind-vigilance/ (accessed January 12, 2010).

Todd NPM, Rosengren SM, Colebatch JG. (2008) Tuning and sensitivity of the human vestibular system to low-frequency vibration. *Neurosci Lett* 444:36–41.

van den Berg GP. (2003) Effects of the wind profile at night on wind-turbine sound. *J Sound Vib* 277(4–5):955–970.

Waye KP, Rylander R, Benton S, Leventhall G. (1997) Effects on performance and work quality due to low frequency ventilation noise. *J Sound Vib* 205(4):467–474.

Wolsink M, Sprengers M. (1993) Wind turbine noise: a new environmental threat? Proceedings of the Sixth International Congress on the Biological Effects of Noise, ICBEN, Nice, France, 2: 235–238.

Wolsink M, Sprengers M, Keuper A, Pedersen TH, Westra CA. (1993) Annoyance from wind turbine noise on sixteen sites in three countries. Proceedings of the European Community Wind Energy Conference, Lübeck, Travemünde, 273–276.

World Health Organization (WHO) (2007) *Night Noise Guidelines* (NNGL) for Europe: Final Implementation Report. World Health Organization, Regional Office for Europe, Bonn Office.

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Effects of the wind profile at night on wind turbine sound

G.P. van den Berg*

Science Shop for Physics, University of Groningen, Nijenborgh 4, 9747 AG Groningen, Netherlands

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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).

*Corresponding author. Tel.: +31-50-363-4867.
E-mail address: g.p.van.den.berg@phys.rug.nl (G.P. van den Berg).

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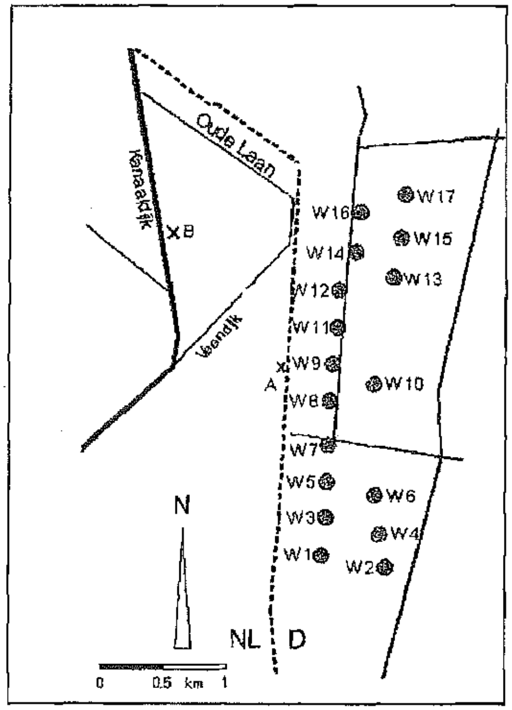


Fig. 1. Location of wind turbines (W_{nn}) and immission measurements (A and B) near the Dutch/German (NL/D) border.

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 $f_{log} = v_{98}/v_{10} = 1.4$. 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

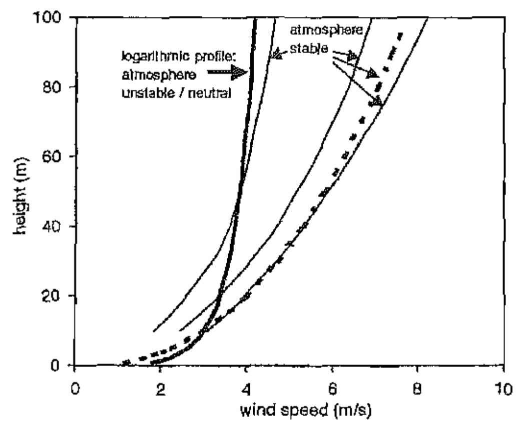


Fig. 2. Measured wind profiles (thin lines, [6]) and wind profile according to TA Luft (dotted line, [8]) in a stable atmosphere, and wind profile according to logarithmic model of formula 2 with $z = 3$ cm (bold line).

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

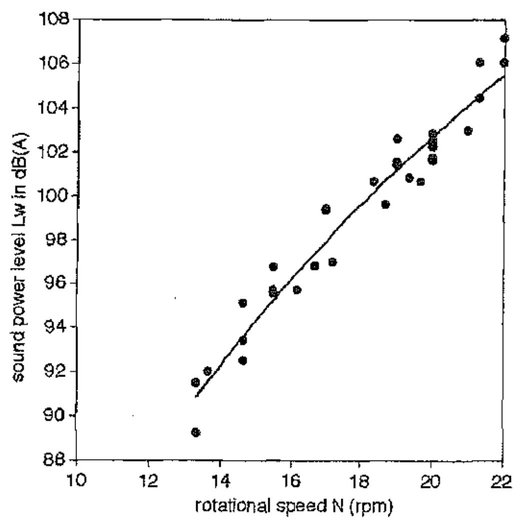


Fig. 3. Measured wind turbine sound power level L_W as a function of turbine rotational speed N.

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: $L_5 - L_{95} \leqslant 4$ dB, where L_5 and L_{95} are 5 and 95 percentile sound level. In a normal (Gaussian) distribution this would equal $\sigma \leqslant 1.2$ 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 $L_{eq,5\,\mathrm{min}}$ 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

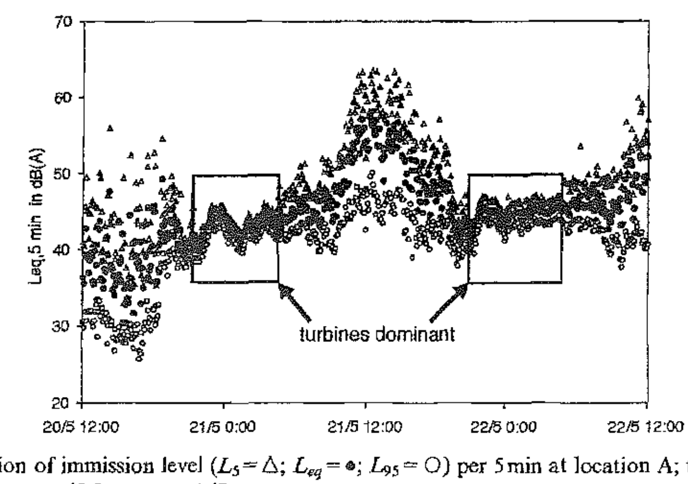


Fig. 4. 48 h registration of immission level ($L_5 = \Delta$; $L_{eq} = \bullet$; $L_{95} = \circ$) per 5 min at location A; turbines are considered the dominant sound source if $L_5 - L_{95} \leqslant 4$ dB.

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%

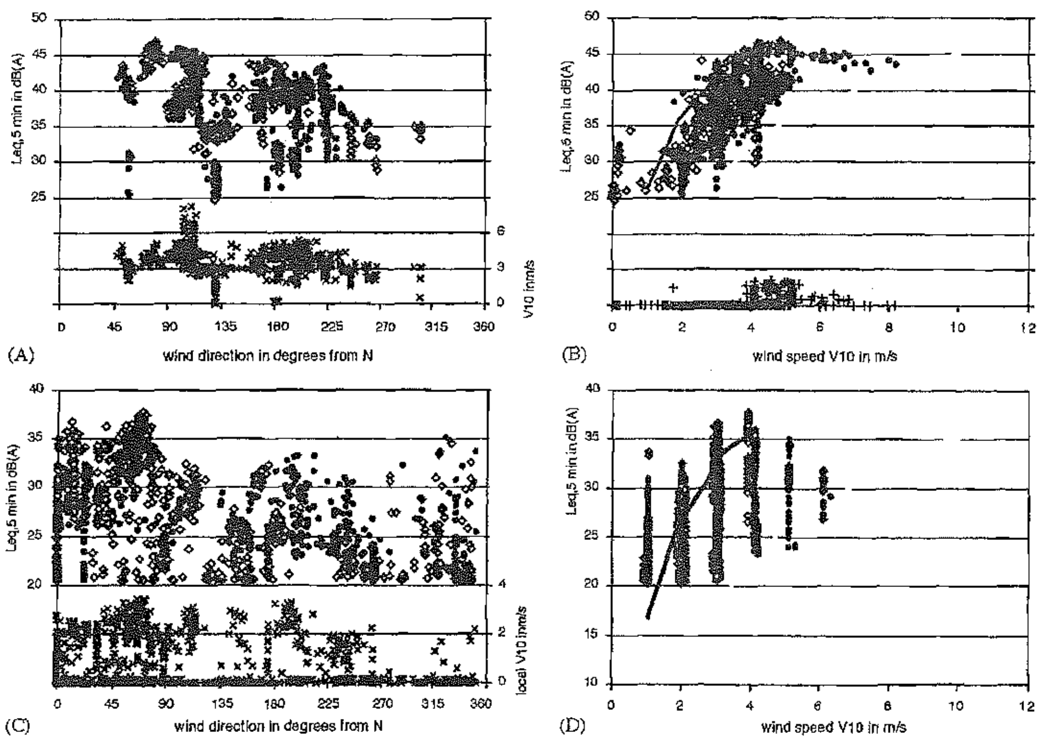


Fig. 5. Measured sound levels $L_{eq,5\,min}$ at locations A (above) and B (below) as a function of median wind direction (left) and average wind speed (right) at reference height (10 m), separated in classes where the atmosphere at Eelde was observed as stable (◇) or neutral (•). Also plotted are expected 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_{10} (A), v_2 (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

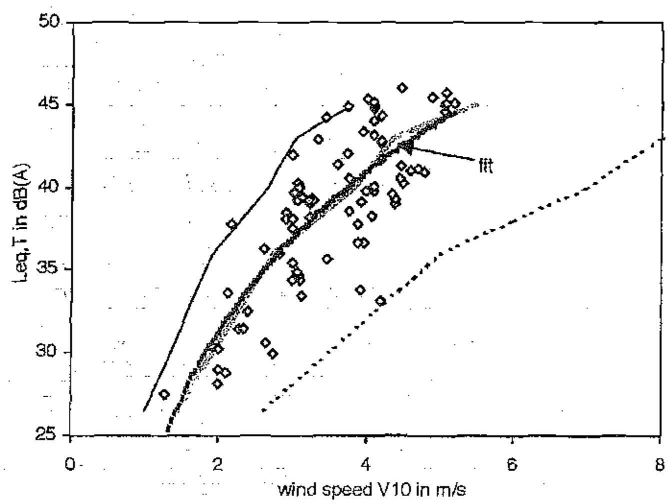


Fig. 6. Measured sound levels $L_{eq,T}$ ($T = 20$–60 min) at location A with best fit; and expected sound levels according to a logarithmic wind profile ($v_{98}/v_{10} = f_{log} = 1.4$; dotted line), a stable wind profile ($v_{98}/v_{10} = 1.8 \cdot f_{log}$; thick grey line) and maximum wind speed ratio ($v_{98}/v_{10} = 2.6 \cdot f_{log}$; 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 3.3 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 $L_{i,T}$ ($T = 5$ 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

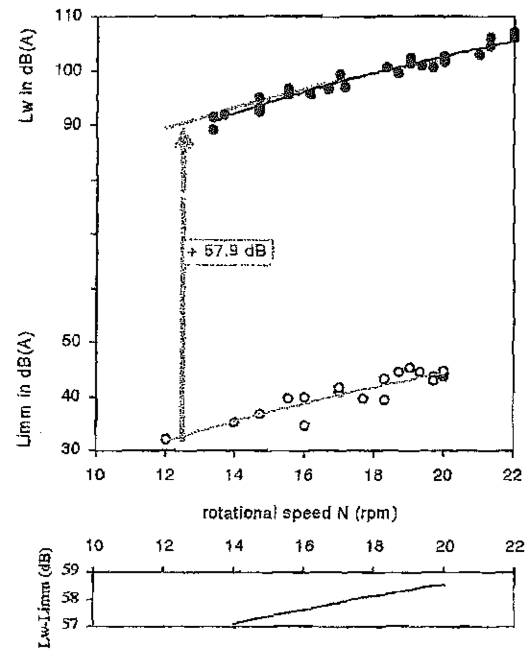


Fig. 7. Turbine sound power levels L_W measured near wind turbines (•) and immission levels L_{imm} measured at 400 m from wind park (○): averages differ 57.9 dB; (below) increase of difference L_W–L_{imm} with rotational speed.

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 $N = 3.4 \times 10^{L_{imm}/57.6}$.

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

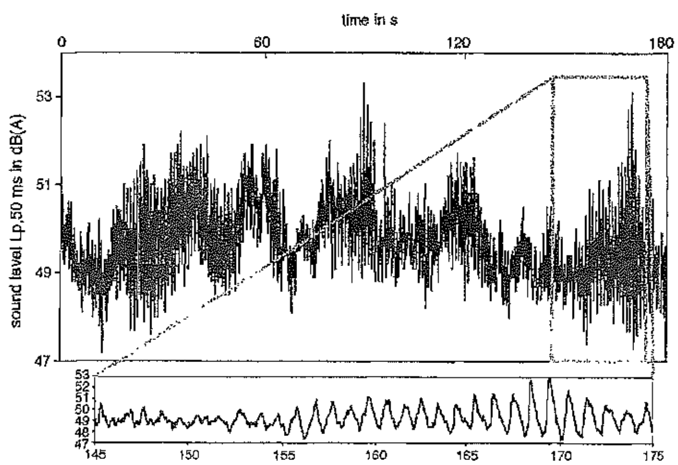


Fig. 8. Sound pressure level caused by wind turbines per 50 ms near dwelling at 750 m from nearest turbine (including reflection at façade at 2 m) over a 3 min period; part of the sequence is amplified below.

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 ($v_{10} \leqslant 4$ 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 then 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 turnbine 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.I. 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.

VISUAL AND NOISE EFFECTS REPORTED BY RESIDENTS LIVING CLOSE TO MANAWATU WIND FARMS: PRELIMINARY SURVEY RESULTS

Dr Robyn Phipps[1], Dr Marco Amati[2], Dr Sue McCoard[3], Dr Richard Fisher[4]

1 Institute of Technology and Engineering, Massey University, Palmerston North, New Zealand
2 School of People, Environment and Planning, Massey University, Palmerston North, New Zealand
3 Palmerston North, New Zealand
4 Faculty of International Studies, International Pacific College, Palmerston North New Zealand
r.a.phipps@massey.ac.nz

ABSTRACT

Since 1996, when Tararua Wind Power Limited commenced the construction of 48 wind turbines, the number of existing wind turbines on the Ruahine and Tararua ranges has risen dramatically, to 158 in 2006, with more to come from unimplemented, approved resource consents. The companies behind the applications have won plaudits for the development of sustainable energy generation. However, the effects of wind energy can be controversial. In particular, it is reported in other countries that those who live near the wind turbines may suffer from undesirable visual and noise effects, and the national benefits and local costs may not be in balance. Assessing the precise impact of future wind farm development is important, since the number of proposed wind farms is likely to grow in the coming years. The objective of this study was to investigate the noise and visual effects on local residents from the existing wind turbines in the Manawatu and Tararua region. A total of 1100 urban and rural residents, the majority living within a 3km radius of the wind farms in the Tararua and Manawatu districts were administered a self-reporting survey. The survey asked residents to assess the visual and noise effects of the closest wind farm. This paper presents preliminary results from this study. It demonstrates that 45 percent of respondents living within 2km heard noise from the turbines, and 80 percent thought that the turbines were visually intrusive.

1 INTRODUCTION

New Zealand has a national goal of increasing the supply of renewable energy, such as wind farms, which is expressed in part by amendments to the Resource Management Act 1991 (RMA). The amendments elevate the importance of renewable energy as a consideration for decision makers to approve or decline a resource consent application. The recent Parliamentary Commissioner for the Environment's report on wind farms presents several scenarios for future wind farm development by 2016 with extremes ranging from 1,300 1.5MW turbines in 65 wind farms, to 67 3MW turbines in 7 windfarms (Parliamentary Commissioner for the Environment 2006). Wind farms tend to be located in prominent locations, such as open or coastal areas and ridgelines. Most are located close to existing infrastructure, such as a transmission line, and roads to reduce development costs. A wind farm consists of the turbines as well as substantial roads, buildings for substations etc., yards and high voltage transmission lines. The expansion of windfarms is likely to cause conflicts, particularly when this expansion occurs near existing housing. The benefits of wind farms are typically accrued nationally and include providing a renewable energy supply. The negative impacts are felt locally and include visual amenity and noise. Given the potential growth of windfarms, examining how these conflicts are addressed should be an important area of research.

Under section 104 of the RMA, planners are required to assess whether the effects of a wind farm can be avoided, remedied or mitigated. An applicant for a resource consent must include an assessment of environmental effects respecting the proposed project. This requirement has already generated a number of landscape assessment reports to show the perceived visual effects, noise modeling and related predictive modeling. However since industrial-scale wind farms are relatively new in New Zealand, little research on existing wind farms exists on post-installation visual and noise effects.

The objective of this study was therefore to undertake a survey of the visual and noise effects experienced by residents' who live near wind farms on the Ruahine-Tararua ranges near Palmerston North. This area is ideally placed to inform understanding of wind generation in New Zealand, due to its concentration of existing wind farms. In this region, there are currently 158 turbines operational with a generation capacity of up to 300MW of wind energy. A further 128 turbines have been consented or are under construction; a development consisting of 129 turbines is in the resource consent and proposals are being developed for at least one other wind farm with more than 60 turbines. In other regions of New Zealand further large scale wind farms are also in the planning or consent stage.

It is generally agreed that a buffer zone between wind farms and housing is important to minimize visual and noise effects but the size of this zone has been subject to considerable debated. To date few turbines have been built within 1km of existing residences in New Zealand. However, with wind farms that are currently seeking consent, the distances between proposed turbines and existing homes is now under 600m.

We aim to investigate and inform planners about the potential effects of wind farms from a visual amenity and noise perspective. Specifically, this paper presents the preliminary analysis of this survey, in which we aimed to answer the following two questions:

- What are the most important visual amenity effects from the wind farms?
- What percentage of residents can hear the noise produced by the wind farms and does wind farm noise vary with distance?

2 RECENT LITERATURE ON THE EFFECT OF WIND FARMS

2.1 PUBLIC ATTITUDES TO WIND FARMS

Most New Zealanders support sustainable energy, and consider wind farms as a clean, green source of energy (Parliamentary Commissioner for the Environment 2006). A survey conducted on behalf of EECA on public opinions in New Zealand found that of the 750 people surveyed, 58.9 percent thought they were environmentally friendly, 0.1 percent thought they were attractive, 24.9 percent thought they were ugly, and 14.7 percent thought noise was a disadvantage (UMR Research Limited 2004).

However, the development of industrial-scale wind farms near existing housing is contentious, and achieving a balance between national interests and local effects is precarious. Both in New Zealand and overseas, opinions among residents who live near wind farms vary greatly. Some are in favour of turbines and consider them as unobtrusive and visually attractive. Others are strongly opposed to wind farms, citing concerns that they ruin the visual quality of the environment, produce noise pollution and adversely affect wildlife (Devlin 2005). In Europe, community protests have had a significant impact on the introduction of wind power generation schemes (Parliamentary Commissioner for the Environment 2006) and it has been estimated that public opposition has prevented planning permission being granted for about 50 percent of European proposals. In the Netherlands 75 percent of proposals have been refused (Van der Loo 2001). A report prepared by the European Renewable Energy Council (Parliamentary Commissioner for the Environment 2006) stated that:

> *"For many years, wind energy was considered environmentally sound. But recently, major social objections and land use concerns related to operation and siting of turbines have been raised. Social acceptance is one of the greatest limiting factors of wind's potential growth."*

In New Zealand few submissions were received in opposition to earlier wind farm proposals, however more recent proposals have seen an increase in both number and sophistication of submitters in opposition. A review of resource consents heard between 1996 – 2005 revealed:

- *An increasing number of objectors*

- *Increasing sophistication of the objections*
- *Increasing uncertainty on the part of the applicant as to the likely success at hearing, in particular how many turbines may be allowed*
- *Increasing requirement for consultation by the applicants* (Fisher 2005)

2.2 VISUAL EFFECTS

Although visual assessment techniques can inform the public how a landscape will look after it has been developed as a windfarm, mitigating this visual effect remains elusive. This was evident at the Meridian West Wind, Makara, wind farm resource consent hearing and the joint Unison Networks Limited and Hawkes Bay Wind Farm Limited hearing, where there was little agreement between the experts (2005; 2006). In the latter hearing the Environment Court made the following comments;

> *"It is self-evident that landscape issues are matters about which reasonable and informed people may hold conflicting views. It is not possible to say that one is right and another is wrong....turbines need to be on or near ridgelines, and will often be on skylines, and there is no real prospect of remedying or mitigating their adverse visual effects. Either the activity proceeds, or the effects are avoided by refusing consent."*

Guidelines developed in Europe specific to the visual effects of wind turbines (Thomas 2002) have not been applied so far as a condition for resource consent in New Zealand. These guidelines provide a matrix showing an increasing visual effect with decreasing distance between the wind farm and the receiver and/or increasing height of turbines. They include assessment criteria that may be useful in New Zealand.

Turbines are visually unique elements in the landscape due to their:

- height (often taller than a 30 storey high rise building)
- the number of blades, 2 or 3
- spacing between turbines and placement, such as clustering, or arranged in rows
- colour
- movement, which contributes to their visibility, visual stimulation and attracts the eye (Parliamentary Commissioner for the Environment 2006)
- flickering shadows (Pederson 2005).

Due to their height and need for wind, turbines are not easy to screen or hide and the *"highly modern, technological and large scale nature of windfarms can dominate..."* (Parliamentary Commissioner for the Environment 2006). The scale and prominent location of wind farms means the visual impact can extend well beyond the site. In the hearing for Tararua wind farm (stage 3) James Baine, (2005) an expert presenting a social impact assessment for TrustPower stated:

> *"For the immediate community of interest and neighbours, separation distance between dwellings and turbines is a critical factor in assessing the significance of effects. This highlights the importance of buffer areas between dwellings and turbines. A separation distance of 2.0-2.5km appears to be the threshold below which acceptance is more likely to be replaced by negative sentiments from neighbours who experience no direct benefits."*

All existing New Zealand wind farms have been developed in rural settings. They therefore impact on rural amenity in several ways. For example, *"they introduce large potentially discordant structures that are not associated with normal types of rural activity. The associated works such as roading and earthworks can be at a scale that is unfamiliar in rural areas"* (Parliamentary Commissioner for the Environment 2006). This may influence public acceptance of subsequent proposals.

2.3 CUMULATIVE VISUAL EFFECTS

Several wind farms located in close proximity can create cumulative effects. This is particularly pertinent to their visual impact. The cumulative visual effects have not so far been comprehensively addressed in New Zealand, possibly because it is a relatively new phenomena in this country, but have been researched elsewhere, notably in a report by the Scottish Natural Heritage (Williams 2005). This report lists the effects on the visual amenity and landscape from wind farms as a function of:

- the number of and distance between individual wind farms
- how wind farms relate to each other visually

- the overall characteristics of the landscape and its sensitivity to wind farms
- and the siting and design of the wind farm.

While the cumulative effect on the whole of New Zealand may not be significant, the cumulative effects at a regional or localized level can be significant (Parliamentary Commissioner for the Environment 2006). The Tararua ranges, near Palmerston North is a New Zealand example where several wind farms of different height turbines, tower types and number of blades have been located together. The Parliamentary Commissioner's report on wind farms states that this raises concerns for cumulative effect in this region. Wind farms are not unique in this regard. Other reports prepared by the Parliamentary Commission for the Environment state that the RMA has not adequately addressed the cumulative effects of other land uses such as subdivisions and urban development (Parliamentary Commissioner for the Environment 2001) This suggests that cumulative visual effects of wind farms should receive closer attention in the consent process and should be a specific section of a visual assessment.

2.4 NOISE

Noise is one of the most frequently raised concerns, both in New Zealand and overseas about wind farms (Parliamentary Commissioner for the Environment 2006). Wind turbines generate noise from a number of sound production mechanisms related to the interactions between the turbine blades and air, and as the blade passes the tower. Gear box and generator noise in modern turbines is not significant when turbines are new but increases significantly as turbines wear (Stewart 2006).

New Zealand planners have recourse to a non-mandatory standard that is specific to the noise from wind turbine generators (*NZS 6808: 1998 Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators*). This standard is designed to provide a level of investigation and reporting that may be specified by land use planning procedures under any relevant legislation' (New Zealand Standards 1998)). This Standard also allows for Councils to apply their own noise criteria to be used, such as noise criteria given in their District Plan.

NZS6808 uses a simple propagation model that does not account for wind, ground or topographical effects, such as contours, and uses a simplified approach to account for atmospheric effects (New Zealand Standards 1998; EPA 2003). This can underestimate both the noise produced and transmission of this noise. A four day caucus of acoustic consultants for the West Wind wind farm hearing heard before the Environment Court, found that NZS6808 is workable but has some significant technical deficiencies that need addressing, such as atmospheric effects (Thorne 2007). A member of the West Wind acoustic caucus concluded that there is a temptation to only fulfill the requirements of the standard without considering the complex nature of wind farm noise, such as third octave data, topographical effects and atmospheric stability (van den Berg 2005). In practice, the application of NZS6808 may too simplistic an approach to something that is as complex as noise from a wind farm (EPA 2003).

The approach of Standard NZS6808 is unusual in that it allows wind turbines to produce noise up to the greater of 40dbA or ambient noise levels plus 5dbA. The premise of this approach is the wind that makes turbines turn will also produce masking noise. However, van den Berg (2006) has found that with modern turbines, which can be 80 - 110m tall, there are frequent periods with sufficient wind at hub height to turn the turbines and generate noise, with corresponding stillness and lack of masking noise at ground level. He found that this effect is most pronounced at night time. Van den Berg, has concluded that the number and severity of noise complaints near wind farms are partially explained by three findings;

- that actual sound levels are considerably higher than predicted noise
- wind turbines can produce noise with an impulsive character which has been described as a "wump, wump sound" each time the turbine blade passes the tower (van den Berg 2004; van den Berg 2006)
- noise measurements, which are expressed as averages of sound energy, substantially under represent the loud/quiet nature of the pulsing sound produced by turbines.

This study found residents up to 1900m away from wind farms expressed annoyance with noise, which is contrary to conventional wind industry calculations, which assumes minimal noise beyond 500m. Significant variations occurred between day and night time noise due to higher wind speeds at hub height turning the turbines during the night hence producing night time noise compared to lower wind speeds and a consequent lack of masking noise at ground level close to residences (van den Berg 2006).

This research highlights some of the technical shortcomings that could be addressed in NZS 6808:1998. The standard was due for review in 2006, however the revised version has yet to be released. It is of interest that a household that was only 400m from the Te Apiti wind farm was deemed uninhabitable and the occupants were relocated by the wind farm owner after irresolvable noise issues (Campbell 2006).

2.5 CUMULATIVE NOISE

Some acoustical consultants consider the approach of NZ6808 in focusing on ambient sound plus 5dbA as erroneous, especially in areas with staged wind farm developments, or where there are a number of wind farms close together. In these situations, each subsequent development or stage of a development is permitted to build on the noise produced by existing turbines, with a net effect of ramping up ambient noise (Stewart 2006).

2.6 LOW FREQUENCY NOISE

Noise, especially low frequency noise, is a particularly contentious component of a planning consent assessment. Some acoustic consultants argue that low frequency noise is below the threshold of hearing, and is therefore undetectable (Leventhall 2005). It is not well addressed in NZS6808:1998 which uses only the dBA scale, which excludes low frequency noise (New Zealand Standards 1998).

However, low frequency noise disturbance has been well documented as an effect from wind turbines (Casella 2001; van den Berg 2004; Jakobsen 2005; van den Berg 2005). The Report of the Noise Review Working Party 1990 published by the Department of the Environment (Batho 1990) commented on low frequency noise as follows: ...."*Low frequency noise can have serious effect on the quality of life of those affected by it*". The Batho report and others (Guest 2003) cited low frequency noise as a significant issue for regulators and planners, due to the difficulties with measuring it and mitigating it. The Casella report has cited low frequency noise as having several pertinent features different to other frequencies of community noise:

- low frequency noise is not attenuated with distance from the source, making low frequency noise more prominent at greater distances
- low frequency noise is not attenuated by typical building envelope designs to the same extent as other frequencies making low frequency more prominent inside a building
- inside buildings resonance can be set up inside a room with nodes (quiet points) and antinodes (loud points), which can elevate low frequency noise inside a room
- older peoples' hearing is proportionally more acute at low frequencies than other mid or high frequencies and
- low frequency noise can cause light weight elements of a building structure to vibrate.

2.7 HEALTH EFFECTS OF NOISE AND LOW FREQUENCY NOISE

Adverse health effects have been reported from wind farm neighbours. The World Health Organisation (WHO) has defined health as "*a state of complete physical, mental and social wellbeing, and not merely the absence of infirmity.*" The WHO guidelines for community noise list specific effects to be considered when setting community noise guidelines. These include interference with communication; noise induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses; effects on social behaviour (Berglund 2000).

Symptoms akin to vibroacoustic disease (Branco 2004) and increased frequency of hypertension and cardiovascular illness have been reported by people living close to wind farms. Although complex and controversial, it is thought that these symptoms arise from a combination of persistent audible noise, flicker and low frequency noise destabilising the human body (Stewart 2006). Hearing has evolved from our survival instincts to respond to danger as well as to alert, warn and communicate; our hearing is operational even when people are asleep. As a result, both wanted and unwanted sound directly evokes reflexes, emotions and actions which are both stimulants and stressors. The auditory system has the fastest response rate in the human brain and processes information hundreds of times faster than other senses (Hudspeth 2000). The extent to which noise is a stimulant or stressor is a factor of noise source, onset of the noise, duration and characteristics of the noise and whether the exposure is voluntary or involuntary (EnHealth 2004).

Worldwide there have been calls to have a mandatory buffer zone of 1.6km around wind farms, and in many situations an even greater distance between wind farms and residences, so as to avoid noise and visual impacts (Gueniot 2006), Stewart 2006). However, until recently there has been little research conducted in New Zealand on the effects from current wind farms to inform the political or planning process. Consequently, we conducted a survey of visual and noise effects to inform the consent process.

3 METHOD

A four-page, self-reporting survey was developed to investigate the visual and acoustical effects experienced by residents who live within 3km of existing wind farms in the Manawatu and Tararua region. Some surveys were delivered to residence outside the 3km notional ring, in order to survey a complete street. Questions were asked about the distance from respondent's house to the nearest turbine, whether they could see turbines from their home, visual impacts, noise impacts, financial gain from the wind farms, effects on television, radio and phone reception, whether they had complained or considered complaining about the wind farm effects. Other questions canvassed their views on future developments and descriptor data, including the number of persons living in the household and length of time living at the address.

Prior to administration, the survey was peer reviewed by two senior academics with considerable expertise in questionnaire design and trialed on a small sample of people not living in the subject region. One of the peer reviewers was a Chair of a Massey University Ethics committee and advised that ethics approval was not required due to the low sensitivity of the questions and appropriate provisions for anonymity of respondents.

The survey was divided into 5 sections; visual, noise, general, complaining about wind farm effects, future developments, and household details. However, as only the visual and noise effects is the subject of this paper, other data will be reported in a subsequent paper. Most questions in the survey only required a tick the box response, with responses mostly on a five point lichter scale or yes/no as appropriate.

Surveys were anonymous to protect the privacy of respondents, however the street address was recorded at time of delivery, so a cross check could be made on approximate distance from turbines to residence. The surveys were delivered to about 1100 urban and rural letterboxes in September 2006. Surveys included a reply paid envelope and a separate detachable postcard that could be completed if respondents were interested in being contacted for further comment or would like to receive a copy of the survey results.

Our first objective was to assess which of the various visual effects of wind farms were considered most significant. Wind farms could be considered visually significant from an aesthetic point of view or because they contain moving parts. Equally their impact could be seen to be important because they involve a change to a significant landscape feature that many residents identify with. The challenge is to understand which of these factors best explains attitude. Respondents were asked to rate on a five point scale (from disagree strongly to agree strongly), to what extent they agreed or disagreed with each of the following statements about visual amenity:

- I think the turbines spoil the view
- I think turbines are quite attractive
- I find the movement of the turbines irritating
- The turbines are intrusive in my view
- The view of the turbines doesn't bother me
- I am aware of shadows or flicker from the turbines
- Watching the turbines can create an unpleasant physical sensation in my body

- The view of turbines reduces my enjoyment of my property
- I enjoy watching the turbines.

Visual questions were asked in both the positive and negative sense e.g. *"I think turbines spoil the view?"* and *"I think turbines are quite attractive?"*, to balance opinions.

In the noise section, questions referred to heard noise from wind turbines, the frequency heard during the day and night, as well as qualitative aspects of the noise e.g. sounds like a train that never arrives or swishing noise. Respondents were also asked if they had altered their house because of noise from the wind turbines.

4 RESULTS AND DISCUSSION

4.1 RESPONSE RATE

Out of a total of 1100 survey forms delivered, 604 where returned, providing a response rate of 55%. This is considered to be high for a self-reporting, self-returning survey and suggests a high level of interest in the subject matter of the survey. Some surveys were returned after the analysis had commenced and will be included in subsequent reports.

It is assumed that many respondents guessed the distance from their home to the closest turbine, as a reported distance greater than 3km was relatively common. These distances will be manually corrected against delivery records in subsequent analysis. Only one respondent gave the distance between their home and closest wind farm as less than 1km, and only forty eight (8 percent) respondents reported they lived closer than 2km.

4.2 VISUAL

Of the 516 respondents that reported being able to see the wind farm, only 483 were used in the analysis, due to incomplete or insufficient answers. We employed a principal component analysis (PCA) to examine which of the above statements accounted for the largest amount of variation in the dataset and which of the above statements was the most important for the residents.

Table 1 shows the PCA results, with the numbers in the diagonal being a calculation of the contribution that each of the components made to the overall variability of the dataset.

Table 1: Principle components of visual amenity

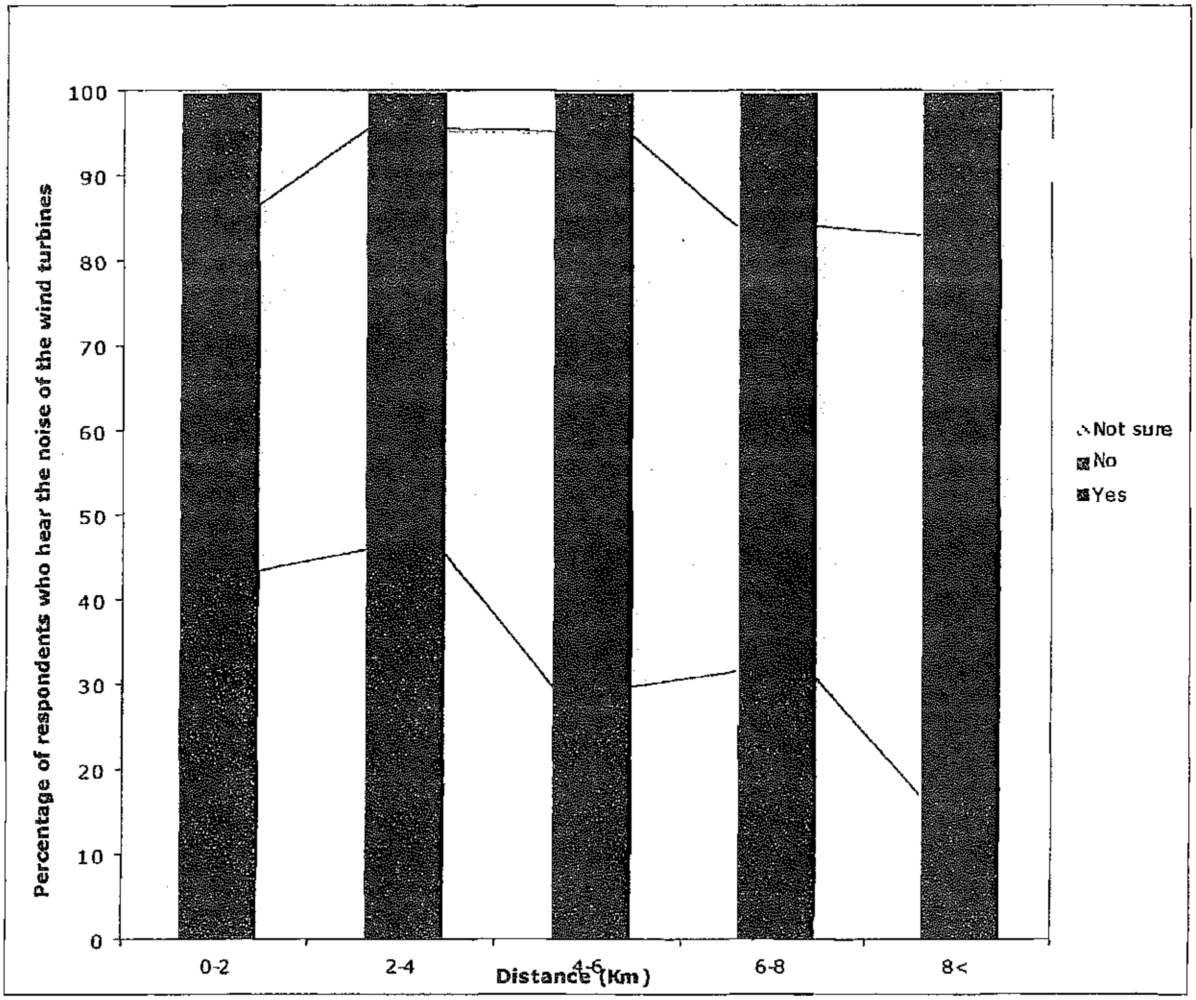
	spoil view	attract-ive	move-ment	Intrusive	doesn't bother me	flicker	physical sensation	reduce enjoy-ment	like watching
spoil view	0.24	0	0	0	0	0	0	0	0
attractive	0	0.36	0	0	0	0	0	0	0
movement	0	0	0.31	0	0	0	0	0	0
Intrusive	0	0	0	8.09	0	0	0	0	0
doesn't bother me	0	0	0	0	0.38	0	0	0	0
flicker	0	0	0	0	0	1.08	0	0	0
Physical sensation	0	0	0	0	0	0	0.20	0	0
Reduce enjoyment	0	0	0	0	0	0	0	0.53	0
Like watching	0	0	0	0	0	0	0	0	0.49
	2%	3%	3%	69%	3%	9%	2%	5%	4%

The results demonstrate that the most important visual effect of wind farms was whether respondents considered that they are visually intrusive. This factor accounted for 69 percent of the variability in the data. The flickering motion of the turbine blades was the only other factor that appeared to affect the views of a significant number of respondents (9 percent) as an area of concern. This result is in agreement with the Sinclair -Thomas matrix (Thomas 2002)

Eighty percent of the respondents considered that the turbines were intrusive, and 73 percent thought that they were unattractive. This latter result is in contrast to the UMR national survey conducted for EECA which found that only 24.9 percent thought wind turbines were ugly. This discrepancy between surveys could be due the EECA survey participants being drawn from all areas of New Zealand, rather than residents living close to wind farms.

4.3 NOISE

Figure 1: The proportion of respondents who hear the wind farms against distance



In the second part of the analysis, respondents were asked for the distance (that is, their subjective estimate of distance) between their home and the wind farm, and to provide data about the kind of noise that they heard. A substantial amount of data on noise was collected in the survey, which will be used in a subsequent publication to highlight, among other points, the qualitative impacts of the noise. For this preliminary paper we were interested in the relationship between the distance of the wind farm and participants' perceptions of possible adverse effects of noise from the wind farm.

Figure 1 is a graph of the data that were analysed. Not surprisingly, the proportion of respondents that could hear the wind farm reduced progressively with distance. What is surprising is that as much as 72 percent of respondents reported hearing turbine noise. In particular, 45 percent of respondents "located" between 0-2 kms heard wind farm noise; while as many as 20 percent of respondents' "located" 8 kms away could apparently still hear the wind farms. A chi-squared analysis showed these results were statistically significant. There was no apparent difference between the numbers of participants who reported hearing them more during the day or night.

These preliminary results suggest strongly that there is an important effect of wind farm noise upon people that may well extend several kilometers from the site of turbines. Further research is recommended, including physical noise measurements that could include third octave data as well as modulation and tonal characteristics, under a range of atmospheric conditions. As noted in the literature review, topography is an important factor in noise propagation. In this geographical area there is also a river and topographic effects that would most probably reduce the noise transmission from the turbines to the majority of receivers. The predominant wind direction is also blowing away from Ashhurst, which was the location of the largest population cluster. Both of these factors may reduce the number of people hearing the wind farm compared to other locations. It is also recommended that this survey be repeated in one - two years to assess if the noise issues are decreasing as people become accustomed to the noise or increase as more turbines are constructed. The first wind farm in this area has been operational for ten years.

The results suggest that the wind farms have significant noise influences upon a large number of people in the area. One immediate suggestion is that by only concentrating on NZS6808:1998, planners could underestimate the noise effects on a large number of people. This could give grounds for the precautionary principle to be used until more research has been conducted on the noise from wind farms. The noise issues may be addressed in the next revision of NZS6808. In this survey only one respondent gave the distance between their home and the closest wind farm as less than 1km. However, wind farms currently in the consent process are proposing distances down to 400m from existing homes, which could exacerbate the noise and visual effects from those reported in this survey.

5 CONCLUSIONS

The wind farm consent process under the RMA is attracting increasing levels of public opposition, with visual and noise effects being two primary concerns. The high response of 55 percent from this survey is higher than expected for a self-reporting - self-returning survey and suggests strong, local public interest in this topic. The results of this paper are preliminary but they do highlight the complexity of assessing the effects of windfarms.

In this survey, 516 respondents reported they could see turbines from their homes. Of these, 80 percent considered the turbines were visually intrusive, and 73 percent thought that they were unattractive. Analysis showed visual intrusiveness was the strongest concern. These concerns of the visual intrusiveness expressed by locals living near wind farms are at odds with the national support for wind energy reported in other studies.

The Parliamentary Commissioner for the Environment has acknowledge that visual effects from wind farms are difficult if not impossible to mitigate, therefore careful selection of the location may help to reducing the visual effect and public opposition.

The results also show that wind farms have significant noise effects on a larger population and at a greater distance than would be expected by applying NZS6808:1998. Noise from Manawatu wind turbines was heard by 75 percent of all respondents. Of these, 45 percent of households living within 2km of the wind farm and 20 percent of households living up to 8km away reported hearing turbine noise. This strongly suggests that NZS6808:1998 is underestimating the number of people affected by noise, possibly exacerbated by atmospheric conditions and special noise characteristics.

Under the RMA, planners in New Zealand are expected to reach an understanding of the likely effects of a potential development before they grant a resource consent. Refining the modeling tools and techniques that planners, landscape architects and acoustic consultants use is a constantly evolving. Research conducted in countries where wind farms have been in existence longer than New Zealand could be relevant to the New Zealand context. Along with these techniques however, planners may employ the precautionary principle where uncertainty or ignorance exists concerning the nature or scope of environmental harm. The results would suggest that unless a review is undertaken of the noise standards for windfarms, resource consent applications for windfarms may be refused in the future on precautionary grounds.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

(2005). Report and Decision of the Joint Hearings panel in the matter of the application for resource consent by TrustPower Limited for the construction and operation of 40 wind turbines and associated services being an extension to the existing Tararua Wind farm on the slopes of the Tararua ranges. Palmerston North.

(2005). Report and Decision of the Joint Hearings panel in the matter of the application to construct, use and maintain a wind farm on 55.8 square kilometre site to the west of Wellington City. Joint Hearings Commissioners. Wellington, Wellington City Council: 1-50.

(2006). Unison Networks Limited and Hawkes Bay Wind Farm Limited v Hastings District Council. Judge Thompson. Wellington.

Batho, W. J. S. C. (1990). Report of the Noise Review Working Party, Department of the Environment.

Berglund, B. L., Thomas.; Schwela, D.H. (2000). Guidelines for Community Noise. Geneva, World Health Organisation.

Branco, M. A.-P., M. (2004). "Vibroacoustic disease." Noise and Health **6**(23): 3-20.

Campbell, J. (2006). Campbell Live TV3. New Zealand.

Casella, S. (2001). Low Frequency Noise Update. DEFRA Noise Programme, Department of the Environment, Northern Ireland Scottish Executive
National Assembly for Wales: 1-11.

Devlin, E. (2005). "Factors Affecting Public Acceptance of Wind Turbines in Sweden." Wind Engineering **29**(6): 503-511.

EnHealth (2004). The Health Effects of Environmental Noise - Other than Hearing Loss. Canberra, Australia, EnHealth Council, Department of health and Aging, Commonwealth of Australia: 1-71.

EPA (2003). Wind Farms: Environmental Noise Guidelines. Adelaide, Australia, Environmental Protection Authority: 1-22.

Fisher, R. (2005). "Wind Energy in New Zealand: Regulatory and Policy Lessons to Date." New Zealand Journal of Environmental Law **9**: 307-335.

Gueniot, C. (2006). Panorama du Médecin. Paris, France, National Academy of Medicine.

Guest, H. (2003). "Inadequate standards currently applied by local authorities to determine statutory nuisance from LF and infrasound." Journal of Low Frequency Noise, Vibration and Active Control **22**(1): 1-7.

Hudspeth, A. K., M (2000). "Auditory Neuroscience: Development , Transduction and Integration." National Academy of Sciences **97**(22): 11690-11691.

Jakobsen, J. (2005). "Infrasound Emission from Wind Turbines." Journal of Low Frequency Noise, Vibration and Active Control **24**(3): 145-155.

New Zealand Standards (1998). "New Zealand Standard NZS6808:1998 Acoustic - The Assessment and Measurement of Sound from Wind Turbines Generators."

Parliamentary Commissioner for the Environment (2001). Managing change in paradise: Sustainable development in peri-urban areas. Wellington, Parliamentary Commissioner for the Environment.

Parliamentary Commissioner for the Environment (2006). Wind power, people and place. Wellington, Parliamentary Commissioner for the Environment: 144.

Pederson, E. W., Kerstin Persson (2005). Human Response to Wind Turbine Noise - Annoyance and Moderating Factors. Wind Turbine Noise: Perspectives for Control, Berlin, INCE/European Conference.

Stewart, J. (2006). Location, Location, Location - An Investigation into the Windfarms and Noise. London, UK, The Noise Association: 1-32.

Thomas, S. (2002). Visual assessment of Windfarms: Best Practice, Scottish Natural Heritage.

Thorne, B. (2007). Noise Assessment Report Proposed Motorimu Windfarm Palmerston North. Brisbane, Australia, Noise Measurement Services: 1-57.

UMR Research Limited (2004). Ominbus results; Research for EECA into public attitudes to wind power. Auckland, UMR Research Limited.

van den Berg, G. P. (2004). Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, the Netherlands, http://www.viewsofscotland.org/library/docs/LF_turbine_sound_Van_Den_Berg_Sep04.pdf.

van den Berg, G. P. (2004). "Effects of the Wind Profile at Night on Wind Turbine Sound." Journal of Sound and Vibration **277**: 955-970.

van den Berg, G. P. (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.

van den Berg, G. P. (2006). The Sounds of High Winds: the effects of atmospheric stability on wind turbine sound and microphone noise. Rotterdam, University of Groningen: 1- 200.

Van der Loo, F. A. (2001). Mediating Windpower in the Netherlands: the Task Force Windpower Implementation. Novem: Ultretch, Dutch Wind Energy Association: 1-4.

Williams, K. (2005). Guidance; Cumulative effect of Windfarms, Scottish Natural Heritage: 1-32.

Deputation
to the Standing Committee on General Government
Regarding Bill C-150
April 22 2009

By Dr. Robert McMurtry M.D., F.R.C.S (C), F.A.C.S

Deputation to the Standing Committee on General Government
Regarding Bill C-150
April 22 2009

First permit me to express my appreciation to the Committee for permitting me to speak and submit this deputation.

My presentation is in four parts:

- Regulations in Canada
- Low Frequency Noise and Wind Turbines
- Report of Adverse Health Events
- A Proposal

Regulations in Canada

Quite simply national regulations do not exist in Canada. According to a November 2008 letter from Morel Oprisan, (Deputy Director S&T, Renewable Energy Technologies, Government of Canada) in an electronic mail to Professor John Harrison (Queens University) he stated:

> "As you correctly noted in your letter, the issue of the wind turbine set-back from a residence, is regulated locally (municipally or provincially)."
> "As part of the work done by the federal government in this area, we have worked together with CSA and, internationally with IEC, to bring international standards to Canada. However, these standards, at this time, are not mandatory and their use is voluntary."

To add to my concern regarding this regulatory uncertainty is the fact that this Provincial Ministry of the Environment has regulations with many flaws. One of these is the failure to measure for low frequency noise (LFN). Instead regulations are stated measure in A Weighted decibels or dBA only. To measure for LFN it is necessary to screen with C Weighted decibels or dBC.

It is not possible to develop authoritative guidelines for set-backs and monitoring of industrial wind turbines specifically if LFN is not taken into account.

Low Frequency Noise

Human auditory range is from 20 – 20,000 HZ. LFN is about 20-200 HZ. (1) It is an area of growing interest and for example there are 15,400,000 hits on Google (accessed April 20 2009) for "Low Frequency Noise". However there appears to be a variance of opinion in recognizing its significance. For example the wind developer IPC Energy contracted Avalon Consulting to do Environmental Screening. I contacted Avalon who indicated to me on 2 occasions that it is "not necessary" to monitor for LFN. The wind industry at large agrees as they also deny the need to monitor for LFN. The Ministry of the Environment of Ontario concurs as all its regulations are based on dBA (Decibels with A weighting) which is relatively insensitive to LFN. dBA however is adequate for higher frequency noises such as the characteristic "swoosh, swoosh, swoosh" of turbine blades which are in the mid-frequency range.

How important is LFN?
The World Health Organization in a 2000 publication ("Community Noise" by Berglund et al) made the following observations:

- "Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would e to use C-weighting"
- "It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health"
- "The evidence on low frequency noise is sufficiently strong to warrant immediate concern" (2)

The answer is clear – LFN is very important.
However there is a crucial difference of opinion.
The author of the foregoing paper (H.G. Leventhall) who quoted the WHO denies that wind turbines generate LFN. He is the prime expert on the subject on behalf of the wind energy industry.

Others disagree.

For example Styles et al observed that there is "..clear evidence that wind turbines generate low frequency sound (infrasound) and acoustic signals which can be detected at considerable distances (many kilometres) from wind farms on infrasound detectors and low-frequency microphones."

Kamperman and James have commented "Some residents living as far as 3 km (two miles) from a wind farm complain of sleep disturbance from the noise. Many residents living one-tenth this distance (300 m. or 1000 feet) from a wind farm are experiencing major sleep disruption and other serious medical problems from nighttime wind turbine noise".

They further comment that "the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate". Clearly, as they conclude C-weighted (dBC) criteria should be used.

Adverse Health Events

There have been many reports of adverse health events. At the outset it must be made clear that there has not been any systematic epidemiological field study that could yield authoritative guidelines for the siting of wind turbines. Secondly there is no epidemiological study has been conducted that establishes either the safety or harmfulness of Industrial Wind Turbines. In short there is an absence of evidence. Accordingly until more authoritative information is available it is important to consider the growing number of reports of cases and case series of adverse health effects that are emerging.

Dr. Amanda Harry reported on 39 cases of people whose health and quality of life were compromised.

She concluded that "…..people living near turbines are genuinely suffering." (5)

Dr. David Manley a Chartered Physicist, Acoustician and Engineer who worked with Dr. Harry stated: "Much work has been done by me near windfarms to evaluate the acoustic effects. It is found that people living within five miles of a windfarm cluster can be affected and if they are sensitive to low frequencies, they may be disturbed."

"It has been found that an extensive seismic signal passes through the earth and may well at night time affect peoples sleep. It is admitted by fellow acousticians that much more research in this subject is needed and that none has been done since 1996 by the DTI. At many inquiries windfarm promoters will not accept there is an acoustic problem."(6)

Todd et al recently found that the human ear is more sensitive to seismic vibration than to hearing. (7) In other words what you can't hear can otherwise be perceived.

Dr. Nina Pierpont has had a substantial experience with wind turbines She too has gathered cases (38 from 10 families) and plans to publish a book this year. (8)

The National Academy of Medicine of France has taken note of adverse health events in their report "Repercussions of the Operation of Wind Turbines on the Health of Man" (March 2006). Their recommendation is for a set-back of 1.5 kilometers for 2.5 MW wind turbines from dwellings. They also recommended an epidemiological investigation into the possible medical effects of wind turbines.

Of course the industry denies any problem and cite more than 20 years experience and at least 68,000 wind turbines in place without adverse health effects.

The European Platform Against Windfarms begs to differ. They currently have 319 organizations from 18 nations opposing windfarms. To quote from their web page

- that hundreds of associations, local initiatives and other groups are totally dissatisfied with wind farms;

- that intermittent, uncontrollable energy does not solve any of humanity's problems, even in part;
- that the only thing wind turbines do is cause considerable harm to people, the economy, national budgets and the environment.(9)

Closer to home those sentiments are clearly arising as this committee heard from Wind Concerns Ontario.

Let me be clear however as to my deepest concern : adverse health effects are occurring as we speak. Many victims have joined us today in the hope of being heard. There is no quetion that they are genuinely suffering and more people are at risk if the rules are not changes substantially.

The victims, lead by Carmen Krogh and Lorrie Gillis organized a survey of people living near wind installatons. (The methodology and detailed results are attached as part of the submission) Seventy-six people responded.Twenty-three denied any problem.Fifty-three indicated that they had experiencesd at least one symptom/complaint and on average had 5 complaints.

The findings are remarkably similar to other work quoted above and to the just released study by Dr. Michael Nissenbaum in Maine who reports on 15 further cases. Virtually always the commonest complaint is sleep disturbance (34). Already thirty-nine individuals indicate that their health has been affected as a consequence of what they are experiencing. One person has had to be admitted to hospital with an acute hypertensive episode, another experinced a cardiac arrythmia (atrial fibrillation), 15 experienced heart palpitations. Further details are in your packages.

Most disturbing of all are the comments describing the sheer anguish and sense of betrayal that many feel. Noone seems to care, noone appears to be listening to their plight. They feel they are losing their homes and their lives.

The situation has been exacerbated for many who have experienced denial, and abusive behaviour by Wind Turbine representatives and on occasion from Ministry of the Environment officials. All this victimizes them a second time.

These findings and victim accounts are new in Ontario but not elsewhere. They have been described too often in other countries.

A Proposal

There clearly are competing claims about LFN and health risks - those who are living the claims and those who deny them

There is a way out of this dilemma. Authoritative guidelines must be established based on sound science. A well-designed epidemiological study conducted by arms-length investigators, mutually agreeable to all sides, must be done. In addition and far more simply is to engage sound engineers, (again mutually agreeable) to determine the presence or absence of LFN near existing wind farms in Ontario.

In the meantime listen to and help the victims.

Anything less would be an abandonment of responsibility by the government.

Summary

When uncertainty exists and the health and well-being of people are potentially at risk, assuredly it is appropriate to invoke the precautionary principle. Until and unless there are authoritative guidelines in place based on the best available evidence the Province of Ontario ought not to proceed with the development of Industrial Wind Turbines any further.

The development of these guidelines must be based on a rigorous epidemiological evaluation of health effects of these turbines.

Respectfully Submitted

R.Y. McMurtry MD FRCSC FACS

1. www.defra.gov.uk/environment/noise/research/lowfrequency/pdf/lowfreqnoise.pdf

2 ibid

3. "Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms" 2005. Styles et al.

4. Kamperman and James "Simple guidelines for siting wind turbines to prevent health risks" July 2008

5. www.flat-group.co.uk/pdf/wtnoise_health_2007_a_harry.pdf.39

6. David Michael Manley PhD BSc(Hons) MIEE MIOA F Inst P C.Dip AF FICDDS C.Eng Chartered Acoustician, Physicist and Engineer http://www.socme.org/acoustic.html

7. http://www.windturbinesyndrome.com

8. Todd, Rosengren and Colebatch. "Tuning and sensitivity of the human vestibular system to low-frequency vibration" Neuroscience Letters 444 (2008) 36–41.

9. http://www.epaw.org/

10. Michael Nissenbaum MD. Presentation to the Maine Medical Association March 2009 [Slides from presentation attached]

Reno, Nevada
NOISE-CON 2007
2007 October 22-24

Communicating the Noise Effects of Wind Farms to Stakeholders

Christopher J. Bajdek[a]
Harris Miller Miller & Hanson Inc.
77 South Bedford Street
Burlington, MA 01803

ABSTRACT

State and local agencies may lack applicable noise criteria and standards for the assessment of noise impact from wind farms used for the production of electricity, and many decision-makers, as well as the general public, have limited experience with the noise effects of modern wind farms. Although largely viewed as environmentally friendly, the wind energy industry does have its detractors. Some of the information posted on the Internet concerning the noise effects of wind farms can be misleading. This paper explores several innovative approaches or strategies to communicate the noise effects of wind farms to decision-makers and the general public including audibility analyses, Virtual Soundscapes™ [b], and supplemental metrics.

1. INTRODUCTION

The American Wind Energy Association anticipates that the wind energy industry is on track to install over 3,000 megawatts (MW) of capacity nationwide in 2007.[1] Many factors are contributing to the growth of the wind energy industry including higher costs of fossil fuels for power generation, passage of Renewable Portfolio Standards (RPS) at the state level, growing public interest in renewable energy, and concerns about carbon emissions and global warming.

Although the wind energy industry is growing and wind farms are becoming more prevalent in some areas of the country, the general public has limited direct experience with this technology and therefore is susceptible to misinformation provided by detractors and opposition groups. As a result, residents and communities may develop a negative attitude toward a wind energy project under consideration in their locality. Developers and proponents of wind energy facilities are then challenged to overcome such predispositions.

Managing expectations about the noise effects of a proposed wind farm from the very outset of a project can alleviate fears for affected communities, counter misinformation floated by detractors and opposition groups, and educate decision-makers about the noise effects of a project. This paper provides an overview of the strategies or approaches for communicating the noise effects of wind farms to a wide variety of stakeholders – from affected communities (participants and non-participants alike) and decision-makers (including regulatory agencies and localities), to developers, manufacturers, politicians, and the public. Specifically, this paper explores the use of audibility analyses, Virtual Soundscapes™, and supplemental metrics.

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[a] Email address: cbajdek@hmmh.com

[b] Virtual Soundscapes™ are special recordings HMMH has developed to give listeners a realistic sense of how a planned facility or project will sound.

2. AUDIBILITY ANALYSES

Perhaps more so with wind farms than for other types of projects, the audibility of a wind farm in a surrounding community can be included as a component of the noise assessment. There are several reasons for conducting such an analysis. The need or desire to perform an audibility analysis might have arisen during public outreach efforts. An audibility analysis would help identify at what locations and at what times of day the wind farm would be heard. In some cases, an audibility analysis is conducted to demonstrate how ambient wind noise may mask noise from a proposed wind farm, while in other cases, these analyses can serve to quantify the prominence of tones, if tones are present.

A. Masking

At times, noise from wind farms can be masked by other sources, such as ambient wind noise, which consists of aero-acoustic noise generated by atmospheric turbulence and radiated aero-acoustic noise generated by the interaction of the wind with trees, other ground vegetation, or man-made structures.[2]

It has been observed that turbine sound levels and ambient wind noise are both dependent upon wind speed, and the degree to which wind turbines are masked by ambient wind noise is dependent upon how each varies with wind speed. In a white paper first published in 2002 and later amended in 2004, Rogers and Manwell pointed out that "wind noise from large modern turbines during constant speed operation tends to increase more slowly with increasing wind speed than ambient wind generated noise."[3]

While the precise wind speed at which wind turbine noise is masked by ambient wind noise varies, there is evidence to suggest that at a wind velocity of 3.5 m/s (7.8 mph) masking of wind turbine noise by ambient wind noise occurs at frequencies above 500 Hz, when located downwind of a forest edge.[4] Other evidence suggests that noise from wind turbines may be masked by ambient wind noise at wind speeds above 9 m/s (20 mph).[5] However, it is often difficult to predict levels of wind-induced vegetation noise. While some current methods attempt to determine the level of masking provided by vegetation noise, those methods assume that the spectral shape of the turbine noise is similar to that of the ambient noise and "that the temporal fluctuation of background noise is limited" – conditions that are often difficult to meet.[4]

Ideally, an audibility analysis requires background noise measurements at a number of locations throughout the study area prior to construction of the wind farm, where one-third octave band data are obtained for a variety of wind conditions over a regime of wind speeds that are consistent with the operating wind speeds of the proposed wind turbine. Note that while one particular model operates over a range of wind speeds from 4 m/s (9 mph) at cut-in to 25 m/s (56 mph) at cut-out (as measured at hub height), acoustic data are not obtained at the cut-out wind speed. Rather, the upper range of wind speeds for which acoustic data are gathered corresponds to the speed at which 95-percent of the rated (electrical) power output is achieved – roughly 13 m/s (29 mph) at hub height, in this example.

B. Tonality

In general, aero-acoustic noise from wind is broadband in nature. The predominant sources of noise produced by a wind turbine are due to the interaction of the wind with the turbine blades and the tower. Under certain operating conditions, however, some wind turbines may exhibit tonal characteristics.

In describing the noise effects of wind turbines to community members, it is important to distinguish between the audibility of tones versus the prominence of tones. For a tone that is audible can be barely audible, and therefore not prominent and not likely to cause increased annoyance. A prominent tone would be considered to be immediately apparent and a "dominant element" of a sound. A tone that is audible may or may not be considered prominent or even noticed, depending on the level of the tone is relative to the adjacent frequency bands.

Manufacturers document the acoustic emissions and tonality of their wind turbines following the methods and procedures in a standard developed by the International Electrotechnical Commission (IEC). The purpose of IEC 61400-11 is "to provide a uniform methodology that will ensure consistency and accuracy in the measurement and analysis of acoustical emissions by wind turbine generator systems." Section 8.5 of the standard, "Tonality," provides methodology to identify the presence of audible tones.[6] The manufacturer must report "tonal audibilities" wherever the tonal criterion is exceeded. In short, the purpose of the standard is to ensure that any audible tones that are generated by the turbine under test are disclosed by the manufacturer.

The IEC standard does not, however, make determinations about the prominence of tones, or whether they would be considered objectionable in a community setting. Other national and international standards have been published whose purposes are exactly that. One such standard was published in 1996 by the American National Standards Institute (ANSI). Annex C of the ANSI Standard, on page 15, describes the recommended approach to evaluating "Sound with tonal content." The annex describes the approach to evaluating "the presence of a prominent discrete-frequency spectral component (tone)."[7] The International Organization for Standardization (ISO) Draft International Standard (DIS) ISO/DIS 1996-2.2 includes a method for assessing the audibility of tones that is consistent with the ANSI standard.[8] The term prominent is used to describe the characteristic of a tone that would be apparent enough to represent a dominant element of the sound, and be significant enough to potentially affect "long-term community response."

For the purposes of evaluating the tonal characteristics of wind turbines in the community, tones should be characterized as to whether they are prominent according to the ANSI/ISO definitions, rather than in the context of whether they are simply audible or not. The presence of tones in the noise signature of a wind turbine may increase one's ability to detect noise from a wind farm, and if prominent, the tone may cause adverse community reaction and increased annoyance.

3. VIRTUAL SOUNDSCAPES™

While there is no substitute for experiencing a wind farm first-hand, many people may not be able to visit a wind farm because of the extensive distance required for travel. In some cases, individuals within an affected community might find it difficult, or might lack the motivation, to visit a wind farm even though one may be within driving distance.[9]

The use of Virtual Soundscapes™ is gaining popularity to help people understand how a new sound will be heard in an existing setting. Soundscape demonstrations are developed starting with binaural recordings of the background environment and then separately, for a newly introduced source of noise, such as a wind farm or a single wind turbine. Then, the two recordings are combined differently to represent what residents in different locations would hear with the proposed facility in operation. The demonstrations are played back through high-quality headphones to achieve realistic sound. Such demonstrations are useful to help facility designers understand residents' perspectives, communicate noise issues accurately and to simulate and evaluate the benefits of noise abatement options, such as the sound insulation of homes.

It should be noted that two significant technical challenges must be overcome for Virtual Soundscapes™ to be used for acoustic demonstrations of wind energy projects. Namely, low signal-to-noise ratios must be addressed, particularly if the audio demonstration is to be representative of a nearby residence, which could be located at relatively significant distances from the wind farm. Furthermore, for a realistic acoustic experience, the presence (or absence) of wind in the ear in the binaural recordings must be accounted for in an appropriate manner. The use of Virtual Soundscapes™ for wind energy projects should be evaluated on a project-by-project basis.

4. SUPPLEMENTAL METRICS

Recently, increased attention has been given to the use of supplemental metrics for describing the effects of noise on people. While the current dialog has focused on aircraft noise effects, the approach could be used for wind energy projects, and perhaps quite effectively.

Over the years, much has been written about the applicability of different noise metrics in the describing aircraft noise effects, and various noise metrics have been proposed to supplement, and even replace, the Day-Night Average Sound Level (DNL) as the official metric for aircraft noise. However, in spite of such proposals, DNL is still used by the Federal Aviation Administration (FAA). Most other federal agencies dealing with noise also have formally adopted the DNL noise metric, and in 1992, the Federal Interagency Committee on Noise (FICON) reaffirmed the appropriateness of DNL. While FAA still requires DNL for use on all of its noise studies, other noise metrics are being reported and included in FAA noise studies, as a means to lend additional information and further description of aircraft noise effects. Examples of other noise metrics that are typically reported in FAA noise studies include the A-weighted Maximum Noise Level (L_{max}) and the Sound Exposure Level (SEL).

The reporting of supplemental noise metrics has increased in recent years because they are considered to be more easily understood by the public than the DNL. In 2006, Eagan proposed a novel and straightforward approach for describing aircraft noise effects, whereby the extent of the <u>effect</u> could be shown graphically, rather than the metric itself.[10] For example, rather than displaying the extent of SEL contours around an airport, a potentially more meaningful display might be the percent of population likely to be awakened over a typical night – in other words, display the extent of the effect (awakenings) rather than the extent of the SEL noise metric, which in practice is used to quantify the likelihood of sleep disturbance.

Supplemental metrics of particular interest for wind energy facilities include annoyance and rattle.

A. Annoyance

A few recent news stories have told about individuals and communities who live in proximity to wind farms in the northeast United States and in Japan, and who started to complain about noise from wind turbines shortly after the facility began operations. The author's own experience demonstrates that noise complaints and adverse community reaction can occur even though a wind farm is operating in compliance with local noise limits.[11]

In 2004, Pedersen and Waye published a dose-response relationship for the perception of wind turbine noise, as represented in the following equation.[12]

$$\%HA = 4.38 * 10^{-2}(LEQ - 32)^3 - 2.413 * 10^{-1}(LEQ - 32)^2 + 2.4073(LEQ - 32) \quad (1)$$

In equation (1), *%HA* is the percentage of people highly annoyed by noise from a wind farm, and *LEQ* is the noise dose expressed in terms of the A-weighted equivalent sound pressure level. The graph of Figure 1 plots this dose-response relationship for wind turbines against the more familiar dose-response relationships for transportation sources, which were developed by various researchers as noted in the legend of the graph.

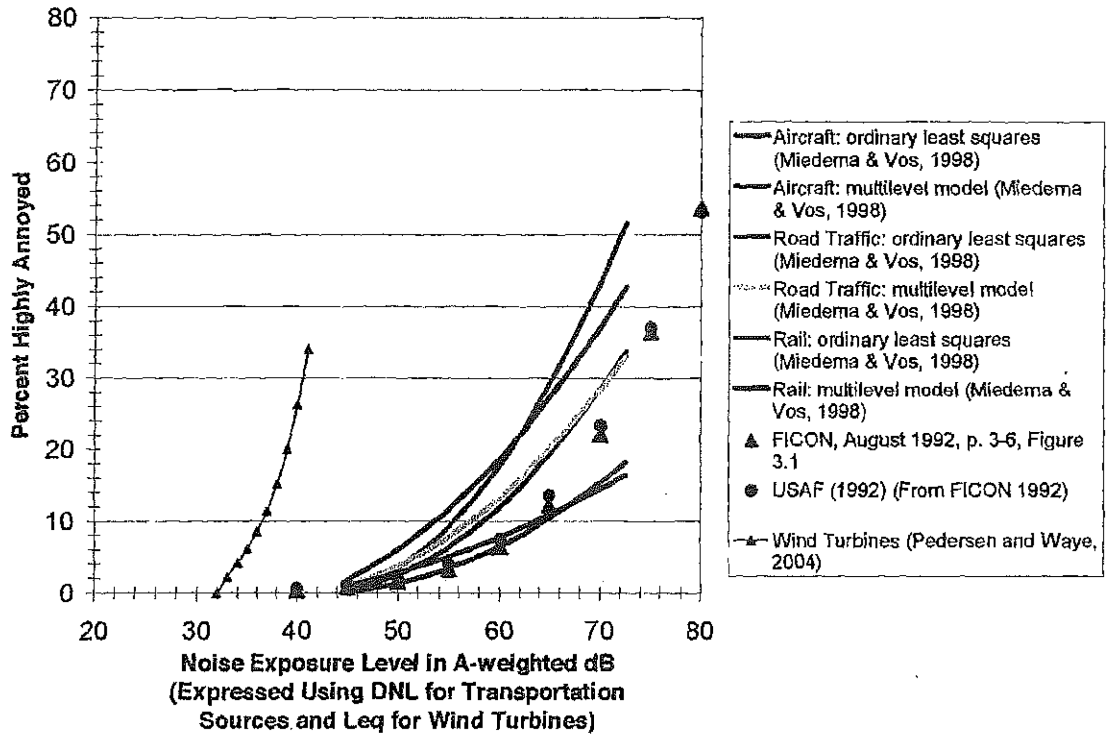

Figure 1: Dose-response relationships for transportation sources and wind turbines

As shown in Figure 1, for a given level of noise exposure, wind turbines were found to produce higher levels of annoyance than transportation noise sources were found to produce. The graph of Figure 1 also suggests that the percent of people highly annoyed increases more rapidly if exposed wind farm noise. So why does wind turbine noise appear to generate more annoyance for a given level of exposure?

In their conclusions, Pedersen and Waye observed that the resultant levels of annoyance were higher than were initially anticipated. The authors speculated that certain characteristics of the wind turbine noise, described by the respondents as "lapping, swishing, and whistling," may have had some influence on annoyance. They also pointed out that the visual impact of the wind turbines may have contributed to the reported levels of annoyance.

Pedersen and Waye recommend additional research into dose-response relationships for wind turbines to further explore the relationship between the visual impact and annoyance. It should be noted that the majority of respondents in the Pedersen and Waye study (95-percent of the respondents) did not own or host a wind turbine. In this author's limited experience, he has observed that levels of annoyance may be influenced by a land-owner's participation (or non-participation) in the wind energy project.

Using the dose-response relationship developed by Pedersen and Waye, the next two figures illustrate how supplemental metrics could be used to convey the noise effects of a wind farm. Figure 2 shows the noise exposure contours for a wind farm located in the upper mid-west of the United States. The noise contours were generated using the noise prediction model, SoundPLAN®, developed by Braunstein + Berndt GmbH. The noise contours were produced for full operation of the wind farm, assuming hard ground, no tree attenuation, and omni-directional sound propagation according to ISO 9613. In this case, the permit application for the wind farm specified a limit on audible noise of 50 dBA, and also included limits for low frequency noise in one-third octave bands, as well as definitions of pure tones and provisions for the presence of pure tones for operation of the wind farm.

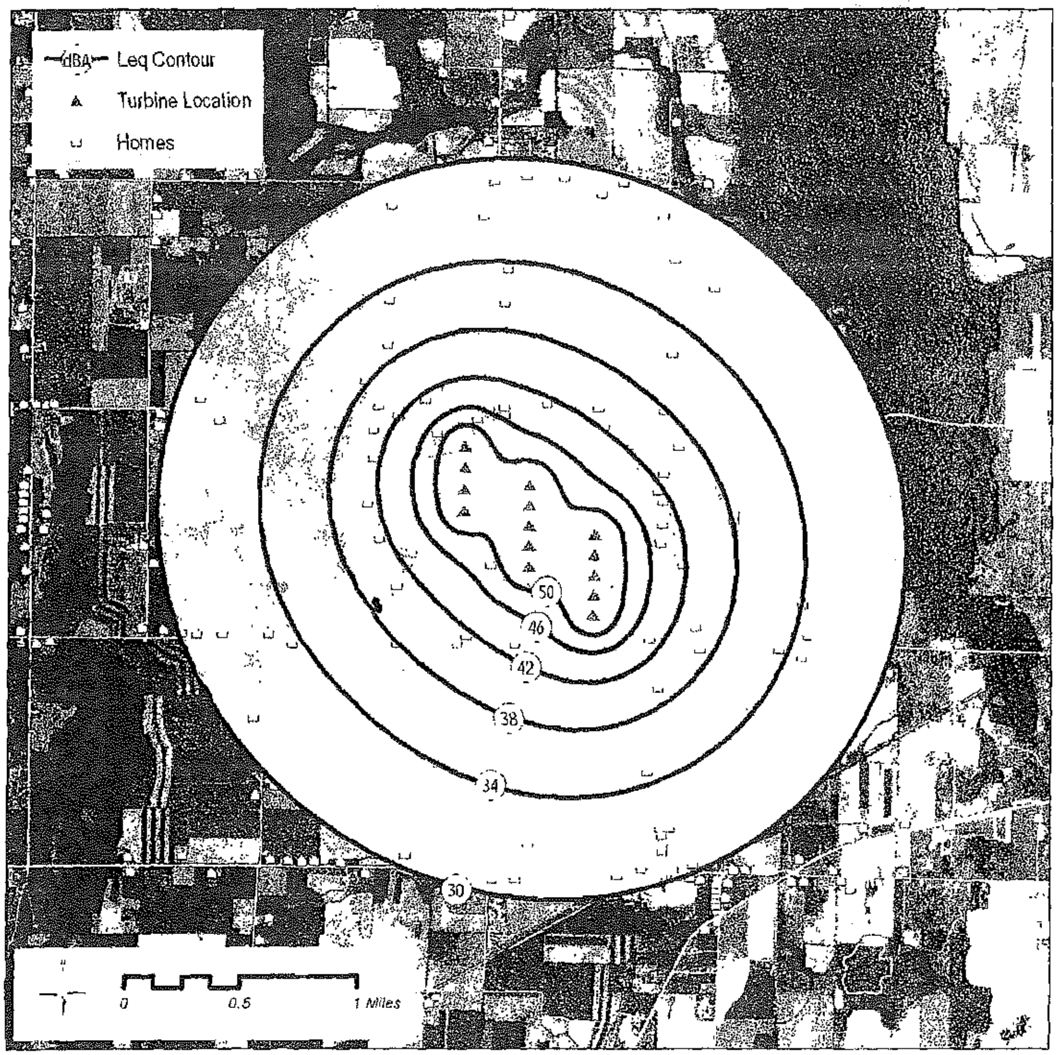

Figure 2: Noise exposure contours for a wind farm in an agricultural area with rolling terrain

Figure 3 shows the extent of people highly annoyed by wind farm noise based on the dose-response relationship given in Equation (1). As shown in the figure, within approximately 0.8 km (½ mile) of the wind farm, 44-percent of the population would be considered highly annoyed due to wind farm noise. At a distance of approximately 1.62 km (1 mile) from the wind farm, the percent of highly annoyed people is expected to drop to 4-percent. Such information could be useful for developers and/or regulatory authorities during the siting of a wind energy facility when deciding upon appropriate set-back distances.

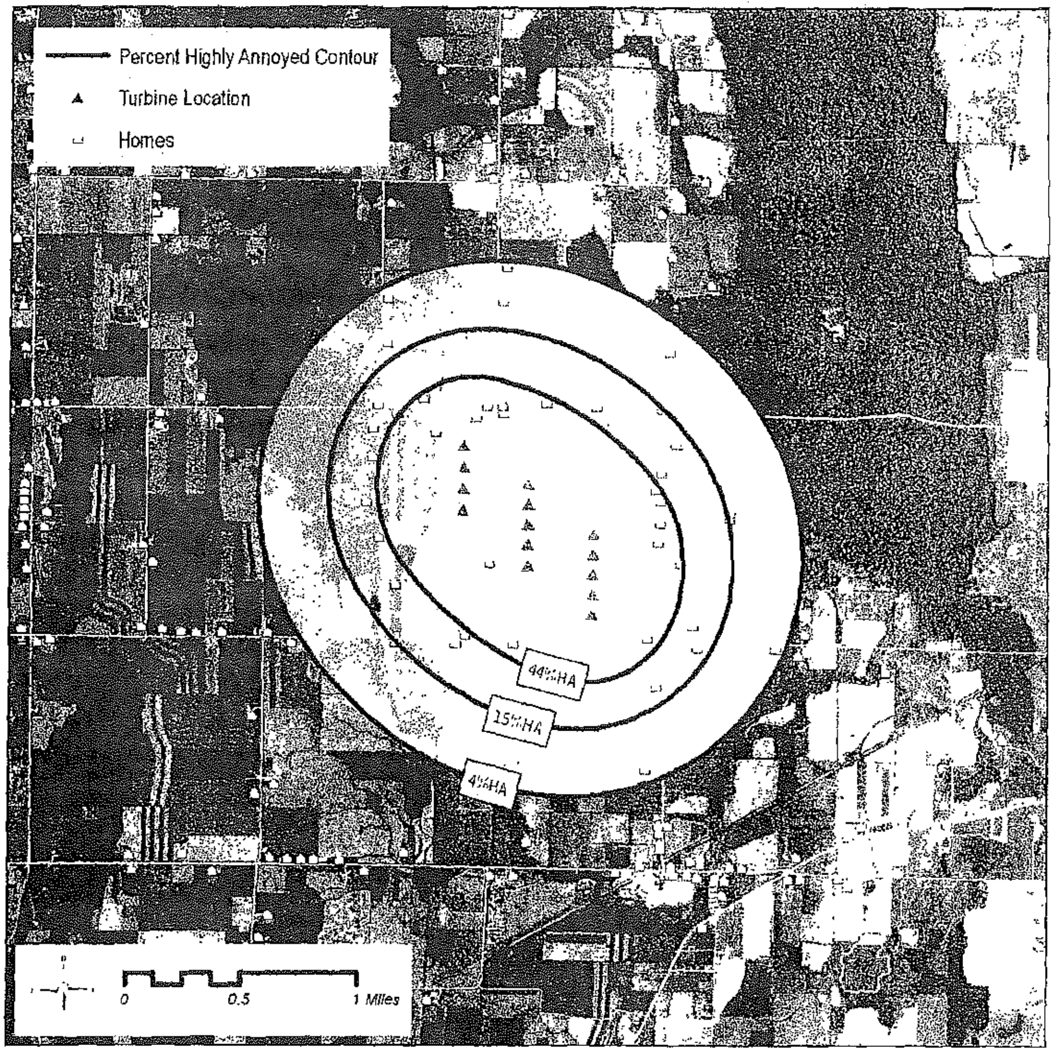

Figure 3: Extent of people highly annoyed by wind turbine noise

The results of Figure 3 could be compared to the results of a social survey performed for this same wind farm.[13] Figure 4 shows responses to three questions from a social survey performed in 2001. In the top chart of the figure, 44-percent of the respondents living from 800 feet to ¼ mile of the wind farm stated that the turbines are "causing a problem with noise." From approximately ¼ mile to ½ mile from the wind farm, the percentage of respondents indicating a problem with noise increased to 52-percent. Similar trends are shown in the responses to questions in the middle and bottom charts of Figure 4. If levels of annoyance were dependent upon noise exposure alone, it would be reasonable to expect that the percentage of people saying that there is a problem with noise would decrease with distance from the wind farm. That is, one might expect that the percentage of people claiming a problem with noise in the range of ¼ mile to ½ mile from the wind farm would be less than the percentage of people in the 800 feet to ¼ mile range.

It should be noted that the findings of the committee with oversight of the social survey suggested that the participation of a land-owner in the project may have had an influence in the elicited response.[9, 13]

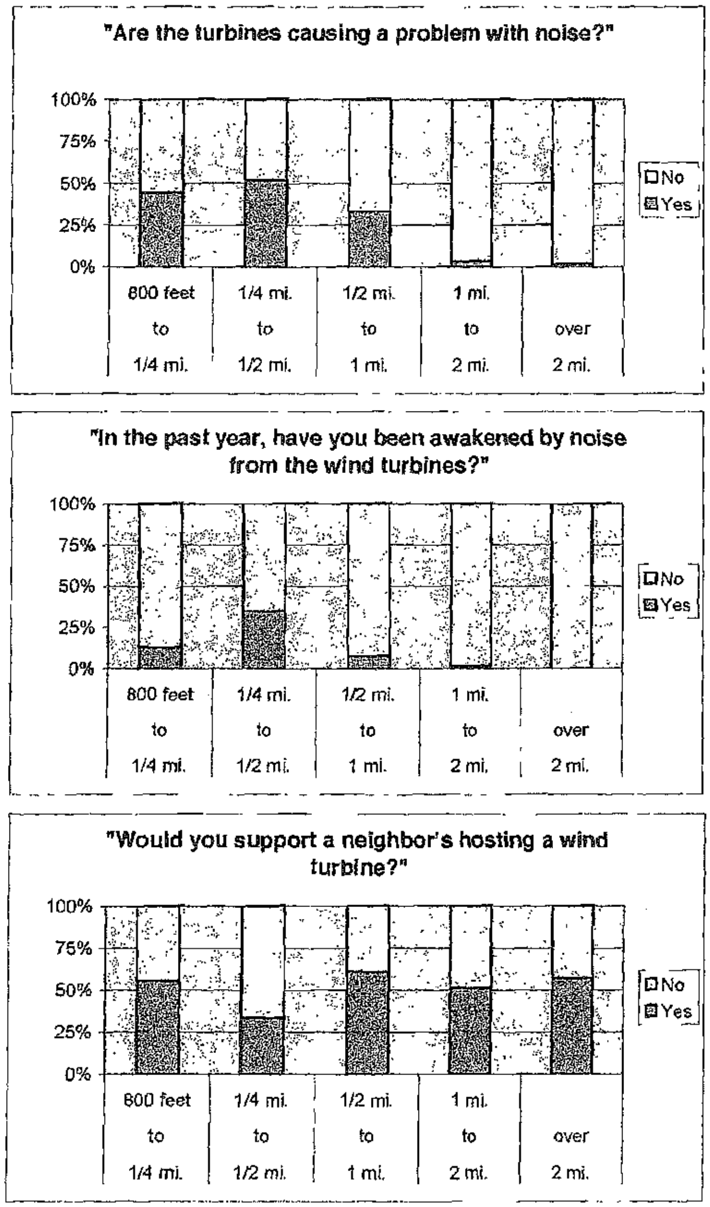

Figure 4: Social survey responses relating to wind turbine noise

Note that this author made this simple comparison to illustrate a point and recommends that additional survey and research be performed to better understand the trade-offs between noise exposure, visual impacts, and annoyance.

B. Rattle

It is generally recognized in the acoustical community that certain A-weighted noise metrics have been shown to correlate well with levels of annoyance. However, it is also recognized that A-weighted noise metrics underestimate the potential impact of low-frequency noise, since people do not hear low frequency sound as well as sound at other frequencies. In such cases, a comparison of C-weighted and A-weighted noise metrics will provide a rough estimate of the significance of noise in the low frequencies. It has been suggested that in cases where the C-weighted noise level generated by a source is 10 to 20 dB greater than the A-weighted noise level, the source is considered to have low-frequency components.

One study has shown that maximum wall vibration levels correlated strongly with C-weighted maximum outdoor sound levels.[14] In that study, outdoor noise levels and wall acceleration levels were measured at several residences in the vicinity of an airport. The measurement results indicated that noise-induced vibrations became perceptible to the touch when exterior C-weighted maximum levels were higher than 75 to 80 dB(C).

The potential effects of low-frequency noise can be described in terms of the potential for "rattle." Wind farm noise levels can be compared to criteria that relate outside sound pressure levels in 1/3-octave bands to thresholds of perceptible vibration in residential building structures.[15] A comparison of projected wind farm noise levels to these criteria indicate whether enough sound energy is present in the lower frequencies to excite the residential structures, and potentially cause rattle inside the home, thereby leading to increased levels of annoyance in the community. These frequency-dependent criteria relate outside noise thresholds to perceptible levels of vibration separately for windows, walls, and floors, as shown in Figure 5.

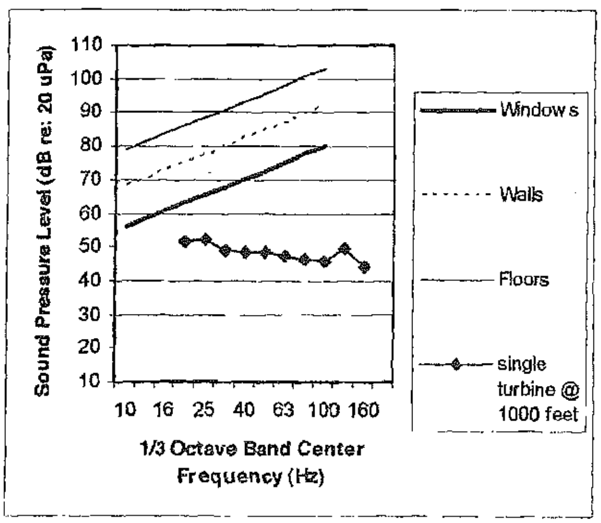

Figure 5: Projected spectrum for a wind turbine at a distance of 330 meters (1,000 feet) with criterion for perceptible vibration in residential structures

ACKNOWLEDGEMENTS

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REFERENCES

[1] American Wind Energy Association. Wind Power Outlook 2007. Accessible on the internet at http://www.awea.org/pubs/documents/Outlook_2007.pdf, July 2007.

[2] Wyle Research. Measurement and Evaluation of Environmental Noise from Wind Energy Conversion Systems in Alameda and Riverside Counties. October 1998, p. 2-6.

[3] Rogers A. and J. Manwell. Wind Turbine Noise Issues – A White Paper. *Renewable Energy Research Laboratory Center for Energy Efficiency and Renewable Energy*, June 2002, p. 13.

[4] Bolin, K. Masking of Sound from Wind Turbines by Vegetation Noise. *Proceedings of the First International Meeting on Wind Turbine Noise: Perspectives for Control*, Berlin, October 17th and 18th, 2005.

[5] DeGagne, D.C. and A. Lewis. Development of Regulatory Requirements for Wind Turbines in Alberta. *Journal of the Canadian Acoustical Association*, Volume 34, Number 2, June 2006, p.27.

[6] IEC 61400-11:2002(E). "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques." International Electrotechnical Commission.

[7] ANSI Standard 12.9-1996 - Part 4, Annex C.

[8] ISO/DIS 1996-2.2, Part 2, Annex D.

[9] Energy Center of Wisconsin. A Study of Wind Energy Development in Wisconsin: A Collaborative Report. Part 1, Section A, July 2004, p. 21.

[10] Eagan, M.E. Eagan, M.E. Using Supplemental Metrics to Communicate Aircraft Noise Effects. Submitted to Noise-Con 2006, November 10, 2006.

[11] Bajdek, C. Noise Issues and the Siting of Facilities. *North American Windpower*, Zackin Publications, Waterbury, CT, Volume 2, Number 3, April 2005.

[12] Perdersen, E. and K.P. Waye. Perception and annoyance due to wind turbine noise – a dose-response relationship. *J. Acoust. Soc. Am.* **116**(6), 3460-3470 (2004).

[13] Town of Lincoln. Final Report of the Wind Turbine Moratorium Study Committee. Lincoln Township, WI, Tab 8, 2002.

[14] Miller, N.P., E.M. Reindel, D.A. Senzig, and R.D. Horonjeff. *Low-frequency Noise from Aircraft Start of Takeoff*, Proceedings Internoise 98.

[15] Hubbard, H.H. Noise Induced House Vibrations and Human Perception. *Noise Control Engineering Journal*, Volume 19, No. 2, 1982, pp. 49-55.

STATE OF MAINE
BOARD OF ENVIRONMENTAL PROTECTION

In Re:

RECORD HILL WIND, LLC	)	
Roxbury, Oxford County	)	**AFFIDAVIT OF**
RECORD HILL WIND PROJECT	)	**MICHAEL A. NISSENBAUM, M.D.**
L-24441-24-A-N (approval	)	
L-24441-TF-B-N (approval)	)	

I, Michael A. Nissenbaum, M.D., being first duly sworn, do depose and say as follows:

1. My name is Michael A. Nissenbaum, M.D. I am a graduate of University of Toronto Medical School with post graduate training at McGill University and the University of California. I am a specialist in diagnostic imaging, whose training and work involves developing and utilizing an understanding of the effects of energy deposition, including sound, on human tissues. I am a former Associate Director of MRI at a major Harvard hospital, a former faculty member (junior) at Harvard University, and a published author. A copy of my CV is attached to this Affidavit as *Exhibit A*.

2. I give this Affidavit in support of citizens of the Roxbury, Maine area who are requesting the Board of Environmental Protection ("BEP") to grant a hearing on the health effects of the proposed Record Hill Wind Project.

3. I developed an interest in the health effects of wind turbine projects after becoming aware of and investigating the wide spread and serious health effects suffered by most of the residents of Mars Hill, Maine who live in proximity to a linear arrangement of wind turbines comprising a ridgeline wind Industrial Wind Project. I am preparing a formal study, which includes a control group, on the subject for publication in a peer reviewed medical journal. The draft will be sent to the New England Journal of Medicine for consideration for publication.

I attach a slide show on the preliminary findings of my research project as *Exhibit B* to this Affidavit.

4. There are some differences in the Mars Hill Wind Project now operating and the proposed Record Hill Wind Project. However, there are also some similarities regarding the DEP assessments and permitting process applied which are generally acknowledged to have failed in Mars Hill, and yet were applied once again at Record Hill. It is my opinion that the BEP should hold a public hearing to examine the potential health effects of the Record Hill Wind Project given the potential seriousness of the health issues, and to ensure that an appropriately corrected modeling process (compared to the flawed model that was in fact used) is implemented to best predict the sound emissions that can be expected from the Record Hill Wind Project.

5. The Final Order in the Record Hill application states at page 10 that "Enrad stated that infrasound has been widely accepted to be of no concern below the common human perception threshold of tonal sounds." This statement is in error. **Infrasound has not been widely accepted to be of no concern other than by non-physicians doing work contracted by members of the Wind Industry, and some of the key non-physicians utilized by the Wind Industry have issued self conflicting and contradictory opinions on the issue. There has been no medical refutation of the potential negative health effects of infrasound emmited by Industrial Wind Turbines and the subject is at the least an open medical issue of concern warranting immediate investigation given the haste with which Industrial Wind Projects are being planned and established. There is additionally at this point a small body of unrefuted medical research indicating that there may be problems associated with infrasound. Regardless, there are clear issues relating to audible low frequency noise of a persistent, pulsatile nature such as created by Industrial Wind Turbines.**

6. The Final Order in Record Hill at pg. 10 also states that "MCDC found no evidence in peer- reviewed medical and health effects from noise generated by wind turbines other than occasional reports of annoyances." **While the word 'annoyance' has been used in European studies relating to this turbine noise, the term has been misinterpreted by the Wind Industry and the Maine CDC to mean an inconsequential disturbance, whereas the authors , not being medical doctors, and not being native English speakers, did not describe the health significance or severity of the 'annoyance' in medical terms. A review of the Mars Hill and Ontario findings, however, indicates that this 'annoyance' is one of the root causes of the sleep disturbances and secondary negative health effects suffered by the residents of Mars Hill, Maine.**

7. Furthermore, and more significantly, the Maine CDC did not investigate the cluster of health complaints in Mars Hill for potential significance. Given that Mars Hill potentially represents a new negative health phenomenon resulting from the interaction of a ridge line source of Industrial Wind Turbines sited too close to human dwellings after faulty pre installation sound modeling, this represents a failure of the Maine CDC to comply with its mandate to investigate newly arising health issues to better understand them and propose solutions for mitigation and future prevention where required. **As such, any statements emanating from the Maine CDC on this subject must be viewed as being based on incomplete information, at this point in time.**

8. **Ex-Governor Angus King, a principal in the Record Hill Wind Project, has publicly admitted to mistakes made in Mars Hill. To the extent that these mistakes relate to faulty pre installation sound modeling, he should be expected to agree that the same modeling mistakes should not be repeated in Record Hill.**

9. Credible evidence of negative health effects from Industrial Wind Projects has been collected in Ontario, Canada by Robert McMurtry, M.D. My own preliminary but significant findings from Mars Hill, Maine and a draft of a potential landmark book, "Wind Turbine Syndrome" by Nina Pierpont, M.D.., and others, are also new sources of concern. Dr. Pierpont is an accomplished and well respected physician who is making significant contributions to the body of knowledge on the health impacts of wind turbines. Her basic premises have been well received by some of the foremost experts in the field of Otorhinolaryngology and Otology. I furthermore agree with her statements and recommendations at pages 11-12 of an excerpt of her Draft Report attached hereto as *Exhibit C*.

10. On Saturday, September 12, 2009, the Maine Medical Association passed a resolution, attached hereto as *Exhibit D*, expressing enough concern about the potential health effects of wind projects to urge caution and appropriate sensitivity in siting and permitting, as well as further studies on the subject.

11. This resolution was passed over the prior objections (to a similar resolution in an MMA subcommittee) of the Director of the Maine CDC. The Maine CDC Director's refusal to recognize even potential negative health effects of wind power projects, and her public statements urging the rapid establishment of Industrial Wind Projects in Maine seem to be at odds with the caution expressed by the wider medical community, as indicated by the attached Maine Medical Association resolution, and, as noted above, appears based upon erroneously interpreted and incomplete information.

12. Pending the use of more appropriately designed modeling studies, and the establishment of more appropriate regulations, the DEP and LURC should exercise more caution and deliberation prior to permitting additional IndustrialWind Projects, recognizing that

there are still currently unknowns. The physical scale of the Industrial Wind Turbines used today is relatively new and we are only beginning to learn, as physicians, about the presence or absence of negative health effects that may result from poor siting decisions. In so doing, they will be better discharging their responsibility to protect the health and safety of Maine citizens.

13. I urge BEP to hold a public hearing on the appeal of the DEP Final Order for Record Hill on health effects of the approved Industrial Wind Project and, if that hearing is held, I will give testimony summarized in this Affidavit.

Dated: September 17, 2009

Michael A. Nissenbaum, M.D.

STATE OF MAINE
Aroostook, ss.

September 17, 2009

Personally appeared the above-named Michael Nissenbaum, M.D., and being sworn, made oath that the foregoing statements by him described are upon his own knowledge, information and belief and that, so far as upon information and belief, that he believes this information to be true.

Before me,

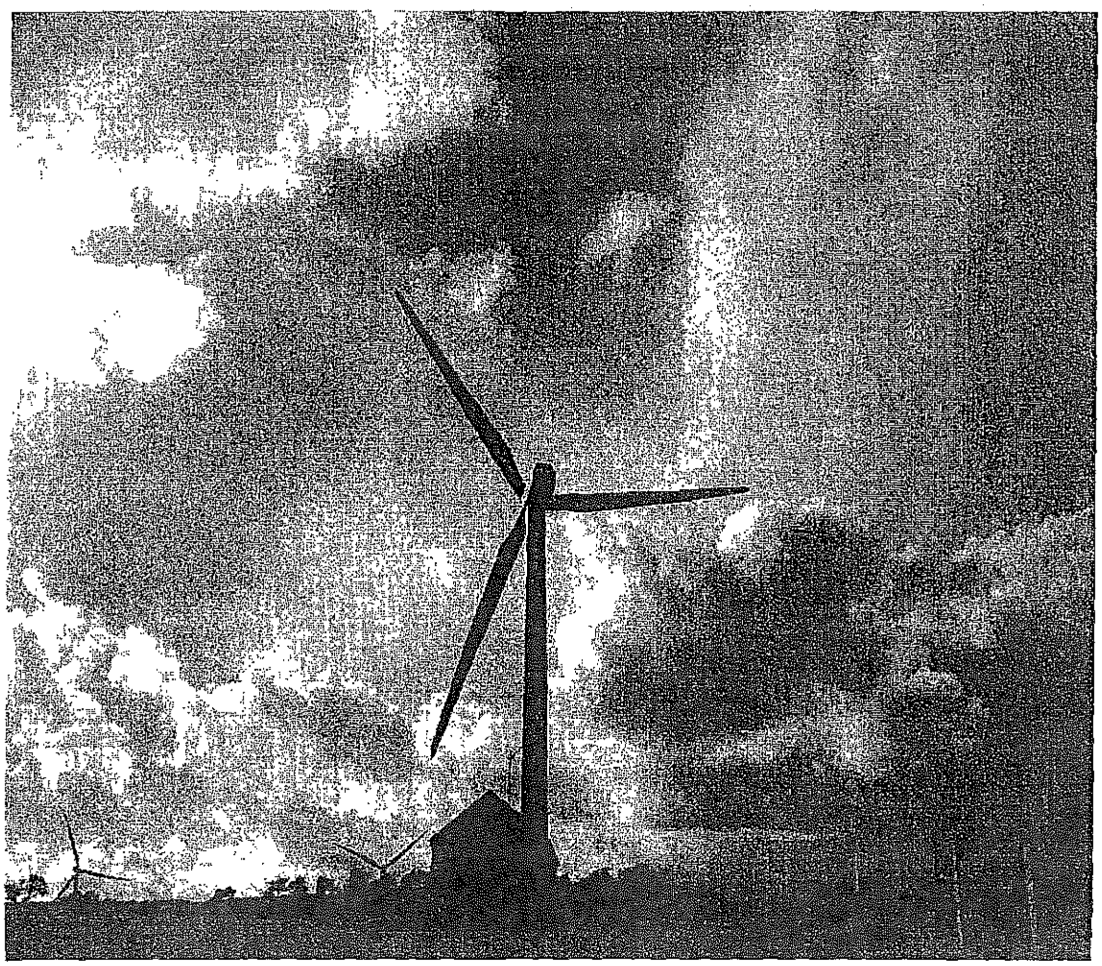
Sally Carrier

Notary Public/Attorney-at-Law
My commission expires:

SALLY CARRIER
Notary Public, Maine
My Commission Expires
February 1, 2014

Location, Location, Location

An investigation into wind farms and noise by The Noise Association



Noise - 'unwanted sound' – can ruin people's well-being and environment

"Peace and quiet is the single most important factor people have in mind when buying a home – with one in five prospective homebuyers rating it as the most important consideration when choosing where they will buy." Alliance and Leicester Survey, 3/6/02

The Noise Association, which published this report, is the research arm of the UK Noise Association. Both organisations are based at 2nd Floor, Broken Wharf House, 2 Broken Wharf, London EC4V 3DT, tel 020 7329 0774, email info@ukna.org.uk www.ukna.org.uk

Contents

Preface

The old windmill is remembered with fond nostalgia. Today's wind farms, by contrast, are causing much controversy. For a variety of reasons they are dividing local communities, green pressure groups, politicians and environmental experts. This report aims to map out a constructive way forward with respect to one of the principal areas of controversy – noise. The report assesses noise from onshore wind farms; it is not concerned with offshore wind farms or any other aspect of the wind farm debate.

We discovered that there is some disagreement amongst acousticians on the impact of wind farm noise. This report reviews the latest evidence. But, in many ways, more important than the theory, is what people who are living with wind farms are saying. We sought their views too, but found that they don't speak with one voice either!

While surveys suggest that wind turbines are not causing a noise problem for the majority of communities, there are people who are suffering badly as a result of the noise generated by neighbouring wind farms. While opponents of wind farms tend to raise noise as an important part of their case against wind power, the wind power industry and its allies can refuse to acknowledge the extent of the suffering that this noise can cause and they sometimes deny its very existence.

Our own conclusion, after reviewing the evidence, is that there is a practical way forward. There are mechanical improvements that can be made to wind turbines, but the key lies in the title of our report – 'Location, Location, location'. So much depends on the location of the wind farm relative to where people live. In the following pages we explain why we have reached this conclusion and suggest a way in which on-shore wind farms can be built without causing unacceptable noise problems.

I hope you find the report a constructive contribution to the debate.

John Stewart

Introduction

The UK, along with other countries in the world, particularly the rich countries, needs to find ways to cut its 'greenhouse gas' emissions. The UK produces about 2.6% of reported global emissions, CO_2 being the most significant of those gases and one which most scientists believe to be the principal cause of climate change. Electricity generation currently accounts for 28% of these CO_2 emissions and, with a very high proportion of UK electricity sourced from fossil fuels, there appears to be a clear need to develop technologies which do not emit greenhouse gases.

The other factor driving the Government's desire to find alternatives is the diminishing reserves of oil. Scientists differ on when the world will become seriously short of accessible supplies of oil, but there is no dispute that it will happen. Governments across the world, therefore, are trying to develop alternative sources of energy.

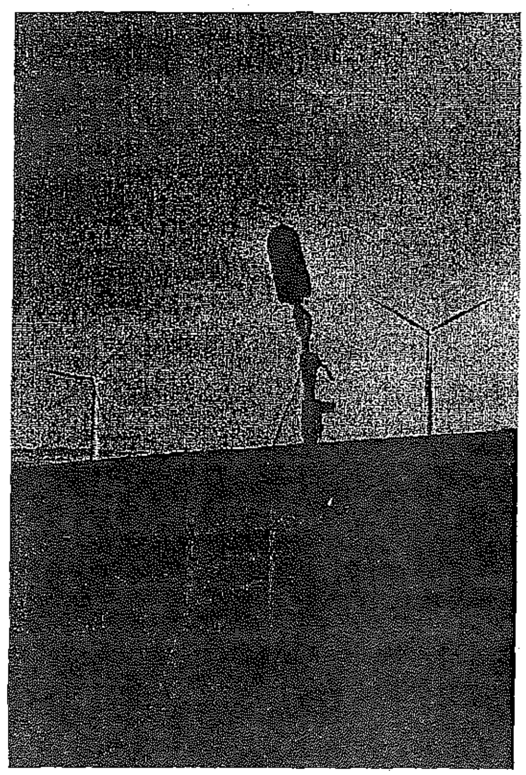
The UK Government has set a target of generating 10% of the country's electricity from renewable sources by 2010. Wind farms could be part of the answer. Government policy is to encourage industry to invest in wind farms through a system of subsidies financed by the electricity consumer. The ultimate aim is that between 60% and 70% of UK wind power will be generated off-shore but most of the first turbines are being built inland as these are cheaper to build and provide an opportunity to test out the technology before going off-shore.

Over the last few years there has been a huge growth in the number of wind farms. By the middle of last year there were over 100 wind farms in the UK, with a further 19 under construction, another 62 having been given consent, and 150 awaiting planning permission.

This officially-sanctioned growth has delighted the supporters of wind farms, but has lead to the emergence of vocal opposition. Green pressure groups – notably Greenpeace, Friends of the Earth and the World Wildlife Fund (WWF) – have supported the idea of developing wind farms. The Royal Society for the Protection of Birds (RSPB) has given general support, except in cases where birds would be badly affected. The Campaign to Protect Rural England (CPRE) has been much more wary.

Some local opposition groups have been assisted by Country Guardian and, latterly, the Renewable Energy Foundation (REF). Visual intrusion and the impact on the landscape are the reasons most frequently cited by opponents of wind farms. At a policy level, some of the opponents question the viability of wind farms and dispute the amount of electricity they will actually generate.

Wind farms have also divided noise experts. There is an on-going technical debate about the noise and vibration produced by wind farms. The debate has led some acousticians to question whether the Government's noise guidelines for wind farms are rigorous enough.



It is to noise we now turn

How Turbines Work

Wind turbines consist of:

- a tower which is between 25 and around 100 metres high;

- a nacelle (similar to the device used in the outer casting of the engine of an aircraft) containing the gearbox and the generator, which is mounted on top of the tower,

- 3 blades, which can reach a significant tip height, that rotate around a horizontal hub protruding from the nacelle.

There are two potential sources of noise: the turbine blades passing through the air as the hub rotates, which creates aerodynamic noise; and the gearbox and generator in the nacelle, which creates mechanical noise.

Mechanical Noise
In the turbines erected during the last ten years, the manufacturers have been able to reduce the mechanical noise from the gearbox and generator to the point where it is generally accepted that it has ceased to become a problem. In any event, the mechanical noise in new turbines is at a level below the aerodynamic noise.

Aerodynamic Noise
As the blades past through the air, they create aerodynamic noise. This noise can come from the speed at which the blades are turning, the angle at which they are set, and indeed the way they are designed. It is the blades which are the cause of the "swish, swish, swish", the thudding sound which is the main noise people complain about. This thumping sound can be made worse if wind turbines on a particular site are placed too close together – the turbulence from the more upwind turbine can create additional thumping from the blades of turbines sited downwind of it. The turning of the blades can also generate low-frequency noise in certain atmospheric conditions (*see low-frequency noise pages for details*).

Modern, Larger Turbines
New turbines are generally mechanically quieter than those installed in the early 1990s. But there are two important caveats to this. Recent research from the Netherlands (1) suggests that the larger modern turbines may be significantly noisier than previously thought. Fritz Van den Berg, a physicist at the University of Groningen, has published a study which argues that the methods used to predict noise from turbines are flawed. He challenges the assumption that wind speeds measured at a height of 10 metres are representative of wind speeds at the greater heights of modern turbines (often 100 metres and above) – because the wind speeds can be markedly greater than at 10 metres.

Van den Berg argues that this is particularly the case at night when wind speeds may fall at ground level to near zero, but remain fast enough at the height of the turbine to turn the blades. His measurements show that wind speeds at night are 2.6 times higher than would be expected. The result can increase the noise experienced by residents at ground level by 10 decibels in areas where there is limited background noise to mask it.

He is supported by other acousticians. Paul Botha wrote: "The historical use of 10 metre high wind speed measurements for the acoustic assessment of both wind turbines and wind farms has the ability to create inaccuracies and sometimes confusion around sound power levels, noise predictions and even demonstration of wind farm compliance. The use of 10m high wind speed measurements appears to be largely historic and there are advantages in using hub height wind speeds throughout the noise assessment process." (2)

Eja Pedersen also acknowledges Van den Berg's work: "Common hub height of the operating wind turbines today in Sweden is 40-50 meters. The new larger turbines are often placed on towers of 80 – 90 meters. The wind speed at this height compared to the wind speed at the ground might (up to now) have been underestimated." (3)

The other concern is that the substantially larger blades the bigger turbines use can make more noise than smaller blades as they cut through the air.

Low-Frequency Noise
Wind turbines also produce low-frequency noise. When the wind and turbulence are high, the movement of the turbine's blades through the air can produce low-frequency noise. Wind farms sited on the very top of hills are particularly prone to such turbulence. Dr Geoff Leventhall, the man whose name has become synonymous with low-frequency noise, put it like this in his paper to a recent Berlin Conference: "All wind turbines produce low frequencies, mainly mechanical noise, which has been reduced to low levels in modern turbines, but there are circumstances in which turbines produce increased levels of low frequency noise. This is mainly when inflow air to the turbine is very turbulent and there are interactions between the blade and the turbulence." (4)

Wind Farms and Noise – the official guidelines

Acoustics is no different from any other area of science – the scientists don't agree! There are several technical disputes raging amongst acousticians about the impact on noise and vibration from wind turbines. There is no reason to suppose that they won't go on for many a year. But it is worth understanding some of the key points being made because they could point to a realistic and constructive way forward.

The Government Stance

The starting point has to be the Government's noise guidelines for companies applying for planning permission to install wind turbines. They are called *The Assessment and Rating of Noise from Wind Farms (ETSU-R-97)*, issued by the Department of Trade and Industry (DTI).

There are separate, though similar, ones for Scotland called *A Planning Advice Note on Renewable Energy Technologies (PAN 45)*, issued by the Scottish Office Environment Department in January 2002.

These guidelines are the starting point because, at present, planning departments and planning inspectors rely upon them when evaluating the potential noise impact of a proposed wind farm. Critics of ETSU R 97 say that it does not deal adequately with amenity issues.

<u>The government guidelines recommend that:</u>

- Daytime noise levels outside the properties nearest the turbines should not exceed 35-40dB(A) or 5dB(A) above the prevailing background, whichever is the greater.

- Night noise limits outside the nearest property should not exceed 43dB(A) or 5dB(A) above the prevailing background, whichever is the greater.

- That a penalty should be added to the predicted noise levels if a tonal component is present in the noise.

The British Wind Energy Association, a trade organisation which supports wind power, argues, with the support of some acousticians, that these guidelines are adequate to deal with the noise impacts of turbines, but this view is not accepted universally in the acoustic community. We assess the adequacy of the guidelines on later pages in this report.

Facts about Noise

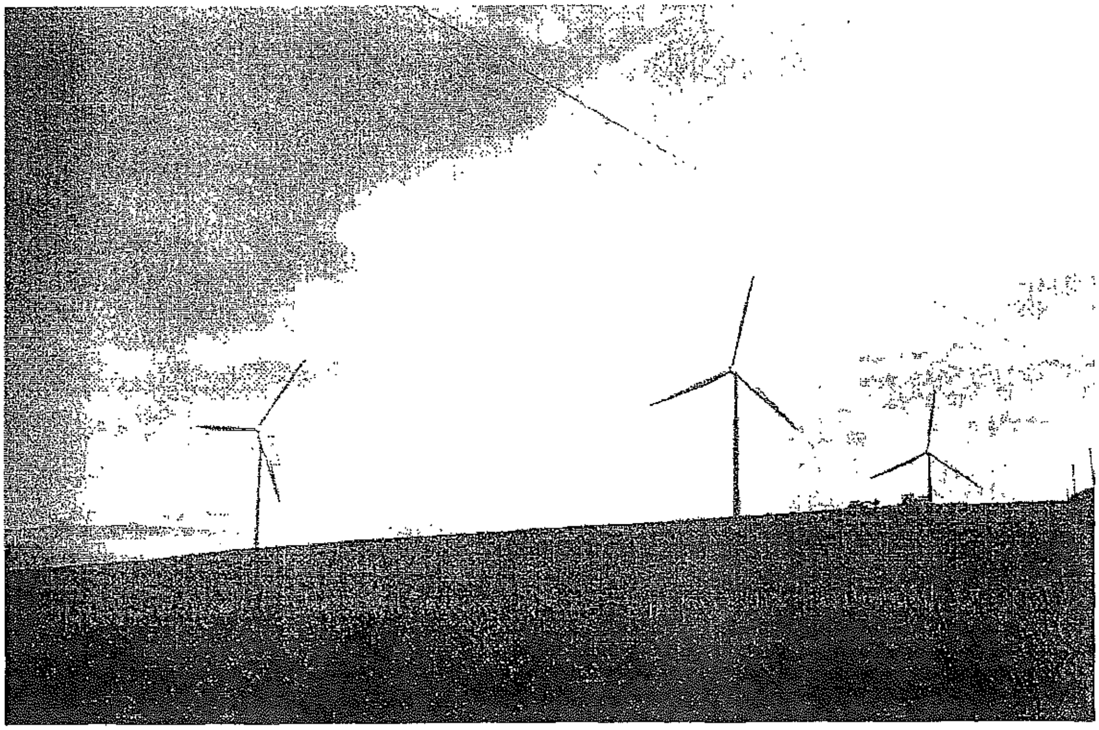
- Noise can be defined as unwanted sound.

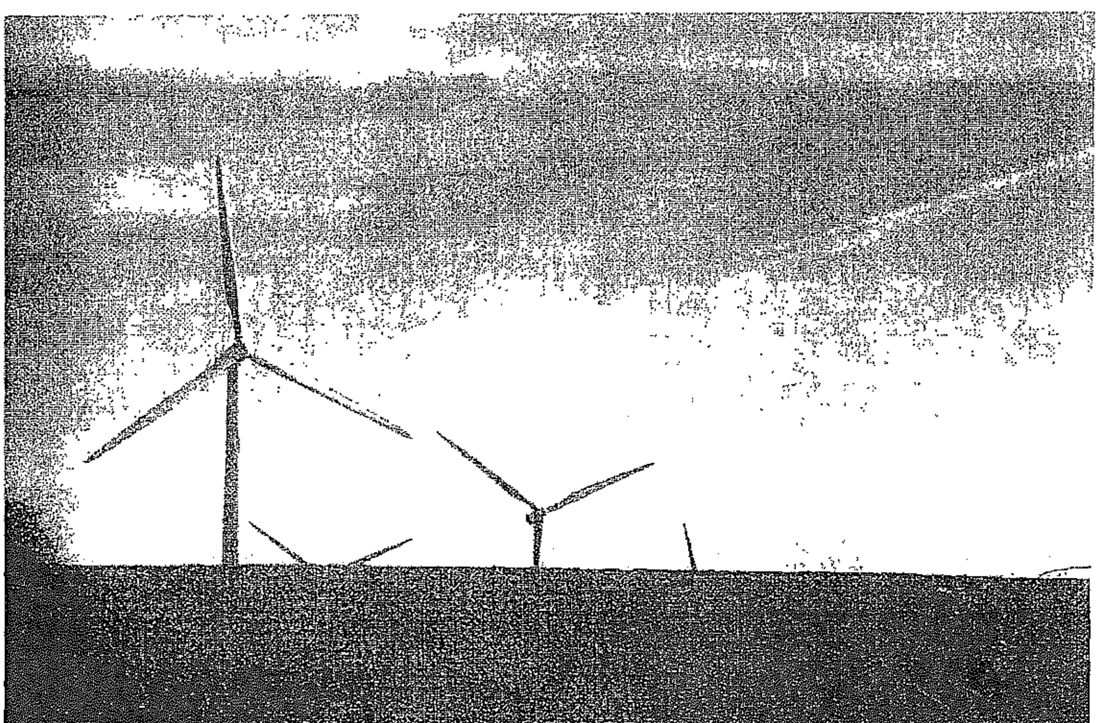
- Noise levels are normally expressed in decibels (dB). A one decibel change in the noise level is just perceptible, a three decibel change is clearly perceptible while a ten decibel change is heard as a doubling or halving of the perceived level.

- Noise levels are usually measured using 'A' weighting – dB(A). Sometimes noise is averaged out over a period of time – to give a reading dB(A) LAeq.

- 'A' weighting is the subject of some controversy. Some acousticians argue that 'C' weighted measurements should be taken in addition to capture low frequency noise.

- In addition to the decibel level (measuring loudness), the frequency of noise is measured in terms of Hertz (Hz). Frequency is to do with the pitch of the noise rather than its loudness. It is the combination of the pitch and the loudness that determines what people hear. It can also have a bearing on a person's health.





Wind Farms and Noise - what the surveys reveal

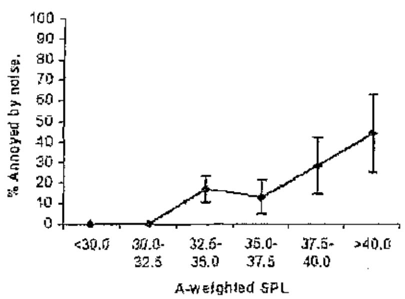
The most comprehensive surveys into people's attitudes to wind farm noise have been carried out in the Northern European countries.

EU Study

In the early 1990s a major study, partly financed by the European Community, was carried out in the Netherlands, Germany and Denmark.(6) The majority of residents questioned experienced noise levels of around 35 decibels (within the limit where noise is officially considered to be a problem for most people). The study was presented in two parts – the German/Dutch findings and the Danish findings. In Germany and the Netherlands, 6.4% of people said they were annoyed by the noise. In Denmark, 7% said they were "rather annoyed" and 4% "very annoyed".

Swedish Study

In 2000 a study by Pedersen was carried out in Sweden.(7) It found that annoyance increased with noise levels.



No residents were very annoyed at levels below 32.5 dBA LAeq. 20% were very annoyed at levels between 37.5 and 40dBA LAeq and 36% when levels were above 40dBA LAeq. Pedersen's study also compared the reactions of people who described themselves as noise sensitive with those who did not. It found there was little difference at levels below 35dBA LAeq, but that at higher levels noise sensitive people rapidly became more annoyed.

All the European studies found that there was a statistically significant link between noise annoyance and annoyance at the flicker effect created by the blades of the turbines.

MORI Survey

In this country MORI conducted a poll for the Scottish Executive in 2003.(8) MORI surveyed people living within 20 kilometres of Scotland's operational wind farms. It asked them about the strengths and shortcomings of living in their areas. It found that, unless prompted, less than 0.5% mentioned wind farms at all. When specifically asked about wind farms, 20% of residents felt they had a broadly positive impact on their area, with 7% feeling they had a negative effect, and 1% saying they were noisy. Most people felt they had neither a positive nor negative effect, even those living within 5 miles of the turbines, but, MORI did not do detailed work with people living within ear-shot of wind farms, the critical area in assessing the impact of wind farm noise. It means the study is of little value to us which is a pity because their general approach, which avoided asking people directly if they were disturbed by wind farm noise (when negative responses rise sharply), is applauded by most social scientists.

Wind Energy Study

In 1994, the British Wind Energy Association commissioned a study of 250 local residents near the 12 turbine wind farm at Kirkby Moor in Yorkshire, six months after it started up. It revealed 83% were "not all concerned" or "not very concerned" about the noise they made.

These studies suggest that while some people relatively close to wind farms do not consider noise to be a major problem, it is a big concern for others. This is illustrated by statements below:

"Our small cottage is just over half a mile from one of these turbines and approximately 200ft lower in elevation. The noise from this one turbine is at times unbearable. At best we get a constant pulsating thump from the blades as they cut through the air. During the summer months it sometimes becomes impossible for us to sit out in our garden. When we go inside it becomes unacceptable for us to have our windows open because the pulsating noise is so invasive."
Letter in the Carmarthen Journal May 2005

"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 anymore – the noise was unbearable. It was as if someone was mixing cement in the sky." **Daily Telegraph 24/1/05**

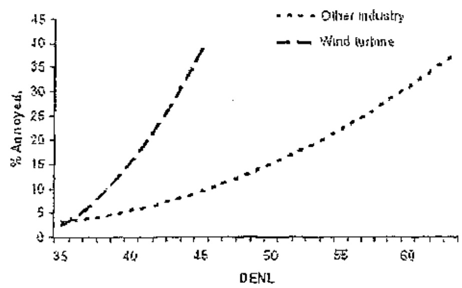
"A recent settler in Caithness claimed yesterday his life is being blighted by ghostly noises from his new neighbours, the county's first large-scale wind farm: 'The problem is particularly bad at night when I try to get to sleep and there's a strong wind coming from the direction of the turbines. They just keep droning on. It's a wooh wooh type of sound, a ghostly sort of noise. It's like torture and would drive anyone mad'." **Aberdeen Press and Journal, 25th May 2005**

"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, unpleasant and may have some psychological effects."
The conclusion of the Welsh Affairs Select Committee after investigating wind farms. (9)

Wind Farm Noise – the general impact

There is little or no dispute that the "swish, swish, swish" of the blades of a wind turbine as they pass through the air make a noise.

Most noise complaints about wind farms are about this swish. What is interesting is that wind farm noise generates many more complaints than equivalent levels of noise from most other sources, including road noise. It is worth trying to find out why this is.



The results when Pedersen and Persson Waye looked at how annoyed people become by different noises

Pedersen and Persson Waye in as yet unpublished work following up their 2002 study *Storiningar fran Vindkraft* found that, once the noise levels exceeded the 35 decibel mark, the percentage of people annoyed by wind farm noise rose much more rapidly than with the other 'stationary' noises. They have tried to assess the reasons for this. Pederson, in a paper (10) (presented to a major conference held in Berlin on Wind Farm Noise last October) based on her work, wrote: "the informants' descriptions of their feelings when exposed to wind turbine noise, as well as shadows and the rotating movement of the rotar blades, were in our analysis interpreted as an intrusion into private domain. The noise was physically perceived in the living environment, e.g. in the garden, in spite of the bushes and fences put up to keep out invaders, and was to those who could not mentally shut it out, an obstacle to pleasant experiences decreasing the joy of daily life at home. For some informants, the intrusion went further into the most private domain, into themselves, creating a feeling of violation that was expressed as anger, uneasiness, and tiredness."

The noise was physically perceived in the living environment................to those who could not mentally shut it out, an obstacle to pleasant experiences, decreasing the joy of daily life at home.

What is interesting is that wind farm noise generates many more complaints than equivalent levels of noise from most other sources, including road noise. It is worth trying to find out why this is

Pedersen's view that it is the combination of the noise, the flickering shadows and the rotating rotar blades that creates the big problems with wind farms is echoed by Dr Amanda Harry, who has done work with communities complaining about the effects of wind farms in Cornwall. We return to her work and explore some of these points in some detail in the *Noise and Health* section of the report.

A major expansion of wind farms could not be justified if it were to result in these problems being replicated across the country.

Recommendations

1. There needs to be a clear and public recognition by the Wind Power Industry that wind turbines are causing significant noise problems for some people.

2. The industry should continue its work to develop quieter turbines.

3. There is case for a moratorium on the installation of the very tall turbines until trials have been undertaken to accurately assess the noise they actually make.

4. Wind farms should only be located in areas where the "swish, swish" of the turbines will not cause noise problems for people.

5. There needs to be further research into the link which has been identified between noise annoyance and the annoyance of the flicker effect created by the blades of the turbines – and the potentially harmful effect this may have on people's health – *see noise and health section.*

Wind Farm Noise – the impact on areas of low background noise

Mid-Wales – a land of hills and valleys. A place where the wind blows frequently and the population tends to be thinly spread. Ideal for wind farms. And, not surprisingly, many are planned.

The best place very often for the turbines to catch the wind is close to the top of a hill. It means that the wind turbines can be at their most productive.

But it also means that the noise may cascade down the surrounding valleys. To makes matters worse, many of the scattered hamlets within the valleys snuggle into corners protected by the hills and the mountains where the background noise level is very low indeed. You only need to visit these areas to hear the 'swish, swish, swish' of the turbines – particularly downwind – over a mile away from the wind farm.

It would appear that the current government guidelines aren't robust enough to deal with areas where the background noise is so low.

<u>The guidelines state:</u>

• daytime noise levels outside the properties nearest the turbines should not exceed 35-40 dB(A) *or 5 dB(A) above the prevailing background, whichever is the greater.* (my emphasis)

• night noise limits outside the nearest property should not exceed 43 dB(A) *or 5 dB(A) above the prevailing background, whichever is the greater.* (my emphasis)

Very low background noise levels

But what if the background level drops as low as 15–20 decibels – as has been recorded in mid-Wales? It means that a turbine creating the maximum amount of noise permitted – 40 or 43 decibels – is way above the background level.

We could trace no study which looked at the impact of wind turbine noise in areas where background noise was unusually low. But a number of studies have been carried out into the impact of aircraft over flying 'wilderness' areas. The most important of these was carried our by Fidell in the USA.(11) It found that people said they were highly annoyed by levels of aircraft noise 7 decibels lower than they would have been in a built-up area.

Are the guidelines adequate?

There is a lot of concern about what the ETSU recommendations say in areas where the background noise levels are low. They aim to give "*indicative noise levels to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or planning authorities.*"

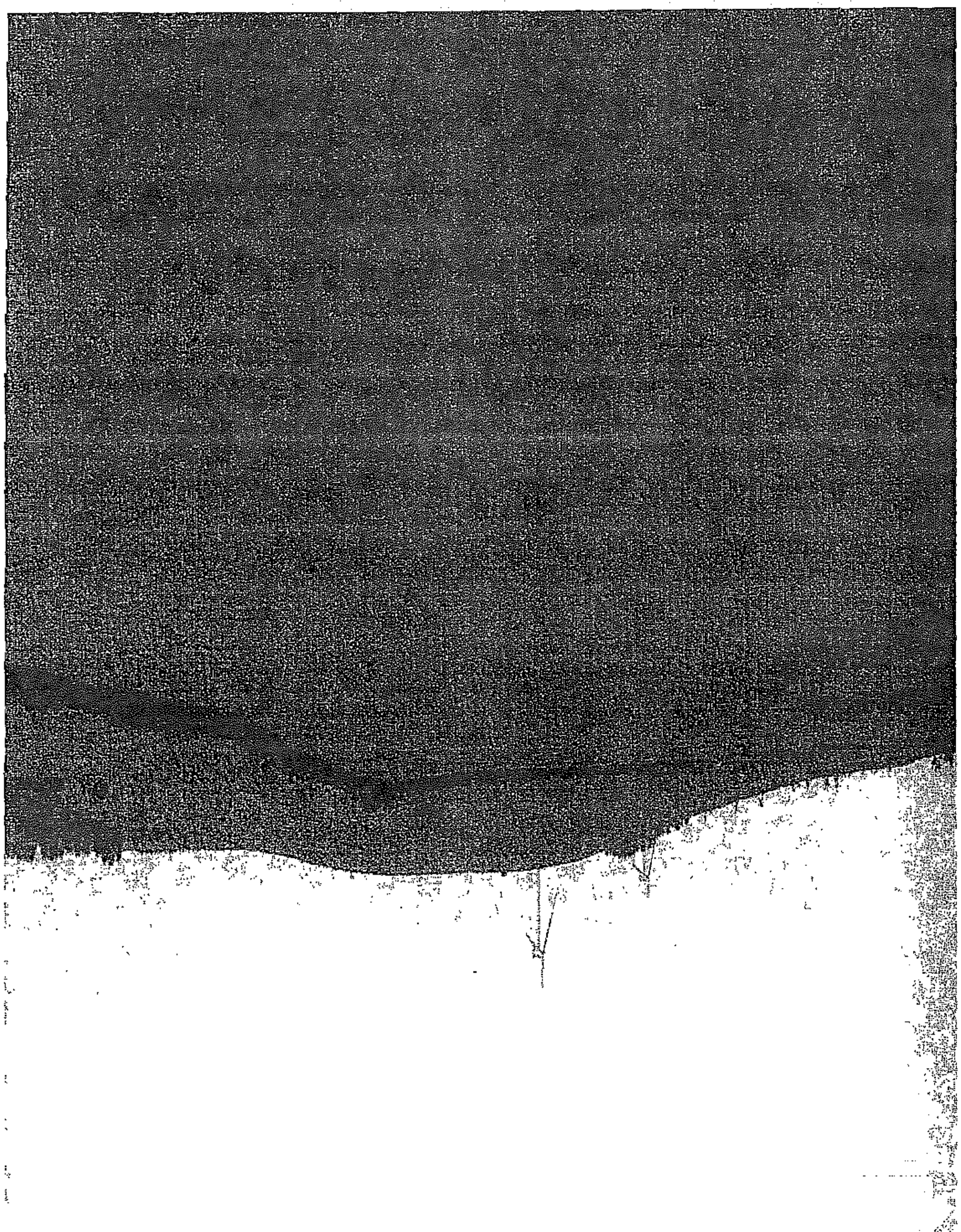
This is quite different from the procedures required by other industries:

"The assessment compares the noise source with existing background noise. A background noise survey must be performed during the proposed operating hours. The worst hour during day time is measured, and the worst 10 minutes at night. Following analysis and corrections to the data in accordance with BS4142 the difference between the source and existing noise level is determined. A difference of +10dB is a positive indication that complaints are likely. A difference of -10dB is a positive indication that complaints are unlikely. A difference of +5dB is said to be of marginal significance."(12)

In other words, the noise levels are not expected to reach decibels significantly above the background noise level. This is the policy that has been adopted by the Dutch province of Utrecht (actually a relatively urban area) as a result of initial opposition to wind farm proposals for the area. Local authorities in Utrecht are required to go through detailed procedures to ensure that wind farm noise does not exceed the levels of background noise. (13)

<u>Recommendation</u>

That the wind farm guidelines (ETSU) be revised to make them more meaningful to areas where the background noise level is unusually low. Revised guidelines, taking account of low background noise levels, which led to wind turbines being more sensitively sited in rural areas – such as mid-Wales, Cornwall and Devon and the Scottish Highlands – would be a constructive step that would reduce conflict and promote consensus.



Wind Farm Noise - the impact of infrasound and low-frequency

What is low-frequency noise?

There is a strong low-frequency element in many of the gadgets we have these days. It's found in the hum of the fridge, the washing machine or the air conditioning. It's very much present in the bass of a sound system. It is not conventionally 'loud' - frequency is to do with the pitch of the noise rather than its loudness. Low-frequency is generally defined as noise between 0-150/200 hertz (Hz), with sounds at the lowest range, 0-20 hertz, known as infrasound.

We all can hear some low-frequency noise – particularly if it reaches a high decibel level – but there are variations in the audibility threshold from person to person which means that some people can hear low-frequency sounds not audible to the rest of the population – **see box**. For these people something like their neighbour's central heating, if it is making a noise, can sound like "living inside an organ pipe." (15)

The source of low-frequency noise can be difficult to trace as it can travel, both through the ground and through the air, much further than conventional sound. Some sources of low-frequency noise, if traced, can be dealt with. For example, a dodgy fan may just need to be properly encased. Other sources – such as oil pipelines – are more problematic.

Noise, at any frequency, can penetrate buildings but the effect is greater in the case of low-frequency noise. The result is that low-frequency noise is much more disturbing indoors than outside. Sometimes the low-frequency noise, from an external source, has embedded itself within the walls of the building and it is that which the low-frequency sufferer is hearing. It means that measurements of low-frequency noise should be taken indoors as well as outside.

Measuring low-frequency noise

To correctly assess the impact of low-frequency noise, both the loudness of the noise (decibels) and the pitch (hertz) must be measured. It is the combination of the two that determines whether and how badly people will be affected by the noise.

Many acousticians would argue that, when measuring low-frequency noise, 'C' weighting should be used rather than the conventional 'A' weighting which doesn't pick up the lowest sounds. They are backed up by the noise experts at the World Health Organisation who argue that "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 10dB, it is recommended that a frequency analysis of the noise is performed."(14) Other people argue that only when there is a 20dB difference is there likely to be significant low-frequency present. ('G' weighting is usually recommended for infrasound).

Dr Geoff Leventhall agrees there are times when 'A' weighting is not entirely adequate: "Audible low-frequency noise does have annoying characteristics which are not shown in conventional environmental noise measures, such as A-weighting."(4) But still most wind turbine measurements continue to use 'A' weighting.

The Low-Frequency Noise Sufferer

Hazel Guest, a low-frequency noise sufferer and a former lecturer in mathematics at London's City University, wrote (15) "the audibility threshold varies considerably from person to person. But for those who do hear low-frequency, it can be very distressing. It has been described as 'like living inside an organ pipe'." It is not the same as tinnitus. If it were tinnitus, it would mean there was a 'ringing in the ears' all the time. That is not the case with low-frequency noise; it is location specific. Guest argues that the noise can be heard, if it is loud enough, when the frequency is below 20 Hz. The low-frequency sufferer seems to hear something quite different from 'conventional' noise. Hazel Guest has described it "like living inside an organ pipe". Others have talked about "a thunder in the ears", though this is likely to be a problem of either hyperacusis or an extreme stress response. Manley, Styles and Scott in their paper, (16) argued that, while most people cannot hear noise between 20 hz and 4hz unless it reaches 80 and 107 decibels respectively, "there is no doubt that there is a link between tonal activity above a certain level and the effects experienced by some sufferers.....the difficulty is that while the cause may be real, the precise frequencies and levels at which individuals are affected may vary from person to person, with perhaps only a few percent of the population able to detect them." Hazel Guest is of the view that the unexplained health effects of low frequency noise could be down to the way it interferes with the brain.

When do people hear infrasound and low-frequency noise?

Whether or not people hear low frequency and infrasound depends on the relationship between the loudness of the noise (decibels) and its frequency (hertz).

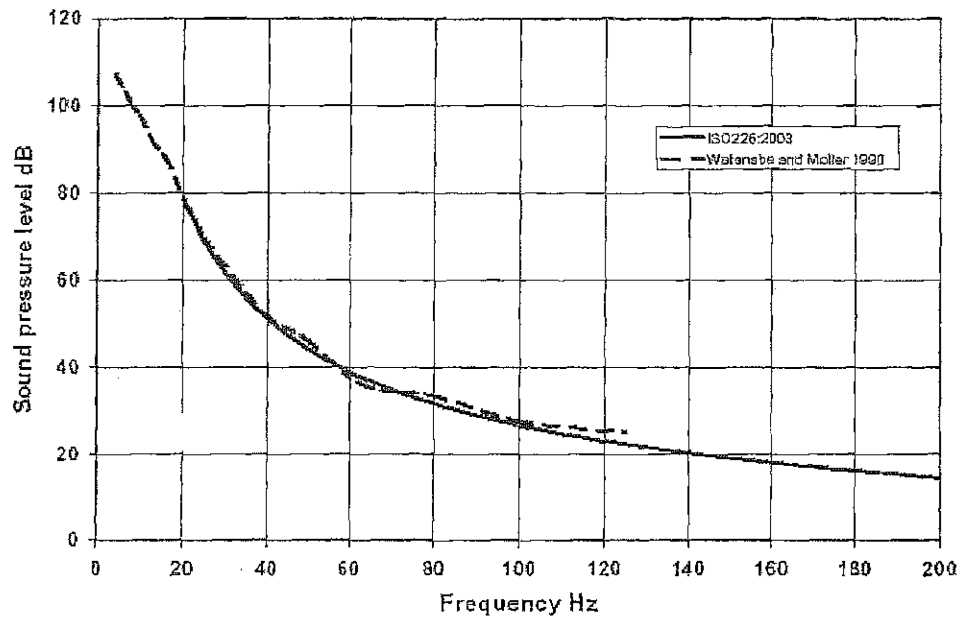


Fig 2. Low frequency threshold

Infrasound

- The median threshold for hearing infrasound at 4Hz is 107 decibels.
- At 10 Hz it is 97 decibels.
- At 20 Hz it is 80 decibels.
- The standard deviation of the threshold measurements is about 6dB, so there will be a very small number of people who may have 12dB or more sensitivity to the mean. For most people, though, noise levels need to be high before infrasound is heard by human beings.

The measurements in the above table, produced by Watanabe and Moller in 1990, are 'G' weighted to best capture infrasound

Low-Frequency

- At 30 Hz, the median frequency is around 60 decibels
- At 40 Hz, it is around 56 decibels
- At 60 Hz, it is around 39 decibels
- At 80 Hz, it is around 37 decibels
- At 100 Hz, it is around 23 decibels.

Wind Farms, Infrasound and Low-Frequency Noise

Are people hearing <u>infrasound</u> from wind farms?

There has never been any dispute that wind turbines generate infrasound. A major study undertaken for the Ministry of Defence (MOD) by Keele University to assess the effect that wind farms might have on its key monitoring facility in Eskdalemuir (17) concluded "we have clearly shown that wind turbines generate low frequency sound (infrasound) and acoustic signals which can be detected at considerable distances (many kilometres) from wind farms in infrasound detectors and on low-frequency microphones." The lead author, Professor Peter Styles, concluded that seismic signals from wind-turbines registering up to 7.5hz can be detected 10 miles from the wind farm. In the report Styles doesn't spell out the levels of infrasound close to the turbines, but he did this in an earlier paper published with Dr David Manley and others.(18) They took measurements at a wind farm in Wales with about 10 turbines. (It is unclear what noise weighting was used).

<u>The survey obtained the following results:</u>

1/3 Octave Frequency Hz	4	5	6.3	8	10	12.5	16	20
Decibel level at100 metres from turbines	62	60	63	66	63	60	60	60
Decibel levels that would be problematic	102	98	94	90	86	82	78	71

These levels are clearly below those that would be problematic, even allowing for a considerable variation in individuals' ability to hear infrasound.

Noise Association Measurements

In the preparation of this report, The Noise Association measured noise levels around three wind farms: Bearsdown and Bradworthy in Cornwall and Blaen Bowi in Wales. The focus of the work was to measure the low-frequency noise, including infrasound. Details in Appendix 1.

<u>The findings in summary:</u>

At 10hz, the noise from the wind farms ranged from negligible (upwind from the turbines) to 75dB(C) (downwind). Because Watanabe and Moller figures are 'G' weighted and the UK Noise Association used 'C' weighting only approximate comparisons are possible. But these findings are well within the 97 decibels where it would become a noise problem at 10hz, whatever the weighting.

At 20hz, the noise from the wind farms ranged from a low of 10dB(C) (upwind of the turbines) to a high 82dB(C) (downwind), with the great majority of the results falling in the 40-70dB(C) range. Again, a direct comparison is not possible with Watanabe, but it is clear that at these levels the noise will be heard by few people.

Conclusion on Infrasound
The findings suggest that at 20hz the very upper range of the infrasound range, there might be a problem for a few people in very specific circumstances, but that infrasound noise from wind turbines will not be heard by most people.

Is <u>low-frequency noise</u> from wind turbines causing people problems?

The important question to be answered here is whether the decibels levels are high enough at low-frequencies (20 – 100/200 Hz) for there to be a noise problem.

Noise Association Findings

At 40hz, the noise from the wind farms ranged from 25dB(C) to 77dB(C). Watanabe found that the noise can't be heard below 56dB(G). Our findings suggest that some low-frequency noise can be heard at times from turbines at 40hz.

At 60hz, the noise from the wind farms ranged from 15dB(C) to just over 80dB(C), with the majority of readings in the 40-70dB(C) bracket. Many of these readings exceed the Watanabe figure of 39 decibels. At this frequency low-frequency noise is being heard at times.

At 125hz, the noise from the wind farms ranged from 20dB(C) to 74dB(C), with the majority of readings between 40-60dB(C). This indicates that at 125hz, the low-frequency content of the "swish" sound is audible.

Comment on the findings

The readings were all taken within about one and a half miles of the turbines. There were variations in the low-frequency levels depending on wind direction and air turbulence. It was usually just when people were downwind and the air was turbulent that low frequency formed a significant part of the noise.

The Noise Association also tested for low-frequency noise indoors

We chose a property in mid-Wales whose residents had been complaining for some years about the effect of the Blaen Bowi wind farm in mid-Wales. The residents have complained, not just about the noise, but the physical effects it is having on their health. The property is in a sheltered valley, about two miles from the turbines which are close to the top of a hill. Detailed results on pages 28 and 29.

The results we obtained were these:

At 10 hz, the noise levels ranged from 44 to 48 decibels, well below the levels at which the noise would be heard.

At 20 hz, the noise levels ranged from 40 to 48 decibels, again well below audible levels.

At 60 hz, the noise levels ranged from 44 to 63 decibels, which suggests that low-frequency noise is being heard at times.

At 100 hz, the decibel levels ranged from 42 to 52 decibels, which indicates that the 'swish' sound is being heard, containing a low-frequency content.

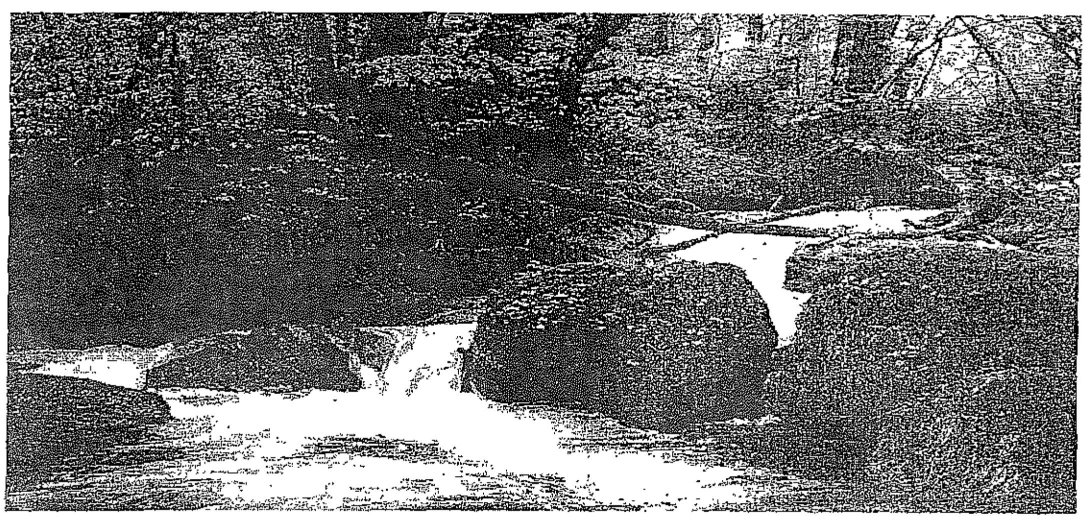
The problems experienced by the two people in this house are very real. They claim that they can 'feel' the noise. Our results certainly suggest that, at times, they can hear the noise. What our results can't provide is any explanation for the claims that they can 'feel' the noise. We can just speculate on the possibility that, in this case, the low-frequency noise, as it can do, has embedded itself within the walls of the property and that it is this, in part, which the occupants are reacting to.

Conclusions

1. There is a low-frequency content in the noise from wind farms that can be heard. It is most marked at the higher range of low-frequency. This means that it is likely it is difficult to separate it out from the 'swish, swish' sound that causes most complaints, but also that it could increase annoyance from the swish sound.

2. The low-frequency content of wind turbines is likely to cause 'low-frequency noise sufferers' a problem. The problem may be no greater, though, than many of them would experience from other potential sources of low-frequency noise, such as air-conditioning or central heating. But it could be amplified in the small number of cases where it resonates with the walls of a building.

3. There is a case for 'C' weighting to be used in measuring wind farm noise as 'A' weighting doesn't fully capture the low-frequency content. 'G' weighting is most appropriate for measuring infrasound.



The Impact on People's Health

People in the United Kingdom have been complaining of health problems since the construction of the wind farms near their homes. In Europe, Australia and North America people have reported similar problems. The range of symptoms mentioned by complainants includes headaches, sleep disturbance, anxiety, depression, stress, vertigo and tinnitus. On pages 18 and 19 we highlight some of the quotes. This section seeks to explain why the symptoms and health problems could be caused by the wind turbines.

There are three ways in which turbines could be affecting people's health.

First, the stress from the noise. When people become seriously annoyed by any noise, they can become stressed out and irritated. This can affect their sleeping patterns, their performance at work or school and their general social and physical well-being. In this respect the "thud, thud, thud" of wind turbines is no different from any other type of noise.

Secondly, the combination of the noise and 'the flicker' from the turbines. We alluded to this on page seven when looking at why noise from wind turbines appears to distress a lot of people much more than noise at similar levels from other sources. We looked at the work of Pedersen and Persson Waye who found that people complain not just about the noise, but also about the vibration and shadow flicker (caused by rotation of the blades and the reflection of the sun). It is this combination, Pedersen and Persson Waye suggest, that could be the reason why wind turbines can have such a devastating effect on some people and on their health: "For some, the intrusion [of the noise, shadows and the rotating movements of the rotor] went further into the most private domain, creating a feeling of violation that was expressed as anger, uneasiness, tiredness."(10).

Thirdly, the overall impact of wind turbines on the body. Some people talk of 'feeling' the noise, in addition to, or even instead of, hearing it. This idea of 'feeling' noise is controversial and complex and not one currently accepted by the majority of acousticians. But there are a number of medical people who are beginning to argue that the dramatic impact which wind farms have on some people's health cannot be explained by the noise and the flicker alone. They argue that the low-frequency content of wind turbine noise (even if it is not heard), along with the 'flicker', can destabilise the human body.

In a paper expected to be published shortly Dr Amanda Harry says, "The low frequencies contribute to the overall audible noise but also produce a seismic characteristic which is one of the common complaints from people when they say that not only can they hear the noise but they can also feel it. This happens because the various parts of the body have a specific natural frequency or a resonance frequency. The human body is a strongly damped system, therefore, when a part of it is excited at its natural frequency, it will resonate over a range of frequencies instead of at a single frequency." (fig 1)

The doctors receive support from the National Academy of Medicine in Paris, presided over by Professor Claude-Henri Chouard. It argues that people living near the towers, the heights of which vary, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma. It points to studies conducted in the neighbourhoods of airports which have demonstrated that chronic invasive sound involves neurobiological reactions associated with an increased frequency of hypertension and cardiovascular illness.

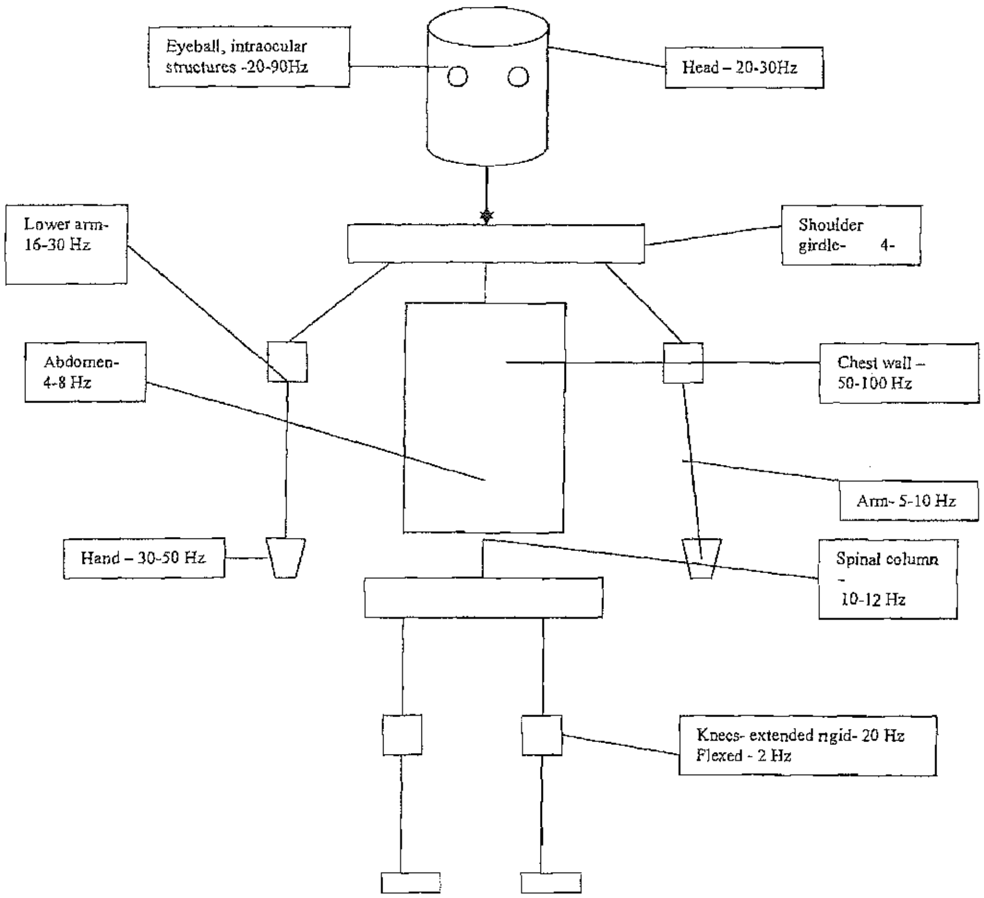
In Portugal, where low frequency noise has been researched extensively, a link has been found with a complex illness known as vibroacoustic disease. Although this research has been mainly concerned with high levels of low frequency noise, it is felt that prolonged exposure to lower levels of low frequency noise may cause similar problems. Certainly the symptoms which some people living around wind turbines complain of are very similar to those of vibroacoustic disease.

Over the years the military has been aware of the way a combination of persistent low-frequency noise, infrasound and visual strobing can destabilise the human body. Some doctors are arguing it at least merits serious investigation to understand whether this sort of cocktail can explain the extreme effect wind farms have on some people's health, an effect seemingly out of all proportion to the noise they make.

Certainly Dr Harry is scathing of the refusal of most acousticians to even look at this area: "On searching through the current literature I can find no papers written showing that turbines are harmless, only statements from acousticians giving their personal thoughts. I feel that these comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent medical researchers".

Fig. 1

The resonance frequency ranges for various parts of the human body- values taken from the International Standards Organisation –ISO standards 2631



A research paper by G Rasmussen (ref) looked at body vibration symptoms vibration exposure at frequencies exposure at frequencies of 1-20 Hz

Symptoms	Frequency
General feeling of discomfort	4Hz – 9Hz
Influence on speech	13Hz – 20 Hz
Lump in throat	12 Hz – 16Hz
Chest pains	5Hz – 7Hz
Abdominal pains	4Hz – 10Hz
Urge to urinate	10Hz – 18Hz
Influence on breathing movement	4Hz – 8Hz

Also in the region 60-90Hz disturbances are felt which suggest eyeball resonances, and a resonance effect in the lower jaw/skull system has been found between 100-200

How Wind Farms Affect My Health - what people are saying

I first realised there might be a problem associated with wind turbines when I was introduced to a couple living near a wind farm in Cornwall. The distance from their home to the nearest turbine is about 400 meters. They told me about poor sleep, headaches stress and anxiety symptoms brought on when the wind was blowing in certain directions. At times, they told me that they have been so disturbed by the noise that after several disturbed nights sleep, they have sought refuge in a nearby bed and breakfast establishment (far enough away not to be similarly affected by the noise).

Dr Amanda Harry went on to conduct a survey on wind farms and health. These results will form part of an academic paper which is expected to be published shortly. The quotes on this page are taken from her work.

I get little sleep when the noise from the turbines is constant in its low frequency noise. I feel so depressed I want to get away and stay away until I know the wind direction has changed.

My symptoms are due to lack of sleep when the wind is in the east or northeast

Constant worry about noise. I feel sick when the turbines are running fast and towards the property. I came here to a rural area for peace after a busy city life. I feel this has been ruined by the turbines.

I get headaches frequently especially when the turbines are running at a fast rate towards us.

Stressed and extremely anxious, as I am constantly disturbed by them when they are turning fast and facing towards me. We are having to live our lives around them due to the constant noise when they are working causing wind pressure throbbing.

I get headaches and thumping in the ears. I also find its continual noise very distressing.

Irritating noise from wind farm in easterly winds. You can almost feel it as well as hear it. It drives you mad over extended periods because of the nature of the noise, not the level per se. Unable to have front doors/windows open when winds are easterly, or use front bedroom if all 7 turbines are in operation.

Suffer with headaches more and feel tired more so find daily tasks difficult to do.

The strobing even when curtains are closed is "HELL". The noise is a pain. TV blocks it, night and day. Can't sit and read a book or write letters.

I dare not sleep at home.

Tired, disturbed by noise Feel it as much as hear it Developers deny there are any problems Unless we can prove it, but how can we do that?

Gwen's Diary

These wind turbines, they're 76m high, there are three of them, they have a looming presence over the beautiful Teifi Valley, I've been trying hard to come to terms with living within a mile of them ever since they appeared there on Moelfre hill twelve months ago.

I've lived here on my farm now with my husband for twenty six years, I know every nook and cranny of the fifty acres. Our farm is only two miles from the farm where I was born sixty years ago, I grew up looking towards Moelfre and was delighted to be farming within my own community. I've been teaching in local schools, I paint landscapes in a converted shed, I've enjoyed good health, twenty six years of hard but rewarding work, I had planned to spend my remaining days here.

Now I sleep in my outhouse shed, it's not comfortable, I don't want to sleep there, I don't choose to be so far from amenities all night and suffer the sounds of mice within a yard of my head. The trouble is that when I am in the house my heart beat seems to alter, there seems to be a repeated slightly thumping pressure on my lungs. There's a slight throbbing in my head, like a headache without the pain. I feel slightly sick. I know that slightly is a term I've used for all the ailments but it is not a normal state of well being. It makes me feel on edge. When I visit a friend on the other side of the valley that's when I feel normal, and that state of normality suddenly seems the most wonderful feeling on earth. To me this is a tragic turn of events. Compared to the total sum of human misery I admit it might sound trivial. Today we had the fire wood cut up for next winter, here we enjoy our own spring water, my garden, my roses and clematis, and oh the first violets and primroses in the woods. The seven thousand trees we've planted, my studio, this is what our life has been about! Now I feel robbed of all I hold dear, and to complicate the situation my husband is not affected by the turbines, he doesn't like the visual impact but they don't make him ill. The low frequency noise/vibrations from the turbines [not the blades] play havoc with my health.

Where do I go from here? When the company was granted permission for the development the local paper reported that this was a lifeline for the struggling Welsh speaking local farmer who otherwise would have had to leave the land, Hey I'm a Welsh speaking local too, where's my lifeline? I belong here, those turbines DO NOT.

A Shattered Dream

All they wanted was the good life in Cornwall, and they needed it for the sake of their health - but no sooner had Colin and Kathy Bird fled the city for a modest rural home than their dream was shattered by the noise from wind turbines.

Last year at Christmas the couple booked into B&Bs in Newquay rather than endure sleepless nights in their caravan home at St Eval. This year they have saved up £1,000 to live in Malta for a month because they cannot bear another winter at home when high winds turn the turbines.

When that noise from the Bears Down wind farm begins, says Kathy, it's like a "a deep throbbing, or a train that never gets there". For Colin it's worse. "You never rest your brain, you never get away from them," he says.

What makes it worse for the couple is that they moved to Cornwall to escape the noise of the city. Colin, 48, had suffered a nervous breakdown when he worked as a car factory worker in Coventry. But he was stirred by warm memories of boyhood holidays in Cornwall. And the couple spent six months each year for three years until 2000 in a rented caravan there, and found it blissfully peaceful. So they plunged what little money they had into their new life. They bought the neighbouring caravan and moved in one year before the 16-turbine wind farm opened in October 2001.

Their caravan is made mostly of aluminium, which exacerbates the tin can effect. But they point out that they were there before the wind farm, and they don't have the money to move anywhere else.

Kathy, 43, says: "I did put in a letter of complaint about the plans. I was very concerned about the wildlife - buzzards and peregrine falcons. Then, of course, noise was one of my concerns, but I never realised how bad it would be. At first I thought it was something in the home, but it was the turbines. "They get to a critical speed, which I believe is 40 knots, and then it disturbs us all the time. It's just as if we're in a box and it's reverberating all the time. "It's almost like a motion sickness, and it always seems to be worst at Christmas. "It's the constancy of them that gets to you, it can be for anything like three or four days, it's this deep throbbing."

The couple calculate that they booked into B &Bs four times last year to escape the turbines. But sometimes they just drive around until the wind dies down.

My plan was to stay here- in my newly converted barn (7 years old) (we farmed here) until I died. We have our own private water supply, a good supply of fire wood, my own painting studio- VERY IMPORTANT TO ME! And a good workshop for my husband; friends nearby, brother and sister nearby. I was born 2 miles away- Now WE HAVE TO MOVE. This move has been forced upon us. We planted 7,000 trees here. Etc.etc.etc……..

We will probably have to move, I can see no future for me here.

Noise disturbance at night – when wind in certain direction, interferes with sleep patterns, causing restlessness. During the day- makes it difficult to stay out of doors for any length of time through excessive thumping sound. Both can cause headaches, anxiety and irritability.

I feel generally off colour

I never suffered from any problems before the turbines. I am convinced that living in a continual state of anxiety over the past four and a half years since the noise nuisance started has contributed to my present problems. Prior to 1999 I always enjoyed excellent health and rarely visited the doctors surgery. As my husband and I have been retired since 1994 and our family grown up and living in different areas of the country we do not have any other problems that are likely to cause stress or anxiety.

The noise is like a whooshing noise. It is intrusive. It keeps me awake- it doesn't affect my husband as much as me but my being awake keeps him awake.

Our lives and home have been trashed and must be seen to be believed. We seem to be short tempered, unable to concentrate. Every thing we have such as mattress, duvets, cushions 4" thick, 3 rolls of sound deadening quilt, 3 sheets of corrugated asbestos, blankets, curtains, pillows, even floor carpet stacked against the walls to try and keep out the sound. Not the peace I volunteered to fight for.

Conclusions on Noise and Health

Pedersen's arguments are persuasive that the dancing shadows and the rotating blades can significantly add to the annoyance and stress caused by noise from the turbines.

The questions being asked by some in the medical profession as to whether this cocktail of effects — the noise, low-frequency, rotating blades, the shadows and the strobing – is leading to ill-health out of proportion to the noise turbines make, need serious examination.

Overall Conclusions

1. Wind Farm noise, in common with noise generally, affects different people in different ways, but the evidence suggests there is rarely a problem for people living more than 1-1.5 miles from a turbine.

2. For many people living relatively close to turbines, the noise does not present a problem. For those who are annoyed by the noise, it is overwhelmingly the "swish, swish, swish" of the turbines which troubles them.

3. For people who are not able to shut out the noise, the problem can be exacerbated by the rotating blades and the dancing shadows of turbines. This can mean that the noise from turbines can be much more intrusive that other noises of a similar decibel level.

4. For some people the impact of turbines can be overwhelming.

5. The noise can be a particular problem in rural areas where background noise levels are low.

6. The infrasound content of wind turbine noise is too low to be heard by most people.

7. At times, low-frequency will form an audible, but not major part, of the "swish" sound of the turbines and can, for people sensitive to low-frequency noise, create additional problems. But the low-frequency content of wind turbine noise is no greater than the low-frequency component found in several other noise sources and can only usually be heard down wind of a turbine when there is a fair bit of turbulence.

8. However, low-frequency may be underestimated because of the persistent use of 'A' weighting in measuring the noise, rather taking 'C' weighted measurements.

9. Research by medical doctors has unearthed persistent complaints from people saying they not only hear the noise from wind turbines, but can "feel" disturbance in their bodies. This has lead to complaints of illness. The symptoms people are complaining about are very similar to those associated with vibroacoustic disease. The suggestion is that the unique combination of noise (containing an element of low-frequency) and the strobing effects of the flickering blades, is having a physical effect on some people.

10. Modern turbines are mechanically quieter, but there is convincing evidence that the noise they emit is being underestimated because measurements continue to be taken at a height of 10ft from the ground, thereby underestimating the speed of the wind (particularly at night) at the top of the large, modern turbines, over 100 metres high.

Overall Recommendations

1. It would be prudent that no wind turbines should be sited closer than 1 mile away from the nearest dwellings. This is the distance the Academy of Medicine in Paris is recommending, certainly for the larger turbines and until further studies are carried out. There may even be occasions where a mile in insufficient depending on the scale and nature of the proposed development.

2. Wind farms should only be located in areas where the "swish, swish, swish" of the turbines will not cause noise problems for people.

3. There needs to be a clear and public recognition by the Wind Power Industry that wind turbines are causing significant noise problems for some people. This could open the door to constructive discussion.

4. The industry also should recognise that the evidence is persuasive that the noise problem can be exacerbated by the rotating blades and the dancing shadows of the turbines.

5. The official government guidelines for the siting of wind turbines need to be revised to take account of the more intrusive nature of the noise in areas where the overall background noise level is low.

6. The debate on wind farms would do well to recognise that the infrasound content of wind turbine noise is too low for most people to *hear*.

7. People need to be careful not to exaggerate the audibility of the low-frequency of the noise. It can be a problem at times, but over-emphasis on it can detract from the main noise problem: the 'swish, swish, swish' of the blades.

8. The guidelines should require the use of 'C' weighting (and 'G' weighting for infrasound) as well as 'A' weighting when measuring the noise from turbines in order to fully capture the low-frequency element.

9. Further work needs to be undertaken urgently to test the claims that the overall effect of turbines is having a physical effect on people to the detriment of their health.

10. There should be a short moratorium on the installation of the large, modern turbines until it is established, through trials, the amount of noise they actually emit.

Concluding Comment

Wind farms can play a role in reducing global warming emissions. But there is a very real danger that, in the enthusiasm to embrace clean technology, legitimate concerns about noise are being brushed aside. There is no doubt that some existing wind farms are causing real noise problems. This report has stopped short of arguing that those turbines should be shut down, though that possibility should never be ruled out. However, it would be quite unacceptable to our fellow citizens for this situation to be replicated in other parts of the country as new turbines come on-stream. But this need not be the case. The positive conclusion of this report is that there is a constructive way forward. It simply requires sensible siting of the new wind farms. It's all about 'location, location, location'. It is in the interests of the wind power industry, environmental groups and local communities for us to get that right.

Appendix 1
Sample Measurements

(the full set of measurements runs to over 130 pages and is available from the Noise Association)

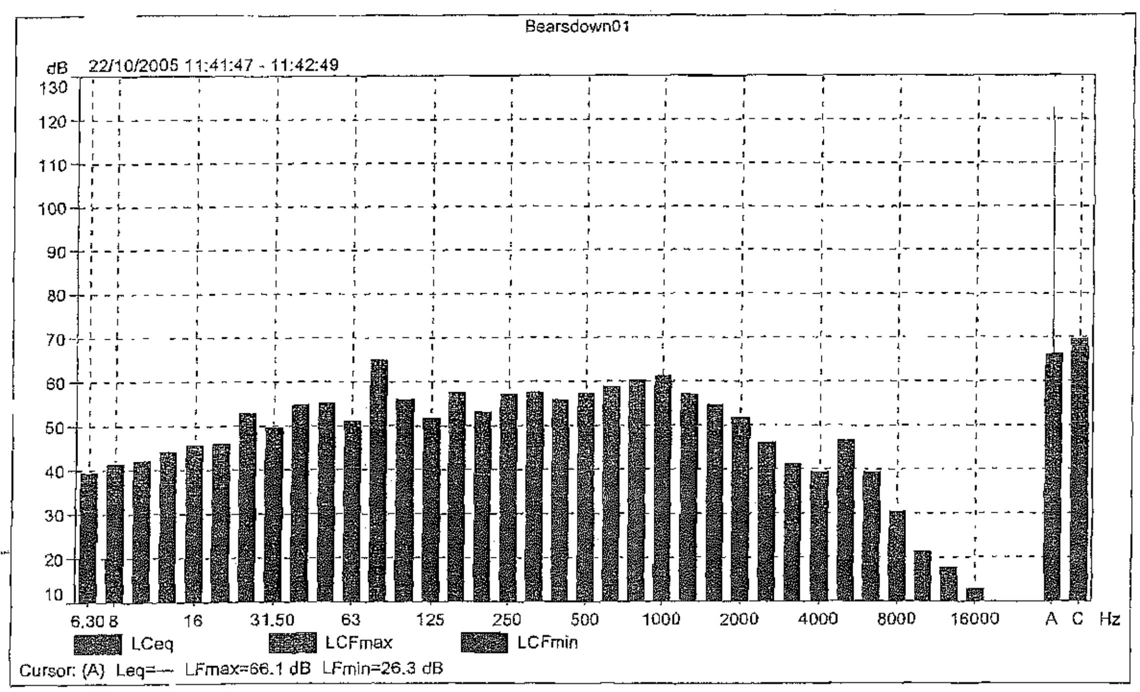
Bearsdown01, Nr St Eval, Cornwall, Wind Farm Noise Monitoring December 2005

Location	SH 893 676
Wind Speed	LOW
Wind Direction	NW
Microphone	Normal
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	22/10/2005 11:41:47
End Time:	22/10/2005 11:42:49
Elapsed Time:	00:01:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field
Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

	Start time	End time	Elapsed time	Overload [%]	LAIeq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	54.7	66.1	26.3
Time	11:41:47	11:42:49	0:01:02				
Date	22/10/2005		22/10/2005				



Bearsdown02 Wind Farm Noise Monitoring December 2005

Location	SH 893 676
Wind Speed	LOW
Wind Direction	NW
Microphone	Normal
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	22/10/2005 11:43:57
End Time:	22/10/2005 11:44:59
Elapsed Time:	00:01:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

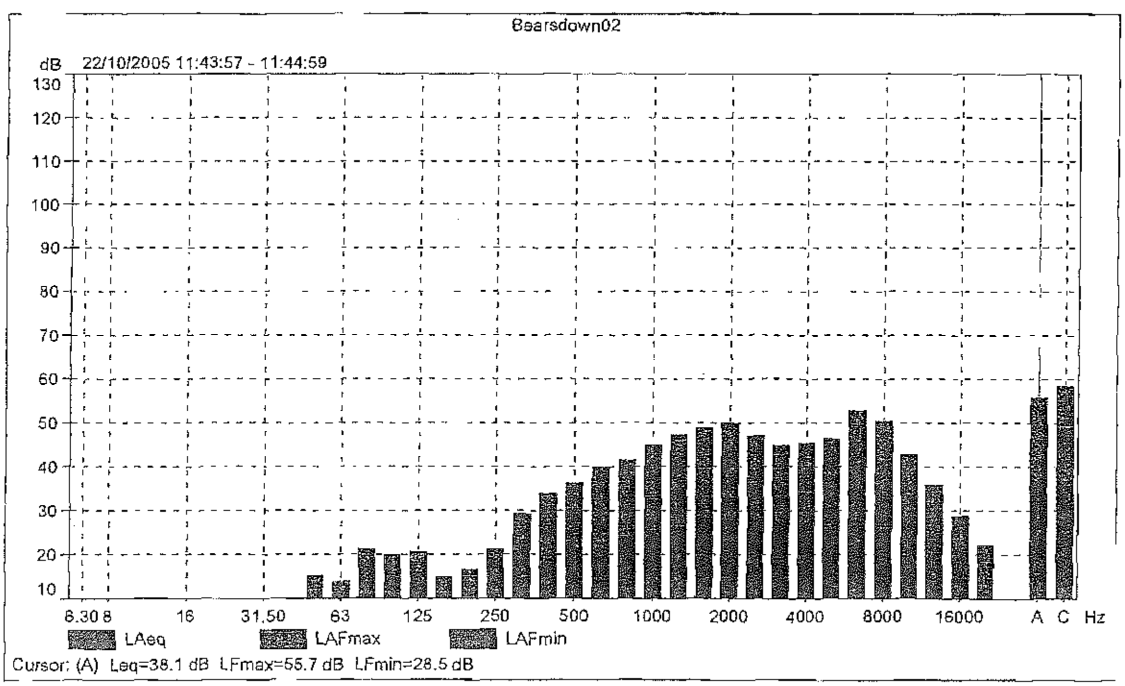
	Time	Frequency
Broadband (excl. Peak):	FSI	AC
Broadband Peak:		A
Spectrum:	FS	A

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

Bearsdown02 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAleq [dB]	LAFmax [dB]	LAFmin
Value				0.00	48.8	55.7	28.5	
Time	11:43:57	11:44:59	0:01:02					
Date	22/10/2005		22/10/2005					



Bradworthy 01, Cornwall – Wind Farm Noise Monitoring December 2005

Wind Direction SW speed 14 – 27 MPH RAIN   In Direct Wind

Location SS 304 135

Microphone - Normal		
Instrument:	2250	
Application:	BZ7223 Version 1.2	
Start Time:	07/12/2005 18:27:17	
End Time:	07/12/2005 18:29:20	
Elapsed Time:	00:02:03	
Bandwidth:	1/3-octave	
Max Input Level:	140.50	

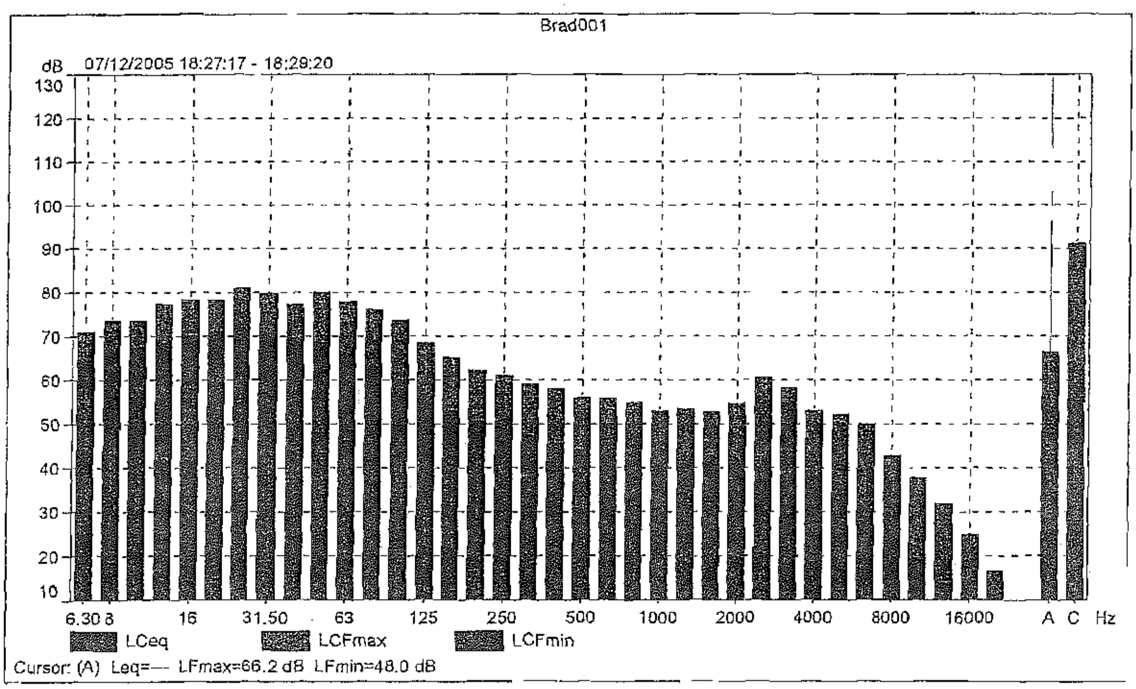
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Brad001 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAleq [dB]	LAFmax [dB]	LAFmin
Value				0.00	57.8	66.2	48.0	
Time	18:27:17	18:29:20	0:02:03					
Date	07/12/2005		07/12/2005					



Bradworthy 02 - Wind Farm Noise Monitoring December 2005

Wind Direction SW speed 14 – 27 MPH RAIN
Shielded from Wind
Location SS 304 135
Microphone – 1Hz

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 18:32:15
End Time:	07/12/2005 18:34:22
Elapsed Time:	00:02:07
Bandwidth:	1/3-octave
Max Input Level:	140.50

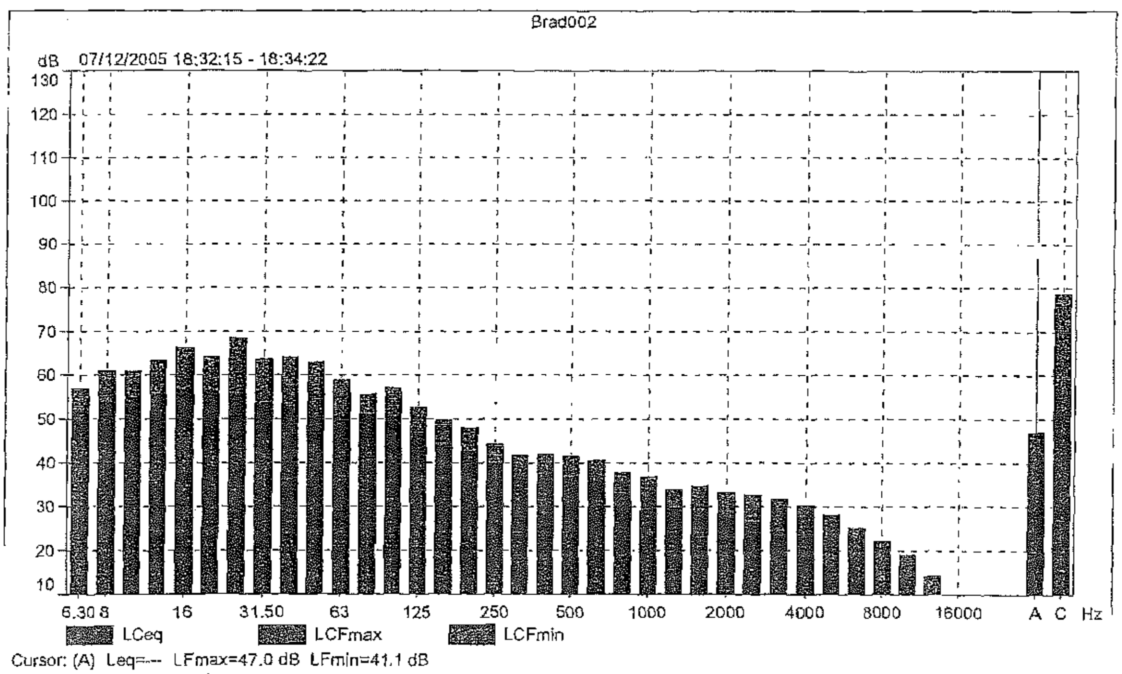
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Brad002 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin
Value				0.00	44.5	47.0	41.1	
Time	18:32:15	18:34:22	0:02:07					
Date	07/12/2005		07/12/2005					



Blaen Bowi, Wales - Wind Farm Noise Monitoring October 2005

Grid Ref SN 32792 BNG 35335

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	13/10/2005 18:22:57
End Time:	13/10/2005 18:27:59
Elapsed Time:	00:05:02
Bandwidth:	1/3-octave
Max Input Level:	140.44

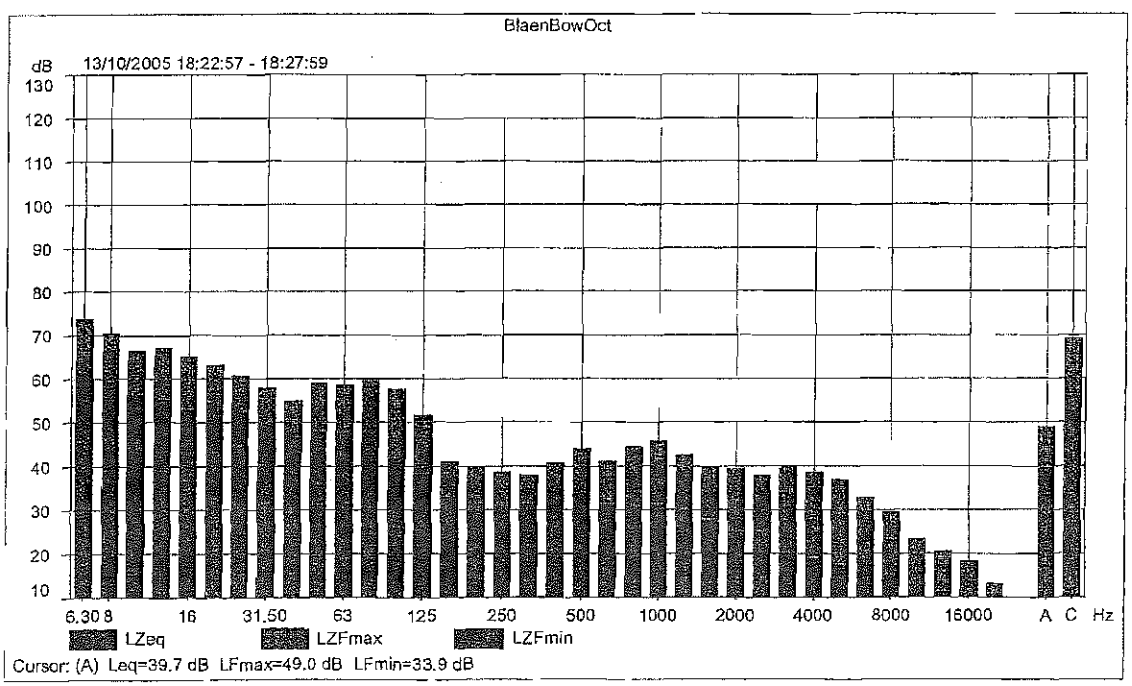
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	Z	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBowOct01 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAleq [dB]	LAFmax [dB]	LAFmin
Value				0.00	41.1	49.0	33.9	
Time	18:22:57	18:27:59	0:05:02					
Date	13/10/2005		13/10/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Grid Ref SN 32793 BND 35335

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	13/10/2005 18:44:40
End Time:	13/10/2005 18:47:09
Elapsed Time:	00:02:29
Bandwidth:	1/3-octave
Max Input Level:	140.44

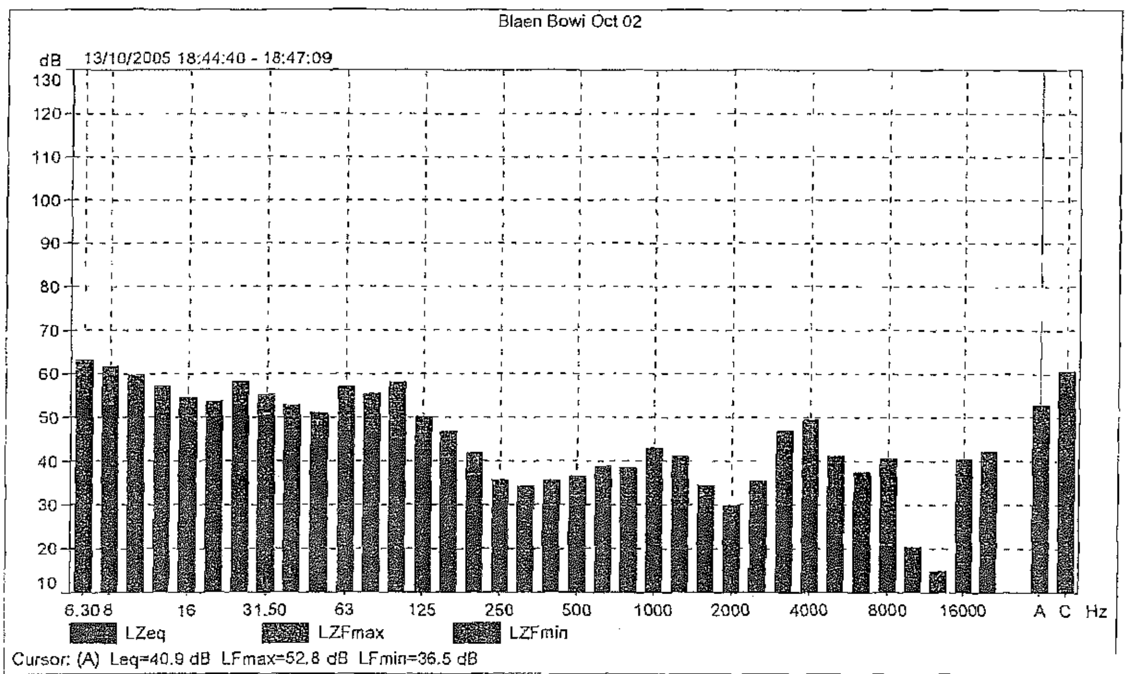
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	Z	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

Blaen Bowi Oct 02 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin
Value				0.00	44.3	52.8	36.5	
Time	18:44:40	18:47:09	0:02:29					
Date	13/10/2005		13/10/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Defach-Velindre,Llandysul,Carmarthenshire (OS Grid Reference 33852 36332)

1hz Filter Installed

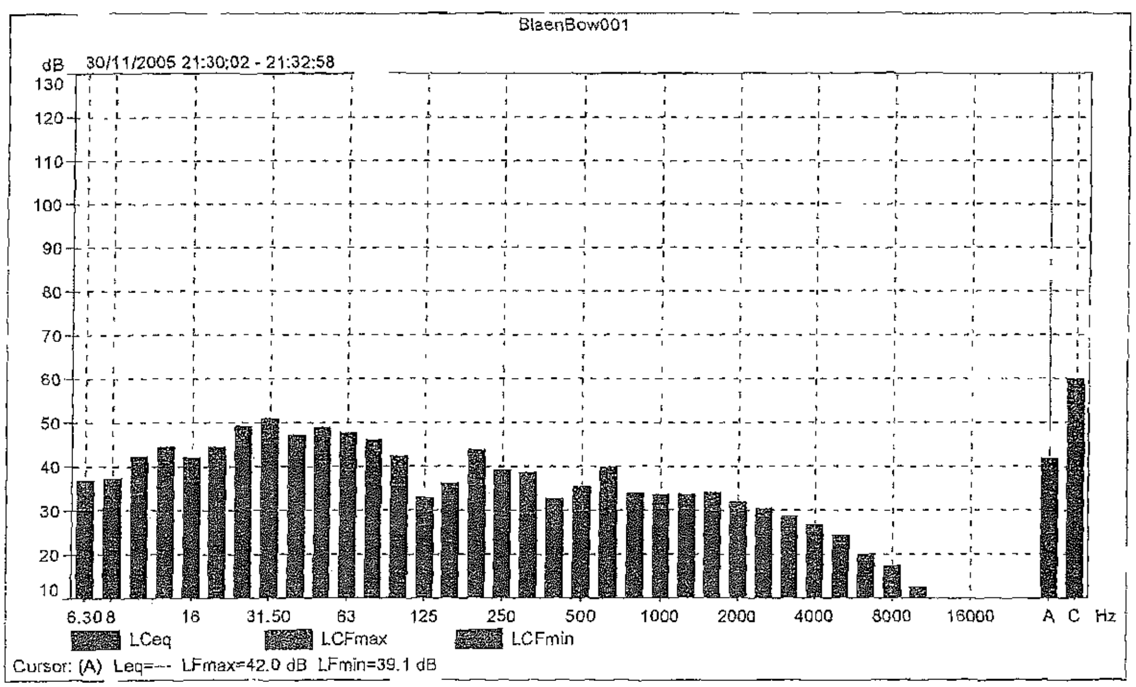
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	30/11/2005 21:30:02
End Time:	30/11/2005 21:32:58
Elapsed Time:	00:02:56
Bandwidth:	1/3-octave
Max Input Level:	140.44

	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field
Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBow001 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAleq [dB]	LAFmax [dB]	LAFmin
Value				0.00	40.5	42.0	39.1	
Time	21:30:02	21:32:58	0:02:56					
Date	30/11/2005		30/11/2005					



Blaen Bowi - Wind Farm Noise Monitoring October 2005

Defach-Velindre,Llandysul,Carmarthenshire (OS Grid Reference 33852 36332)

1hz Filter Installed

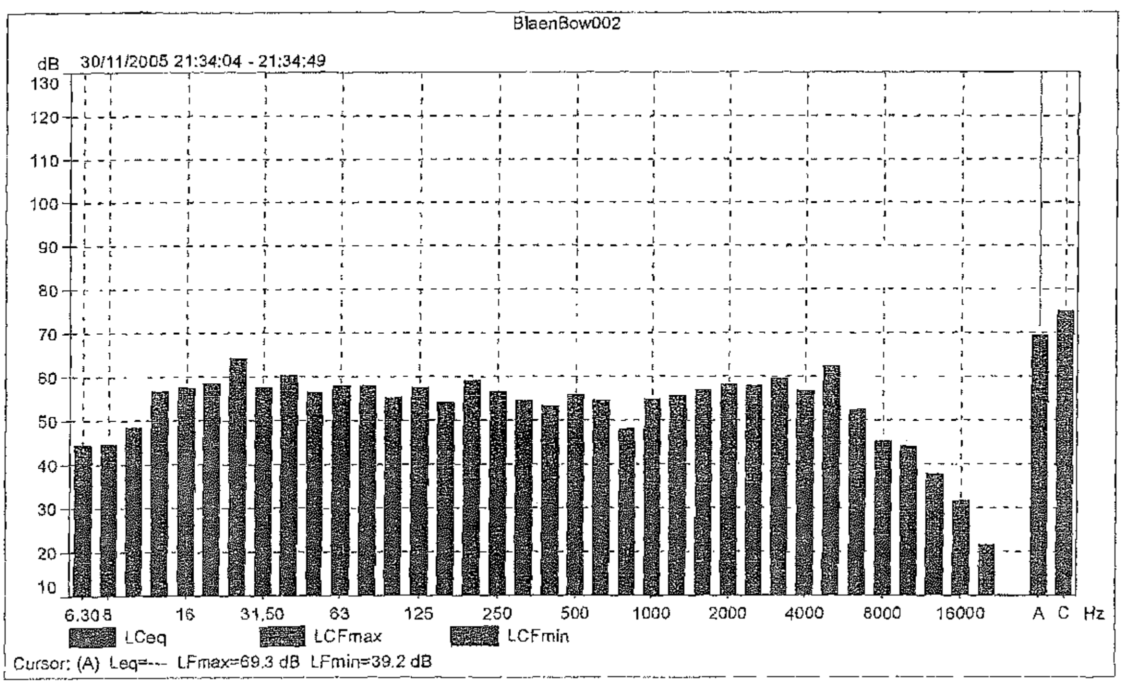
Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	30/11/2005 21:34:04
End Time:	30/11/2005 21:34:49
Elapsed Time:	00:00:45
Bandwidth:	1/3-octave
Max Input Level:	140.44

	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	
Instrument Serial Number:			2505941
Microphone Serial Number:			2508682
Input:		Top Socket	
Windscreen Correction:			None
Sound Field Correction:			Free-field

Calibration Time:	09/09/2005 14:47:53
Calibration Type:	External reference
Sensitivity:	53.03 mV/Pa

BlaenBow002 Text

	Start time	End time	Elapsed time	Overload [%]	[dB]	LAIeq [dB]	LAFmax [dB]	LAFmin
Value				0.00	59.1	69.3	39.2	
Time	21:34:04	21:34:49	0:00:45					
Date	30/11/2005		30/11/2005					



References

(1) Effects of the wind profile at night on wind turbine sound by Fritz van den Berg, published in the Journal of Sound and Vibration, 2004)

(2) The Use of 10 metre Wind Speed Measurements in the Assessment of Wind Farm Developments, paper given by Peter Botha at Berlin Conference.

(3) Noise Annoyance from wind turbines – a review, August 2003, published by the Swedish Environmental Protection Agency.

(4) How the Mythology of Infrasound and Low Frequency Noise Related to Wind Turbines Might Have Developed, Dr Geoff Leventhall Oct 2005.

(5) Mitigation measures for night time wind turbine noise, paper presented to Berlin Conference, Fritz van den Berg Oct 2005.

(6) Wolsinki et al Annoyance from wind turbine noise on sixteen sites in three countries, 1993.

(7) Pedersen and Persson Waye, Storiningar fran Vindkraft 2002.

(8) Public Attitude to Windfarms, Scottish Office, 2003.

(9) Paper by David Craig submitted to Enterprise and Culture Committee – Renewable Energy in Scotland Inquiry, 10/2/04.

(10) Human Responses to Wind Farm Noise – Annoyance and Moderating Factors. Berlin Conference Oct 2005.

(First International Conference on Wind Turbine Noise, Berlin, October 17/18th 2005)

(11) Fidell et al. Effects of aircraft over-flights on wilderness recreationists 1996.

(12) British Standard 4142, Method for rating industrial noise affecting mixed residential and industrial areas.

(13) Mitigation measures for night-time wind turbine noise, van den Berg, October 2005.

(14) Guidelines for Community Noise

(15) UKNA Briefing, Hazel Guest, 2004

(16) Perceptions of the Public of Low Frequency Noise, Manley, Styles and Moorhouse, published in the Journal of Low Frequency Noise, Vibration and Active Control (2002),

(17) Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms, Styles, Keele University

(18) Low Frequency Noise & Vibration Levels at a Modern Wind Farm, 1996, by Styles, Manley et al - the work was funded by ETSU on behalf of the DTI.

Acknowledgements

Location, Location, Location has been researched, written and designed by John Stewart, who chairs the UK Noise Association. He received invaluable help from Hazel Guest, Peter Haddon, Dr Amanda Harry, Paul Harry (who took the measurements), Richard Hendin, the late Dr David Manley, Monica Robb, Henry Thoresby and Val Weedon. Thanks also to Dr Geoff Leventhall who made the proceedings of the Berlin Conference on wind farms available free of charge.

We are particularly grateful to the Ashden Trust for their grant in funding the research

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Evidence of Dr Robyn Phipps,

In the Matter of Moturimu Wind Farm Application

heard before the Joint Commissioners
8^{th} – 26^{th} March 2007
Palmerston North

1 MY EXPERTISE

In addition to being a person directly affected by this proposal, I have some qualifications and expertise which equips me to be able to comment on this proposal with knowledge.

1.1 MY CURRENT POSITION IS:

Senior Lecturer in Building Technology,
Massey University

1.2 MY QUALIFICATIONS ARE:

Bachelor of Building Science,
Bachelor of Architecture (Hons),
PhD the topic of which was healthy building environments
Certificate of mould remediation
Partial completion of Masters of Architectural Technology

1.3 HONORS, MEMBERSHIPS ETC RELEVANT TO THIS HEARING INCLUDE:

Director Health and Housing Research Programme. This is a world class and very active research unit that attracts Health Research Council and private sector funding. This research unit produces research that is regularly presented as keynotes at WHO scientific meetings, and is published in esteemed medical journals such as British Medical Journal and informs changes to the Building Code. Energy and cost benefit issues are central to the centre's research . My role in this established team is in the physical science and measurement of building environments, however physical science is intrinsically interwoven with health outcomes

Principle Researcher with the National Energy Research Institute (NERI) which is one of 6 research centers of excellence funded by the Tertiary Education Commission (TEC). I am a founding member of this centre for my recognized expertise in solar energy use.

Principle Investigator with Centre for Urban Health and Development (CUHAD). I am a principle investigator and theme leader with this centre of research excellence, which is recognition of my expertise in integrating the physical properties of the living environment and human health.

Associate Investigator with New Zealand Energy Research Centre (NZERC), I am a founding member and associate researcher with this centre for my recognized expertise in solar energy use. My role in this centre is passive solar technologies.

Past chair and currently Deputy Chair of the Clean air Society of Australia and New Zealand, special interest group for indoor air quality. This includes an advisory role to the Australian and New Zealand government and public bodies on indoor air quality in buildings, as well as training, conference organization and initiation of research projects.

Active member of International society for Indoor Air Quality and Climate and have been highly involved in several international tasks forces for healthy indoor environments

1.4 **SENIOR LECTURER IN BUILDING TECHNOLOGY AT MASSEY UNIVERSITY.**

- I have 12 years experience in research into indoor environmental quality and the effect this has on human health and wellbeing and energy efficiency of buildings.
- I am suitably qualified and experienced to interpret scientific data and literature on topics close to my expertise.
- I have developed and lead a postgraduate program at Massey University for in Indoor Air Quality and Healthy Environments. My own PhD thesis was in this subject and I have since supervised many other postgraduates in this area.
- I am leading the development of new taught papers on energy efficiency of buildings and research in this area.
- I have conducted research projects on many aspects of indoor environmental quality, energy efficiency and health outcomes, solar design of housing, energy efficient lighting in buildings, the effects of dampness and ventilation rates in buildings. I am a co-leader on a project investigating health, noise and other environmental parameters in primary schools.
- The transmission of noise through building elements is one of the topics that I teach at undergraduate level.

1.5 **CODE OF CONDUCT FOR EXPERT WITNESS**

I have read and understand the conditions of conduct for being an expert witness. I comply with all criteria for being an expert witness except that I am an affected party, in that I live at 408 Scotts Road. However, there is no one else in my field with my level of expertise in New Zealand to have as a substitute expert. This evidence has been peer reviewed by Bob Thorne.

2 **EVIDENCE**

2.1 My evidence consists of four areas of concern.

- The first is a presentation of a survey of Visual and Noise effects experienced by residents currently living close to the existing wind farms in the Tararua and Ruahine ranges.
- The second aspect is a review of literature on health effects, other than hearing loss, from exposure to noise and vibration as well as the transmission of noise and vibration into buildings.

- The third aspect is addressing the suggestion that adverse impacts of noise can be satisfactorily remedied by modifications to homes. Particularly it addresses an assessment of the effectiveness of sealing a home to stop noise intrusions.

- The fourth topic is solar energy and energy efficiency as alternative means of addressing energy supply issues.

3 SURVEY OF VISUAL AND NOISE EFFECTS EXPERIENCED BY RESIDENTS LIVING NEAR THE EXISTING WIND FARMS IN THE TARARUA AND RUAHINE RANGES.

3.1 I led a survey of the visual and noise effects experienced by residents living within a notional 3km ring of the existing wind farms in the Tararua and Ruahine ranges. A four-page, self-reporting/self-returning survey was developed to investigate the visual and acoustical effects experienced by residents who live within a notional 3km ring of existing wind farms in the Manawatu and Tararua region. Some surveys were delivered to residence outside the 3km notional ring, in order to survey a complete street. Questions were asked about the distance from respondent's house to the nearest turbine, whether they could see turbines from their home, visual impacts, noise impacts, financial gain from the wind farms, effects on television, radio and phone reception, whether they had complained or considered complaining about the wind farm effects. Other questions canvassed their views on future developments and descriptor data, including the number of persons living in the household and length of time living at the address.

3.2 The methodology and preliminary results have been peer reviewed by two reviewers and are in press for the New Zealand Planners Institute Conference. The full NZPI paper is appended (Appendix 1) and a blank survey form in Appendix 2. Further to the NZPI publication, more detailed analysis has been conducted on the data, which is reported below. Some surveys that were returned after the preliminary data analysis had commenced have also been included in this latter analysis.

3.3 METHODOLOGY

3.4 Prior to administration, the survey was peer reviewed by two senior Massey University academics with considerable expertise in questionnaire design and it was trialed on a small sample of people not living in the subject region. One of the peer reviewers is Chairman of a Massey University Ethics committee and advised that ethics approval was not required due to the low sensitivity of the questions and appropriate provisions for anonymity and confidentiality of the households.

3.5 The survey was divided into 5 sections; visual, noise, general, complaining about wind farm effects, future developments, and household details. Most questions in the survey only required a "tick the box" response, with responses mostly on a five point lichter scale or yes/no as appropriate.

3.6 Surveys were anonymous to protect the privacy of households, however the street address was recorded at time of delivery, so a cross check could be made on approximate distance from turbines to residence. The surveys (one per household) were delivered to about 1100 urban and rural letterboxes in September 2006. Surveys included a reply paid envelope and a separate detachable postcard that could be completed if households were interested in being contacted for further comment or would like to receive a copy of the survey results.

3.7 **Visual affects questions**
The first objective was to assess which of the various visual effects of wind farms were considered most significant. Wind farms could be considered visually significant from an aesthetic point of view or because they contain moving parts. Equally their impact could be seen to be important because they involve a change to a significant landscape feature that many residents identify with.

3.8 Households were asked to rate on a five point scale (from disagree strongly to agree strongly), to what extent they agreed or disagreed with each of the following statements about visual amenity:

- I think the turbines spoil the view
- I think turbines are quite attractive
- I find the movement of the turbines irritating
- The turbines are intrusive in my view
- The view of the turbines doesn't bother me
- I am aware of shadows or flicker from the turbines
- Watching the turbines can create an unpleasant physical sensation in my body
- The view of turbines reduces my enjoyment of my property
- I enjoy watching the turbines.

3.9 Visual questions were asked in both the positive and negative sense e.g. *"I think turbines spoil the view?"* and *"I think turbines are quite attractive?"* to balance opinions.

3.10 **Noise affects questions**
In the noise section, questions asked if households heard noise from the wind turbines (yes/no or not sure), the frequency they heard during the day and night. Data was sought on the qualitative aspects of the noise e.g. sounds like a train that never arrives, hum or swishing noise; respondents could select from 7 options or add their own description. Households were also asked if they had altered their house because of noise from the wind turbines.

3.11 RESULTS AND DISCUSSION

3.12 RESPONSE RATE:

Out of a total of 1100 survey forms delivered, 614 were returned, providing a response rate of 56%. This is considered to be very high for a self-reporting, self-returning survey, with no follow-up for late returned surveys and suggests a high level of interest in the subject matter. The surveys reported the affect experienced by the household, rather than just an individual

3.13 DISTANCE BETWEEN HOUSEHOLD AND CLOSEST WIND FARM

All distances from homes to closest turbines have been manually checked against delivery records. These distances are approximately accurate to 0.5km. All households responding to the survey were more than 2km from operational turbines. Only 16 percent lived between 2 and 2.5 km, 40% lived 2.5km away, and 29% lived 3km away. The frequency of distance from the respondent's home to the closest wind farm is shown in Figure 1 below.

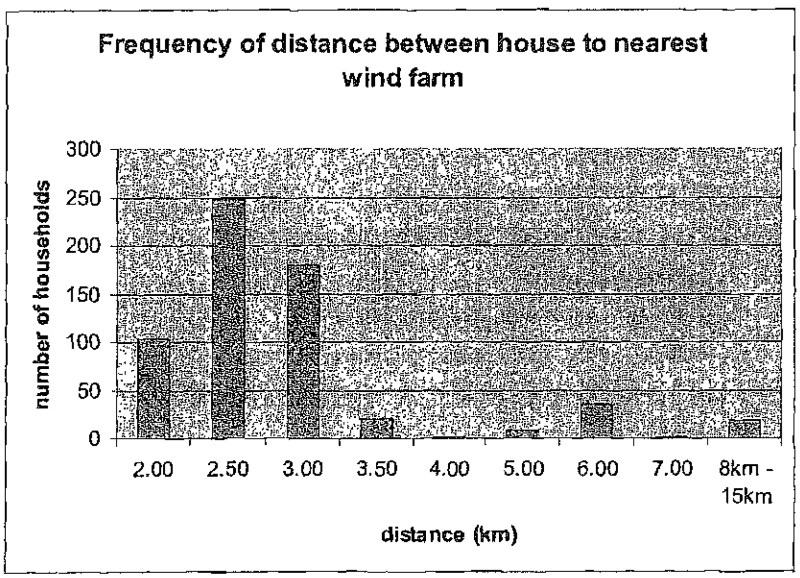


Figure 1 Frequency of households at distance bands to nearest wind farm

3.14 VISUAL

Of the 516 households that reported being able to see the wind farm, only 483 were used in the analysis, due to incomplete or insufficient answers.

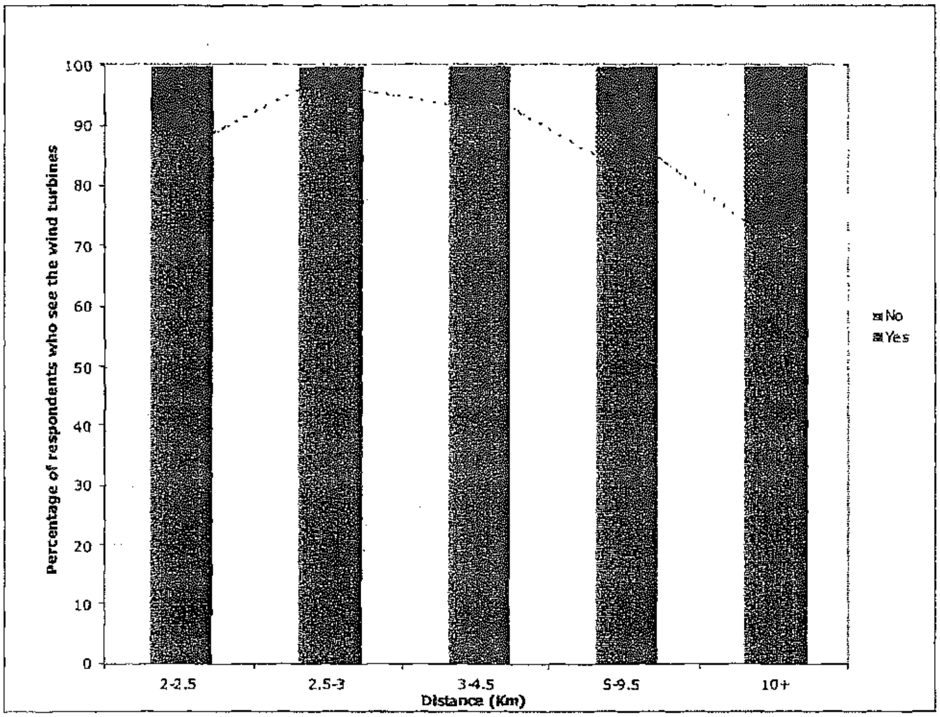


Figure 2 Percentage of households who see turbines with distance

3.15 Eighty percent of the households considered that the turbines were intrusive, and 73 percent thought that they were unattractive. This latter result is in contrast to the UMR national survey conducted for EECA which found that only 24.9 percent of the general public thought wind turbines were ugly. This discrepancy between surveys could be due the EECA survey participants being drawn from all areas of New Zealand and represents the idealogy of wind energy, rather than residents living close to wind farms who presented the reality.

The flickering motion of the turbine blades also affected a significant number of households (9 percent). This result is in agreement with the Sinclair – Thomas matrix for visual assessment of wind farms (Thomas 2002).

3.17 An unsolicited comment was *"strobing shadows fill my kitchen when we cook my 2 year old boy hates them with a rage. Meridian told me to close the curtains but that can't keep them out".*

3.18 NOISE

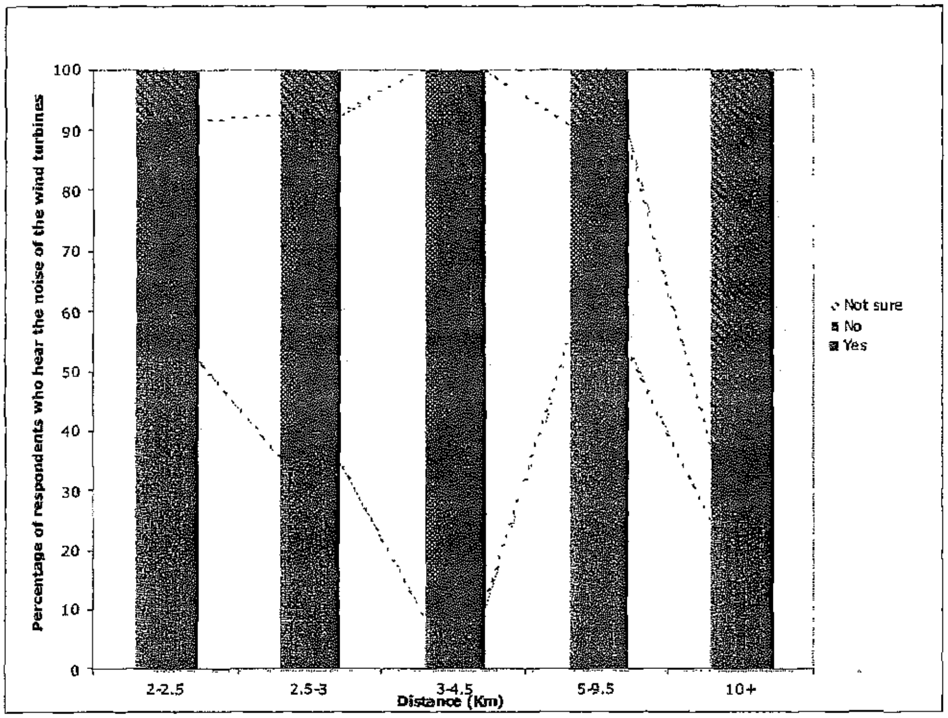


Figure 3. The proportion of households who hear the wind farms against distance

3.19 Figure 3 shows that proportion of households that could hear the wind farm noise plotted with distance. What is surprising is over 52 percent of households located between 2-2.5 kms and 5-9.5 reported they heard wind farm noise; 36% of households located 2.5-3 kms away believe they hear wind turbine noise; while as many as 25 percent of households' located 10 kms away and said they could still hear the wind farms. A chi-squared analysis showed these results were statistically significant.

3.20 Other literature has shown night time is often the period when people living near wind farms are most affected by noise. However, in this survey there was little difference between the frequency which turbine noise was heard during the day or night. Of the 284 households who answered the question on night time noise;

- 29% reported they never hear turbine noise at night
- 58% occasionally hear turbine noise at night
- 10% frequently hear turbine noise at night
- 3% hear turbine noise at night most of the time

3.21 Forty two households reported wind turbine noise disturbed their sleep occasionally; 21 had their sleep disturbed frequently and 5 most of the time.

Unsolicited comments included *"we sleep with ear plugs to try and block out the noise but we still hear it".*

Table 1. Results of quality of life questions

Quality of life questions	Never	occasionally	frequently	most of the time
Noise from the turbines reduces quality of my life	195	51	36	5
Noise from the turbines means we don't spend as much time outside as we would like	212	47	23	2
Noise from the turbines means we close our windows more than we would like	244	45	41	2

3.22 Unsolicited comments included;

- *"We want to double glaze but can't afford to* (3 people made comments to this effect)".
- *"It makes no difference if the windows are open or closed, the noise just invades us"*
- *"The noise thumps the house we can't change it"*
- *"We've put in more insulation but it comes thumping up under the floor"*

3.23 Several questions were asked on the qualitative characteristics of the wind farm noise. Households were asked what the noise sounded like and asked to tick boxes from the options in column one of Table 3 below. The second column shows the number of households identifying with each descriptor.

Table 2. Qualitative description of wind farm noise

The noise from the turbines sounds like:	Number of residents reporting this quality in the noise
A train that never arrives	128
Hum	90
Swishing noise	108
Rumbling noise	79
Low frequency sound	68
The noise makes by my house vibrate	12
The noise gives me an unpleasant physical sensation in my body	13
Other	94

3.24 In designing the questionnaire we deliberately avoided any descriptors that could have an emotional bias, such as thumping. However most of the descriptors volunteered by the households are emotional. The number of households using this or a very similar descriptor is given in brackets. Their choice of descriptions includes, *thumping (12), whooping (5) , booming (3), storm coming (7), river in flood (7), storm in the ocean (13), crashing waves (5), washing machine, thump on top of rumble, clothes dryer, heavy machinery working at night, shuddering, boom box, metal on metal, screeching machinery metal, hovering helicopter, concrete mixer in the sky, street sweeper truck coming up my driveway, bulldozer on the horizon, never ending thunder, low throbbing, flapping, motorway, and geographical resonance.*

3.25 It is pertinent to note that most of the above description of the wind turbine noise, apart from screeching and metal on metal which are likely to be attributable to noise from mechanical failure, are sounds associated with lower frequency component of noise or the impulsive character of the wind turbine noise. This could be explained by four phenomena:

- When noise generated from outdoor sources strikes a building, the amount that penetrates the building envelope depends of the noise frequency. Low frequency noise penetrates a typical New Zealand domestic structure much more readily than higher frequency noise. Low frequency noise is difficult to stop without the use of heavy mass constructions like solid concrete walls, roof and floor.
- High frequency noise experiences a much greater degree of molecular absorption (and consequently noise level reduction) than low frequency noise as it moves away from the source . Consequently low frequency noise is more efficiently propagated and can be heard over greater distances.
- Goldstein (1994) showed that humans perceive low frequency noise as louder and more annoying than higher frequency noises with equal pressure levels. The effect of increased annoyance was observed regardless of the noise scheme weighting.
- The impulsive characteristic of wind turbine noise is more attention grabbing and annoying than a constant noise source (van den Berg 2006).

3.25.1 It is important to emphasis that the survey instructions asked households to report on the effects they experienced in their homes. In his evidence Mr Hunt referred to an effect where turbine noise could be heard by a receiver standing 500m directly in front of the turbine. As all homes in the survey were more than 2 km from the nearest turbine it doesn't appear this result can't be explained by the 500m effect described by Mr Hunt.

COMPLAINING ABOUT WIND FARMS

3.27 Ninety three (15%) of households reported they were sufficiently bothered by the visual and noise effects to feel like complaining, while sixty one (10%) of households reported that they had made complaints. Those who were sufficiently bothered but had not complained reported that they were either not a complaining type of person, didn't know who to complain to and many doubted it would make a difference. Six people offered unsolicited comments along the lines of *"there was nothing that could be achieved by complaining once the turbines were in place."*

3.28 The 61 households who had made complaints reported using a number of avenues or agencies including PNCC (25 people), Meridian (22 people), their local member of Parliament (2), their neighbours, friends and family (15) Aokautere or Ashhurst Guardians (4), letters to newspaper (2) local ward committee (2) television (1) or had made submissions opposing future wind farms (11). Several reported they had complained on a number of occasions. The number of people reporting to have complained to PNCC is difficult to reconcile with Mr Bakers evidence that PNCC have not received any complaints. This may suggest there are deficiency in the monitoring, administration and remediation of complaints.

3.29 Complaints are often used as an annoyance measure but these clearly under report community concerns given that only a small percentage of those affected complain. A community noise survey found only 44% of people seriously affected by noise complained (enhealth, 2004) .

3.30 Although the survey didn't asked about the response to their complaints, four people volunteered that nothing had happened. One expressed it was a David and Goliath situation and the locals would never be heard against big business and profitability of the wind farm. The tone of some of these unprompted responses to the lack of action from their complaints could be summarised as irate.

3.31 GENERAL QUESTIONS

A few general questions were asked in the survey. None of the households reported that a member of their household had gained employment or increased business from the local wind farms. One person reported they had lost business as a result of the wind farm development but didn't give details. Some considered the wind farm development had affected their television reception (41), radio reception (14) or phone reception (32). One resident who had lived in Ashhurst for 16 years commented that *"we had to buy a bigger TV antenna after the windmills started".*

3.32 SUMMARY OF RESULTS

516 households reported they could see turbines from their homes. Of these, 80 percent considered the turbines to be visually intrusive, and 73 percent thought that they were unattractive. These local expressions of concern are at odds with the national support for wind energy expressed in other published studies and could reflect the reality of living near wind turbines as opposed to the ideology of renewable energy.

3.33 Turbine noise was heard by 52 percent of households living within 2-2.5 km of the wind farm, 36% living within 2.5-3 km away and 25 percent of households living over 10 km away reported hearing turbine noise. This strongly suggests that NZS6808:1998 is underestimating the number of people affected by noise, possibly exacerbated by atmospheric conditions and special noise characteristics.

3.34 This survey shows that wind farms have significant visual and noise effects upon a larger population than is envisaged under current visual assessment techniques and the New Zealand noise standards, and at a much greater distance.

3.35 It is a reasonable assumption that the numbers of people affected by visual intrusion and noise would be considerably higher if the terrain was more open and not obstructed by a river valley compared to the Linton area where there is less obstruction from topography.

PHONE CALLS FROM PUBLIC

3.36 In research questionnaires it is standard procedure to provide the contact details of the project leader and invite people with questions or concerns to make contact. In the 3 weeks following the distribution of the survey I had 54 phone calls from people within the survey area who wished to make more comments than allowed for in the survey and a few people in the Pohangina Valley who wished to discuss their experiences with wind turbine noise or vibration. All calls were handled by listening, opened questions to gain more understanding of their issues and in some cases offering advice on energy efficiency measures that may address their concerns. I didn't seek names or addresses from callers and if these were offered I didn't record them to protect caller privacy.

3.37 The callers could roughly be divided into;

- Group A wind farm supporters (13 callers) and
- Group B people who were distressed by living near a wind farm and wished to voice their concerns (41). There were no neutral callers. All callers expressed strong to very strong emotions.

3.38 Nine of the Group A objected to people who complained of wind farms. Eleven of the Group A callers expressed fear either of the alternative to wind farms being nuclear electricity generation or of a power crisis leading to wholesale black outs or massive energy price rises. None of these callers were aware that they could make energy efficiency improvements to their home to reduce their consumption and all but one were interested to learn about energy efficiency. None of these callers were aware of EECA or that they may be eligible for subsidiaries for insulation or solar hot water. Four of these callers were concerned that labeling homes in the vicinity of the wind farms as having noise problems would affect their property prices; two used the word "blight" and said they experienced noise but didn't discuss this widely as they were fearful of ramifications of their house price and they queried the confidentiality of the survey.

3.39 All of the group B callers reported they either experienced noise issues (27) vibration issues (19) or both (5). Disturbance of sleep was reported by all but 2 callers in group B. All callers were very emotional; two were audibly crying. All but one described the noise as having an impulsive character eg thumping or whooping. Some thought the noise was worst inside their home whilst some said it was worse outside. Many (19) described frustration with the complaints going nowhere. One caller was having their house investigated by Meridian but expressed no confidence that the measurements would achieve anything. 21 of group B callers were very concerned about the windfarms under construction and described the ranges as saturated, or overcrowded. Sentiments such as "Enough is enough" and "why are we generating electricity for Auckland" were mentioned by 12 callers. One caller in this group was irate that the survey hadn't asked about financial lose. He operated a corporate style farmstay and long standing clients had complained of the noise and stopped returning. Two callers said the often stayed with friends in town to have a restful sleep away from turbine noise.

3.40 Three of the group B callers reported they lived on the western side of Pohangina valley, which is about 15km north of Ashhurst. These three callers all reported that they experienced parts of their house rattling and they attributed this to the wind turbines.

3.41 INTREPRETATION OF SURVEY RESULTS IN RELATION TO MOTURIMU

These results clearly demonstrate that wind farm noise has a significant effect on people that may well extend more than 5 km from the site of turbines. There were no people responding to this survey who lived within 2 km of operational turbines; there a large number of people living within 2km of the proposed Moturimu wind farm.

3.42 There are both differences and similarities between the wind turbines in the survey region and Moturimu. Some of these features will increase the noise at the households, some will reduce it.

- The turbines close to the survey population are of different power outputs to those proposed at Moturimu (most are smaller, some are larger).
- the distance from the turbines to the receivers in this survey was greater than 2km for all households which gives an additional 1.3 km buffer zone compared to the closest homes near Moturimu.
- In geographical area of the survey there is a river and topographic effects that would most probably reduce the noise transmission from the turbines to the majority of receivers. This does not exist for Moturimu.
- The predominant wind direction is also blowing away from Ashhurst, which is away from the location of the largest population cluster, however with Moturimu there are a large number of homes in Kahuterawa Valley down wind of the predominate wind direction.
- The existing turbines in the survey and the proposed Moturimu are all modern tall upwind wind turbines generators.
- The existing and the proposed Moturimu are both located in rolling to steep terrain with strong shifting winds.

3.43 There is no reason to suggest that the population surveyed deviated from a population of average people with average noise sensitivities. If there is any potential effect it could be that people with noise sensitivities have already self selected out of the population by shifting out of the area. There is evidence of this in the Tailor Baine survey were a person affected by noise was in the process of selling and shifting away. Further in the Phipps survey the ????

3.44 The housing in the survey area is representative of typical New Zealand housing stock, albeit with a skew towards newer more tightly constructed housing. It is typical of mixed age and condition and would contain housing with both thermal insulation and no insulation.

3.45 A "habituation effect" has been reported where people get used to road noise soon after a new road is constructed. Wind farms have been operational in the survey area for many years. It is unlikely any further habituation will occur.

3.46 The evidence from my research and the evidence of Dr Mosley at Ashhurst clearly indicates severe and significant adverse noise and vibration effects on residents that is not anticipated by either the approving authorities or the owner of the windfarm. Such effects are not anticipated in NZS 6808 and this standard is not adequate to protect the health and amenity of residents. The potential for the noise effects to occur are highlighted in Mr Thorne's evidence as having high probability of occurrence within our community.

3.47 Based on the research and evidence produced to this hearing it is clear that the turbines will create significant adverse health and amenity effects on residents in the locality. It is my submission that the wind farm should not be approved.

3.48 Further, and based on the evidence presented to this Hearing, it is my submission that the shortcomings evident in 6808, clause 4.4.2 of NZS 6808 must be amended to reduce the indicative allowable level of noise in clause -

4.4.2 As a guide to the limits of acceptability the sound level from the wind farm should not exceed, at any residential site, and at any of the nominated wind speeds, the background sound level (L95) by more than 5 dBA, or a level of 30 dBA L95, whichever is less.

3.49 As a comparison, other international bodies have recommended much lower community noise limits to protect health and well being and in particular a quiet sleep time. The limits recommended by the International Standards Organisation are setout below and it is important to note that health based noise limits set much lower levels of noise for rural environments in recognition of the lower ambient noise levels. In particular this standard seeks to protect the night time quiet period. This noise level should be enforced under section 4.4.4 of NZS6808.

Table 3 ISO 1996-1971 Recommendations for Community Noise Limits – limits to protect health and wellbeing

District type	Daytime upper limit	Evening time upper limit (7-11pm)	Night time upper limit (11pm-7am)
Rural	35 dBA	30 dBA	25 dBA
Suburban	40 dBA	35 dBA	30 dBA
Urban residential	45 dBA	40 dBA	35 dBA
Urban mixed	50 dBA	45 dBA	40 dBA

3.50 This noise criteria is very relevant to Moturimu. I have conducted many night time and early morning noise measurements at the top end of Scotts Road and ambient noise levels are typically between 17 to 22 dBA. In still conditions all 10 minute nighttime noise measurements were under 20dBA L95. It is important to note that a volume change of 3-5 dB is clearly noticeable and a volume change of 10dB is perceived as twice as loud (Alberts, 2006). While NZS 6808 allows for 40dBA to be produced from the wind farm on quiet still nights this will produce a volume increase of over 20dBA over background noise.

3.51 With regard to Moturimu, it is essential that noise levels are met at residences for construction noise including traffic movements as well as operation of the turbines. To enable this strict hours of operation of the construction activities, including site traffic, is vital to protect amenity values and avoid sleep disturbance and ensuing health problems. ISO 1996-1971 provide relevant guidance for appropriate noise levels for different times of day to protect health and wellbeing.

A REVIEW OF LITERATURE ON HEALTH EFFECTS, OTHER THAN HEARING LOSS, FROM EXPOSURE TO NOISE AND THE TRANSMISSION OF NOISE INTO BUILDINGS

4.0 INTERPRETATION OF LITERATURE

There are several generalised rules which scholars use to assess the quality of research and reports. Some confusion of these quality assessments was apparent in the Applicants evidence and I would like to take the liberty to give a brief clarification to quality assessments of research literature.

4.1 Papers presented in journals are of higher quality than papers presented at conferences. The peer review process is more rigorous for a journal than a conference and researchers get more credit for journals so place their most important findings for journals. Conferences are a quicker way of publishing material than journals and are often used for preliminary results or smaller studies that aren't suitable for journals.

4.2 Not all journals are equal. The rating of journals is called the impact factor. A journal with a high impact factor will attract the best quality research papers and the best quality reviewers. They publish only the cream of papers and may reject over 80% of good quality papers that go on to be published in other journals with a lower impact factor.

4.3 Reports can be peer reviewed or not peer reviewed and there are degrees of robustness of the review process of reports. For example reports released by organisation such as the World Health Organisation (WHO) have a higher level of peer scrutiny by international experts, and generally carries more weight than a report prepared for a smaller organisation.

4.4 Research sponsored by private organisations or industry groups can be subject to commercial bias. This bias can occur through several mechanisms. Sponsors can withhold research if the results don't fit their commercial cause. Alternatively, authors can produce results that will favour the sponsor to gain economic advantage. Commercial bias of papers can often be identified in the acknowledgements and for report commercial bias can be found by a scrutiny of the list of organisation or affiliations of authors. Work of this nature would generally be given lesser weight than research funded by impartial providers such as a government health research funding agency or WHO.

4.5 A PhD thesis in the European or New Zealand education system is usually the equivalent of a substantial 3 year full time study. The examinations process is very robust with the thesis examined by 3 experts, one being an international expert in the respective topic, the other two are national experts and all of whom had no previous involvement in the project. European PhD often involve a public defense in that the candidate faces an auditorium full of experts probing the research, which gives a very high level of scrutiny.

4.6 A masters thesis is typically only a 1 year body of work and scholarly level is significantly lower than a PhD. The review process varies between universities for example Canterbury University only requires 1 external national expert reviewer other universities require 2 external reviewers.

5.0 NOISE IS A SIGNIFICANT EFFECT FROM WIND TURBINES

5.1 The Parliamentary Commissioner for the Environment (PCE) has also identified noise as one of the most frequently raised concerns, both in New Zealand and overseas about wind farms (Parliamentary Commissioner for the Environment 2006). Wind turbines generate noise from a number of sound production mechanisms related to the interactions between the turbine blades and air, and as the blade passes the tower. Gear box and generator noise in modern turbines is not significant when turbines are new but increases significantly as turbines wear (Stewart 2006) and this effect was noticed by respondents in the above survey. Wind turbine noise has been reported in many publications and there has even been an International conference solely on this topic.

6.0 NZS6808

6.1 New Zealand Standard NZS 6808:1998 Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators is a non mandatory Standard. It allows for Councils to apply their own noise criteria to be used, such as noise levels established in ISO1996-1971. The inadequacies of NZS 6808 have been addressed in several key documents (EPA, Bellhouse, West Wind caucus of noise consultants). These inadequacies include lack of consideration of:

- low frequency noise and infrasound
- atmospheric effects,
- cumulative noise,
- the impulsive nature of wind turbine noise.

6.2 This standard was due for review in 2006, however the revision has yet to occur.

LOW FREQUENCY NOISE

6.4 Some acoustic consultants have claimed that wind farms don't produce low frequency as they haven't measured it. The literature suggests this is more due to a problem with the assessment method, in that the use of the dBA weighting attenuates (filters out) the low frequency noise.

6.5 In a review of low frequency noise and infrasound from wind turbines Bellhouse (2004) concludes that International Standard IEC 61400-11 Wind Turbine Generator Systems – Part 11 Acoustic noise measurement techniques deals with the concerns around infrasound and low-frequency sound that are not covered in NZS6808, and that these two standards should be used in conjunction to cover all noise pressure levels. NZS6808 also references IEC61400-11. The purposes of IEC61400-11 include"*that it will would be applied by the:*

- *Wind turbine manufacturer striving to meet well defined acoustic emission performance requirements;*
- *The wind turbine purchaser in specifying such performance requirements;*
- *The wind turbine operator who may be required to verify that the stated or required acoustic performance specifications are met for new and refurbished units;*
- *The wind turbine planner or regulator who must be able to accurately and fairly define acoustic emission characteristics of a wind turbine in response to environmental regulations or permit requirements for new or modified installations."*

6.6 This International Standard states "*that optimum measurements will include directivity, infrasound, low-frequency noise, low frequency modulation of the broad band noise, impulses, and unusual noises such as hisses, whine, hiss or hum, and distinct impulses in the noise such as bangs clatters, clicks, or thumps, or noise that is irregular in character to attract attention.*"

6.7 Annex A to Standard IEC61400-11 provides useful information on infrasound and low frequency sound from wind turbines. It concludes that "*although infrasound can be barely audible to the human ear, it can still cause annoyance*" and that "*The annoyance caused by noise dominated by a low-frequency component is often not adequately described by the A-weighted sound pressure level, with the result that the nuisance from such noise may be underestimated if assessed only using an LAeq value*" and goes on to recommend the use of the of the G –weighted sound pressure level rather than A-weighted.

6.8 Low frequency noise is not well addressed in NZS6808:1998 which uses only the dBA scale, which excludes low frequency noise (New Zealand Standards 1998). A- weighted sound measures have been particularly criticised as not being accurate indicators of the disturbing effects of noise with strong low frequency components (Kjellberg, 1984, Persson & Bjorkman, 1988; Broner & Leventhall 1993; Goldstein, 1994) A highly peer critiqued review of community noise written by two of the world's most eminent environmental health experts Birgitta Berglund and Thomas Lindvall WHO, 1995) found significant failings with exclusive use of the A weighted noise level. They have stated;

> *"In the past sound pressure levels has been measured by A-weighting. At the same time, both in the laboratory and field, evidence has accumulated that an A- weighting predicts loudness and annoyance of community noise rather poorly. Not only does A-weighting sound pressure level under estimate the impact of the low frequency components of noise (Goldstein 1994) but it is strongly dependent on the exposure pattern at the time.*
>
> *The A-weighting filter is unrepresentative of the loudness of sounds containing a mixture of noises and tonal components. In such cases, A-weighted sound pressure level is less suitable for the prediction of loudness or annoyance. That is also true for noise containing most of its energy in the low frequency range of 15Hz – 400Hz. It may then under- predict perceived loudness by 7 to 8 dBA relative to a 1,000Hz target noise (Kjellberg 1984). The reason is that loudness increases due to the bandwidth increase and that spectrum shape is not accounted for to a satisfactory degree by the A-weighting filter. A decrease in A-weighted sound pressure level can result in a corresponding increase in loudness or annoyance. This clearly reveals the shortcoming of using overall SPL either unweighted or A-weighted, as an indicator of loudness or annoyance.*

6.9 Mr Hunt, in his evidence presented during the first week of the hearing, showed two different shaped graphs of the noise output from the V52 turbine and explained that "believe it or not they presented the same data". I noticed general confusion from those present at the hearing on how the two graphs could be the same data and consider it worth while to pick up on an explanation as Mr Hunt was under tight time constraints and didn't have a chance to explain how the two different shaped graphs do show the same data in slightly different formats. I have reinterpreted the data as best as possible from the limited data provided by the applicant. The data in Figure 4 is unweighted, that is it shows all noise frequencies. Clearly the highest noise levels are produced at the lower frequencies . The third octave data shown overlaid in figure 5 is the A-weighted data. The lower frequency noise has removed from the analysis by the use of the A weighted filter; it is important to note that in reality the turbine will still produce this noise. The lower frequency noise hasn't been eliminated by clever engineering; however it has been removed from analysis. Also the third octave data is based on an average and this can mask some tonal characteristics. These are the characteristics that need to be considered in section 4.4.3 of NZS6808 and the evidence produced by Mr Hunt is inadequate allow full and essential consideration of these special tonal effects. `Figure 6 shows the amount of noise lost from the analysis.

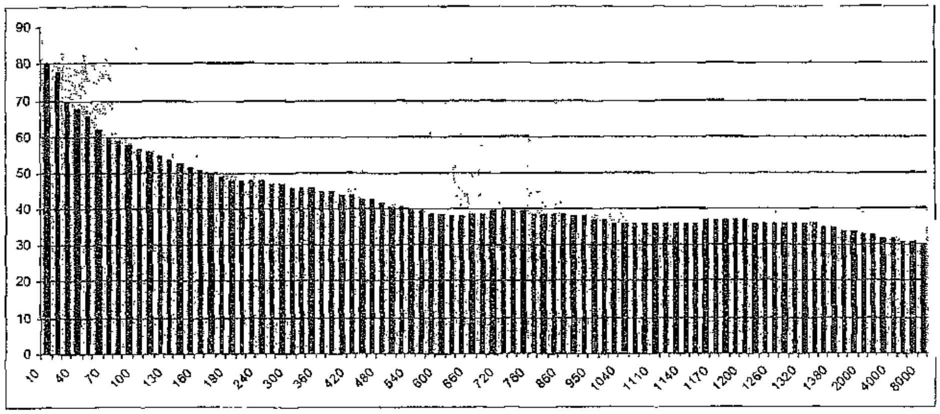


Figure 4 V52 unweighted data

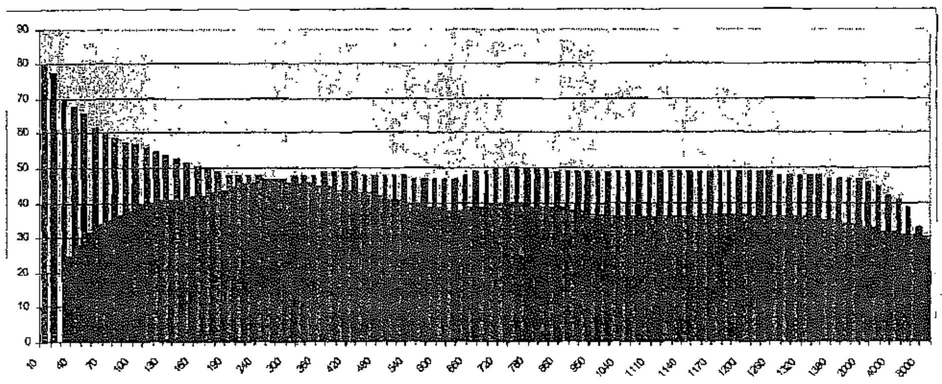


Figure 5 V52 unweighted and A-weighted data overlaid

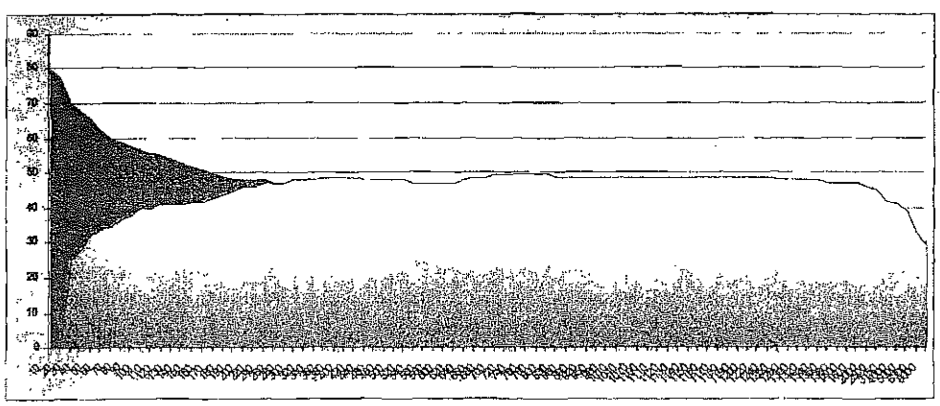


Figure 6 V52 Noise lost the analysis

6.10 The Batho report and others (Guest 2003) cited low frequency noise as a significant issue for regulators due to the difficulties with measuring it and mitigating it. The Casella report (Casella 2001)has cited low frequency noise as having several pertinent features different to other frequencies of community noise:

- low frequency noise is not attenuated with distance from the source, making low frequency noise more prominent at greater distances for example the low frequency or bass noise from a neighbours loud music will carry to households many streets even though the high frequency noise or melody has been attenuated with distance.
- low frequency noise is not attenuated by typical building envelope designs to the same extent as other frequencies making low frequency more prominent inside a building
- inside buildings resonance can be set up inside a room with nodes (quiet points) and antinodes (loud points), which can elevate low frequency noise inside a room
- older peoples' hearing is proportionally more acute at low frequencies than other mid or high frequencies and
- low frequency noise can cause lightweight elements of a building structure to vibrate, such as a vibrating or rattling window.

6.11 These points have been reiterated by many other authors. Adverse effects from noise may be greater than for low frequency noise other noises for equal sound pressure levels regardless of which weighting scheme is used.

NZS6808 DOESN'T ACCOUNT FOR ATMOSPHERIC EFFECTS

6.12 NZS6808 uses a simple propagation model that does not account for wind, ground or topographical effects, such as contours, and uses a simplified approach to account for atmospheric effects (New Zealand Standards 1998; EPA 2003). This can underestimate both the noise produced and transmission of this noise. A four day caucus of acoustic consultants for the West Wind wind farm hearing heard before the Environment Court, found that NZS6808 is workable but has some significant technical deficiencies that need addressing, such as atmospheric effects (Thorne 2007). A member of the West Wind acoustic caucus concluded that there is a temptation to only fulfill the requirements of the standard without considering the complex nature of wind farm noise, such as third octave data, topographical effects and atmospheric stability (van den Berg 2005). In practice, the application of NZS6808 may be too simplistic an approach to something that is as complex as noise from a wind farm (EPA 2003).

6.13 The approach of Standard NZS6808 is unusual in that it allows wind turbines to produce noise up to the greater of 40dBA or ambient noise levels plus 5dBA. The premise of this approach is the wind that makes turbines turn will also produce masking noise. However, van den Berg (2006) has found that with tall (80 – 110m) modern turbines there are frequent periods with sufficient wind at hub height to turn the turbines and generate noise, with corresponding relative stillness and lack of masking noise at ground level. He found that this effect is most pronounced at night time. Van den Berg, has concluded that the number and severity of noise complaints near wind farms are partially explained by three findings;

- that actual sound levels are considerably higher than predicted noise
- wind turbines can produce noise with an impulsive character which has been described as a "wump, wump sound" each time the turbine blade passes the tower (van den Berg 2004; van den Berg 2006)
- noise measurements, which are expressed as averages of sound energy, substantially under represent the loud/quiet nature of the pulsing sound produced by turbines.

6.14 Van den Berg found residents 2km away from wind farms expressed annoyance with noise, which is contrary to conventional wind industry calculations, which assumes minimal noise beyond 500m. Significant variations occurred between day and night time noise due to higher wind speeds at hub height turning the turbines during the night hence producing night time noise compared to lower wind speeds and a consequent lack of masking noise at ground level close to residences (van den Berg 2006).

6.15 The Applicant has suggested that the effects found in this study would not occur in New Zealand due to the difference in topography. However the impulsive characteristic of noise produced as the blade passes the tower is a universal phenomena, irrespective of topography or nationality. The same applies to the under-representation of peaks and lows when data is averaged. Inversions, and higher air speeds at higher altitudes relative to stiller air at ground level and a consequent lack of masking noise are also universal phenomena. Mr Hunt in his evidence made some criticism of Mr van den Berg's research and queried his impartiality in that he has appeared for communities opposing wind farm developments. I have sufficient confidence in the research peer review process to reassure Mr Hunt that Dr van den Berg's work would have been scrutinized by leading acoustic experts for both method and analysis. Acceptance of his PhD thesis and publication of his research in acoustics journals ranked at 9 & 10 worldwide is sufficient testament.

CUMULATIVE NOISE

6.16 Some acoustical consultants consider the approach of NZ6808 in focusing on ambient sound plus 5dBA as erroneous, especially in areas with staged wind farm developments, or where there are a number of wind farms close together. In these situations, each subsequent development or stage of a development is permitted to build on the noise produced by existing turbines, with a net effect of ramping up ambient noise (Stewart 2006).

7.0 HEALTH EFFECTS OF NOISE AND LOW FREQUENCY NOISE

7.1 WHAT IS HEALTH?

The World Health Organisation (WHO) has defined health as *"a state of complete physical, mental and social wellbeing, and not merely the absence of infirmity."*

This definition has been established for nearly 50 years and has been extensively peer reviewed and accepted. Every international environmental health conference that I have attended has had at least one presenter display this definition which is met with nods of agreement from an informed audience. The definition clearly includes emotional states such as annoyance and sleep disturbance as health effects, in addition to diseases such as diabetes or depression and cardiovascular disease.

7.2 THE RMA AND HEALTH

The RMA is intrinsically about protection of health. While the overriding purpose of the Act is to promote the sustainable management of natural and physical resources, this is defined in Section 5(2) as meaning:

> *"managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their **health** and safety."*

Health effects are also covered in numerous other sections of the Act.

7.3 HEALTH AND NOISE

The Applicant stated there is no evidence of health effects from noise. This is difficult to reconcile as substantial body of compelling evidence in the literature on adverse health affect from noise including a high ranked international journal called Noise and Health, dedicated to this topic as evidence in biomedical, medical, and environmental health literature, published both in peer reviewed reputable journal papers and peer reviewed reports.

7.4 Research shows that the effect of noise is much more than auditory. Noise stimulates the brains reticular activating system. Neural impulses spread from the reticular system to the higher cortex and through out the nervous system. Noise can therefore influence perceptual, motor and cognitive behaviors and also triggers glandular, cardiovascular and gastrointestinal changes by the means of the autonomic nervous system (Suter, 1991 in Enhealth, 2004).

7.5 It is recognised that hearing has evolved from our survival instincts to respond to danger as well as to alert, warn and communicate; our hearing is operational even when people are asleep. As a result, both wanted and unwanted sound directly evokes reflexes, emotions and actions which are both stimulants and stressors. The auditory system has the fastest response rate in the human brain and processes information hundreds of times faster than other senses (Hudspeth 2000). The extent to which noise is a stimulant or stressor is a factor of noise source, onset of the noise, duration and characteristics of the noise and whether the exposure is voluntary or involuntary (EnHealth 2004).

7.6 While acousticians working with the wind energy industry conclude audible and low frequency noise from wind farms is unlikely to cause health effects, it is important to note that experts who approach this issue from a medical perspective have arrived at the opposite conclusion.

7.7 Forty years ago the World Health Organisation (WHO) (WHO,1966) concluded noise was an occupational hazard and public nuisance and identified that the level of annoyance involved more the characteristic of the noise than the intensity. Further it disturbed sleep and was a danger to physical and mental health.

7.8 More recently, WHO, the European Community members and numerous other high level health organisations have determined that there is a large body of evidence linking exposure to noise with many health effects and social consequences other than hearing loss. The WHO guidelines for community noise health effects as

> *...."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."*

7.9 These effects were reiterated by Berglund who lists health effects from community noise as

> *"interference with communication; noise induced hearing loss; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; annoyance responses; effects on social behaviour"* (Berglund 2000).

7.10 Disruption to the ability to learn, sleep disturbance, ischaemic heart disease and hypertension have been proven effects. Further adverse health effects ensue from sleep deprivation and sleep disturbance and this is discussed in more detail later in this evidence.

7.11 The link between noise and annoyance has been well established. Noise can't be blamed for initiating serious mental health problems but it is well established that people who are stressed or depressed are more affected by noise. Noise acting as a stressor and sleep disruptor has an impact on the cardiovascular system. Both stress reactions and sleep deprivation will evoke mechanism such as increased release of stress hormones, including adrenaline, noradrenalin and cortisol. These have a cascade of physiological effects and will increase blood pressure and vasoconstriction. Cortisol will increase blood pressure, suppress the immune system. A cross sectional study found an association between environmental noise annoyance and cardiovascular disease (Belojevic 2002). Pederson and Wayne found an association between
wind turbine noise and annoyance and lower sleep quality and negative emotions and found this adverse effect was stronger on rural than suburban environments and in hilly terrain (Pederson 2005; Pederson 2007)

7.12 NOISE AND CHILDREN

The health effects of noise on children has been given special attention by the environmental health, biomedical and education research community. On one hand children have the ability to hear extremely quiet noise, yet they haven't developed the mental ability to tune out distractions. Impaired cognitive function, reading, motivation, headache, annoyance, and hypertension are most pronounced in children exposed to environmental noise and can result in life-long academic under achievement and sub optimum health (Enhealth, 2004).

7.13 Evidence is very strong for the effects on child health from exposure to noise (Evans 1993). Tasks involving central processing, and language comprehension, reading, attention, problem solving and memory are most affected by exposure to noise.

7.13 Children exposed to environmental noise will have;

- Deficits in sustained attention and visual attention,
- Difficulties in concentrating in comparison with children in quieter environments
- Poorer auditory discrimination and speech perception
- Poorer memory
- Poorer reading ability and school performance on national standardized tests
- Habituation to auditory distraction,
- less motivation, more annoyance,
- poorer quality of life
- raised catecholamine secretion and altered blood pressure (Evans 1993; Heines 2001)

7.14 The effects on vulnerable sub-groups within the child population (learning disability, autism, hearing impaired) has been highlighted in the research as being especially susceptible to environmental noise. This will be discussed in more detail by another submitter. The effects of noise on children is pertinent to this resource application as large number of families with young children live near the proposed wind farm, many potentially within the 50dBA contour, and two primary schools are located within the 40dBA contour, as shown in the noise contour maps produced by Mr Thorne.

7.14 HEALTH AND LOW FREQUENCY NOISE

"Low frequency noise (levels below 200 Hz) are perceived through both touch and hearing, which accounts for the greater level of annoyance from people exposed to low frequency noise. Recently greater attention has been given to the effects of low frequency noise because it is pervasive and many structural attempts at remedy are inadequate" (Enhealth, 2004)

7.15 The Report of the Noise Review Working Party 1990 published by the Department of the Environment (Batho 1990) commented on low frequency noise as follows:

> *...."Low frequency noise can have serious effect on the quality of life of those affected by it".*

7.16 Professor Des Gorman, Head of the School of Medicine at Auckland University and Professor of Occupational Medicine, has given his permission for me to repeat a quote from him. Prof Gorman is both a neurologist and environmental health practitioner and so is conversant on the effects on the brain as well as noise. He has stated:

> *"low frequency noise is very distressing for people exposed it. It torments people and compromises sleep".*

7.17 While not suggesting that the following comment has the standing of a journal report for completeness I refer to a recent report on Campbell Live stated most people can't hear low frequency noise but those who can are driven crazy with the sensation. It disturbs sleep and can be a physical sensation in the human body as much as it is an auditory response.

7.18 The WHO are clearly concerned about low frequency noise and health effects and have concluded

> *"The evidence on low frequency noise is sufficiently strong to warrant immediate concern....Health effects due to low frequency noise components in noise are estimated to be more severe than for community noises in general* (WHO, 1996).

7.19 Leventhall, who is an acoustic consultant to the wind energy industry, and who is often cited as a key opponent of the relationship between low frequency noise and health has presented conflicting conclusions. His conclusions have oscillated between "low frequency noise is below the threshold of hearing, and is therefore undetectable" (Leventhall 2005) to "Low-frequency noise causes extreme distress to a number of people who are sensitive to its effects". It is worth noting that the introduction to the Dti report on low frequency noise quoted by the Applicant, the report has a disclaimer that it is not a Government report and should not in anyway be considered as such. The authors of this report are largely acoustic consultants to the wind energy industry this could possibly introduce some bias.

7.20 Exposure to low frequency noise has been found to elicit stress reactions and in some instances resonance reactions in vocal chords and internal organs. Stress reactions in response to low frequency noise include bizarre auditory sensations such as pulsations or flutter in the ear. It increases the release of stress hormones like adrenaline, noradrenalin and cortisol. Cortisol extraction has a wide range of effects on the metabolism of proteins, carbohydrates and fats and will temporarily suppress the immune system and sharpen attention (Enhealth, 2004). As with other noise, low frequency noise has been found to affect annoyance, stress, irritation, unease, fatigue, headache, nausea and disturbed sleep. (Casella 2001)

7.21 Low frequency noise disturbance has been well documented as an effect from wind turbines (Casella 2001; van den Berg 2004; Jakobsen 2005; van den Berg 2005). A number of physiological (blood pressure and heart rate) and psychological effects were found in laboratory studies (Chen 2004).

7.22 NOISE AND SLEEP

It is not known why mammals need to sleep, however it is well established that it is a fundamental for restoring biological function, body chemistry as well as mental outlook, behaviors and emotion. It is essential to our wellbeing and health and we are programmed to spend more than a third of our life in a semi conscious and unproductive state. Sleep quality and its effects on health is not only about duration but the ability to cycle undisturbed through the various sleep phases (Dutch Health Council, 2004; (Netherlands 1994).

7.23 Noise interferes with sleep in a number of ways;

- awakening – it causes the sleeper to awaken repeatedly resulting in poor sleep as well as other health impacts,
- alter sleep pattern- noises may make the sleeper change from heavier to lighter sleep,
- reduce the percentage and total time in REM sleep
- increase body movement
- change cardiovascular responses
- cause effects on slow wave sleep

7.24 These changes can affect mood and performance the next day (Enhealth, 2004).

7.25 Sleep loss reduces cognitive function and can affect physiology, behaviour and subjective outcomes. Statistically significant variations occur in vigilance, memory, learning, hormone levels and sexual function. All stages of sleep are equally vulnerable to disturbance by noise and cardiovascular irregularities and increases in blood pressure can occur without the sleeper awakening (Carter 1994).

7.26 Professor Philippa Gander, from Massey University, Public Health Research Centre, is a world expert of sleep. She has found that disturbed sleep, either due to disruptions of the REM cycles or duration lead to significant physiological changes including the release of two appetite hormones (which leads to over eating), headaches, blood pressure, impaired cognitive function and reactions, tinnitus, and type-2 diabetes.

7.27 The medical consequences and social cost of over-eating, obesity and cardiovascular disease and type-2 diabetes are documented extensively in other literature. These include fatalities, days off work or school, hospital cost, and medications.

7.28 Professor Ganders's research centre has also demonstrated a sleep deprived driver will have their reaction time impaired similar to a driver under the influence of alcohol. Both sleep deprived drivers and drunk drivers place the driver, their passengers and other road users at high risk of accidents (Gander 2005). The NZ Police have determined from accident reports that fatigue can impact on a drivers reaction times, their concentration and general understanding of the road and traffic around them. In 2005 fatigue was a significant factor in 40 fatal traffic crashes, 162 serious injury crashes and 449 minor injury crashes. For every 100 drivers or motorcyclists killed in road crashes where fatigue was a factor, 45 passengers and another 27 road users were also killed. Driver fatigue is difficult to identify or recognise as contributing to a crash. This means it's likely that fatigue is under-recorded (Landtransport 2005). The medical and social costs of road accident injuries and fatalities and damage to property is well established in other literature.

7.29 Measurable sleep disturbance has been observed as noise levels exceed 35dBA and the effects increase with increasing noise levels. These and other health effects have given sufficient evidence for WHO to recommend that the equivalent sound pressure level should not exceed 30dBA indoors, if the negative effects on sleep disturbance are to be avoided (Berglund 1999).

7.30 The guideline categorically state that

> *"to avoid sleep disturbance, indoor guideline values for bedrooms are 30 dB LAeq for continues noise and 45dB LA max for single loud events.... Lower noise levels maybe annoying depending on the nature of the noise source. If the noise includes a large proportion of low frequency components, values even lower than the guidelines values will be needed, because low frequency components in noise may increase the adverse effects considerably....*

and it goes on to recommend the use of dBC weighting rather than dBA

> *... More regular variations with time have been found to increase the annoying aspects of the noise. For example, noises that vary periodically to produce a thumping or pulsing sensations can be more disturbing than continuous noise.*

This document also recognises the need to sleep with a window open for ventilation and for cooling in warm weather.

7.31 The Institute of Environmental Medicine at Stockholm University has undertaken extensive research on the impact of community noise and sleep. They found noise affects sleep in several ways including;

- Increasing the time needed to fall asleep,
- Altering the cycle of sleep stages and
- Deceasing the quality of REM sleep,

7.32 Any one of these problems over an extended period can lead to more serious health problems. Sleep disturbances have been linked to three characteristics of noise exposure, including:

- The total noise exposure (including daytime exposure)
- The peak noise volume,
- For intermittent noise, the number of volume peaks

7.33 Sleep quality has been found to be eroded much more by a number of noise events that were roughly 5dBA above the threshold of the noisy event.

7.34 Symptoms akin to vibroacoustic disease (Branco 2004) and increased frequency of hypertension and cardiovascular illness have been reported by people living close to wind farms. It is thought that these symptoms arise from a combination of persistent audible noise, flicker and low frequency noise destabilising the human body (Stewart 2006; Pederson 2007).

VIBRATION AND HEALTH

7.35 The Phipps survey, Morsley survey and Bennett survey all independently observed that people living close to wind turbines in New Zealand experience vibrations from wind turbines. The effects of vibration in buildings and health effects from vibrations have been well researched and documented for over four decades.

7.36 The American National Standard Guide to the Evaluation of Human Exposure to Whole Body Vibration ANSA S3.18-1979 and the International Standard ISO 2361 Human Response to Whole Body Vibration are both widely referenced in public health and occupational health text books. Whist the adverse health effects from vibration were first observed in occupational medicine, it is well established and noted in ANSA S3 18 – 1979 that vibrations will also cause adverse health in non occupational settings. This standard states that "avoiding vibration in the home environment is of high importance" due to prolonged exposure. This standard goes on to state that "high standards should be applied to the home, and perceptible vibration should be minimal or absent, particularly at night." This standard states that primary adverse health affects can occur from the direct physiological effects, and secondary reactions occur in response to noise from vibrating or rattling building components. "In addition startle reactions, fear of damage to the structure or fear of being hit by falling objects, and interference with sleep, conversation or other activities will occur when parts of the home are rattled by vibrations (American National Standard Institute 1979).

7.37 When the building structure vibrates these vibrations are transferred to the human body as a whole through the supporting surfaces; through feet when standing, the buttocks when sitting, or the supporting area of the body when reclining. Vibration in buildings can interfere with activities and affect occupants in many ways. The quality of life can be reduced as can work efficiency (American National Standard Institute 1979)

7.38 Whole-body vibration has many widespread and varied effects and these effects are not always easy to diagnose, as the body does not have one receptor for this energy as for example the ear does for sound energy or noise resulting in hearing loss, but vibration effects are manifested far and wide in the body and may be mistaken for a number of other common ailments (Joubert, 2001).

7.39 The most pronounced and common effect is lower back pain which is caused by various mechanisms of vibration on the musculo-skeletal system of the body, namely the degeneration of the intervertebral discs, which leads to an impairment of the mechanics of the vertebral column allowing tissues and nerves to be strained and pinched leading to various back problems. The nutrition of the discs is also affected by long periods of sitting aggravated by vibration exposure, which causes tissue nutrients needed for growth and repair of the discs to flow outwards by diffusion instead of inwards where they are required and this leads to increased wear and reduced repair of the discs. The vertebral bodies are also damaged by the vibration energy that leads to an accumulation of micro fractures at the end plates of the vertebral bodies and associated pain. Muscle fatigue also occurs as the muscles try to react to the vibrational energy to maintain balance and protect and support the spinal column, but these are often too slow as the muscular and nervous system cannot react fast enough to the shocks and loads being applied to the body. Other health effects that have been associated with whole-body vibration are haemorrhoids, high blood pressure, kidney disorders and even impotence and other adverse reproductive effects in both men and women (Seidel 1986; Joubert 2001).

7.40 There is also the effect of resonance, or natural frequency, wherein the human body as well as other physical structures, respond by acting as a sort of a vibration "tuner" rejecting certain impinging vibration frequencies and responding or "tuning" to other vibration frequencies by actually amplifying and exacerbating these impinging vibration frequencies. For example, human whole body vibration resonance occurs in the vertical (up-down) direction from 4-8 Hertz. This means that if a person is exposed to vibration in this range these vibrations will reach the spine, then the spine will most likely involuntarily respond by actually amplifying and exacerbating the effects of the whole body vibration exposure. In other words, our body has the ability to select, accept, and amplify certain vibration frequencies over others in doing so it can worsen the effects of the vibration (Wasserman 2005).

7.41 Professor Alan Hedge from Cornell University is a co-author of a leading text book on health effects from vibration, and has concluded that whole body vibrations may create chronic stresses and sometimes even permanent damage to affected organs or body parts. Professor Hedge also stresses the adverse health effects stem from the amplification of the vibration and the effect of resonance where the original vibration is amplified in the body or structure. Individual body members and organs have their own resonant frequencies and do not vibrate as a single mass. This causes either amplification or attenuation of the original vibration by certain body parts due to their own natural resonant frequencies. Vibration is the range of 0.5 to 80 Hz have significant effects on the human body. Vibrations between 2.5 and 5 Hz generate strong resonance in the vertebrae of the neck and lumbar region with amplification of up to 240%. Vibrations between 4 and 6 Hz set up resonance in the human truck with amplification up to 200%. Vibrations in the order of 20 and 30 Hz set up strongest resonance between the head and shoulders with amplification of up to 350% (Stanton 2004).

7.42 Professor Hedge found health effects from vibration include;

- Blurred vision
- Motion sickness
- Decrease in manual coordination
- Drowsiness (even with proper rest)
- Low pack pain or injury
- Insomnia
- Headache
- Upset digestion

7.43 Impaired health from vibration can take 4 years or more of exposure for conditions to be medically observable.

NOISE MITIGATION MEASURES

7.44 At a public consultation held in the Plaza shopping centre, I asked Mr Voll what mitigation measures would be provided if turbine noise was a nuisance to residents. Mr Voll replied they would install double glazing to affected homes.

7.45 While it is helpful that Mr Voll has both recognised the adverse impacts and suggested a method of mitigation, this is a solution that is marginally effective as noise especially for noise in the lower frequency range which has a long wave length and will readily be transmitted through the typical New Zealand house construction. In the vicinity of the proposed wind farm there are many dwellings constructed prior to the 1978 change to the building code that would have no thermal insulation in the walls or floor and at best would have thermal insulation added to the ceiling cavity. Homes constructed after 1978 will have a degree of thermal insulation to walls and the ceiling. However, thermal insulation is not effective at reducing noise transmission and even acoustic insulation is not effective in reducing low frequency noise. Installing double glazing without also installing acoustic insulation in the walls, ceiling and underfloor cavity (if the house has one) is not effective, as external noise will pass through any building element with the least resistance. All affected homes would require a mitigation package that would address all elements of the building envelope.

7.46 This requires a whole house approach and would include heavy mass materials for roof, walls and floor, such as concrete, concrete tile, or concrete block, acoustic insulation to all external walls and the ceiling, as well as double glazing and sealing of all penetrations. Recladding the exterior with thick heavy mass walls will require alterations to window and door joinery. Careful design or services, including power points, waste pipes, water pipes, vent pipes etc. is required to avoid transmission pathways. This will affect internal layout as it will preclude the placement of plumbing fittings on external walls unless there is sufficient room to construct a services duct for pipes so as not to inadvertently create a transmission pathway. As the house is now a sealed box it is essential to add and operate a mechanical ventilation system with acoustically dampened air intakes. Tight sealing of the homes envelope will have significant impacts on the indoor air quality, which in turn can impact on the occupants' health. All of this is a significant undertaking and will involve significant loss of amenity to the household.

7.47 The reality is there is no mitigation measures that can address noise in the outdoor living areas, other than very tall trees which will take longer to grow than the predicted life of the turbines or separation distance between the turbine and the households of 5 km.

DETRIMENTAL EFFECT ON INDOOR AIR QUALITY FROM TIGHTENING THE HOME'S ENVELOPE TO MITIGATE NOISE INGRESS

7.48 The consequences on the indoor air quality and human health of tightening up housing are significant. Air inside a home can be up to 1000 time more polluted than outdoor air. Any measure that impede ventilation will concentrate indoor pollutants. Over 40% of New Zealand houses have fungi contamination that may include species which are respiratory irritants, toxic or carcinogenic. New Zealand has one of the highest rates of asthma in the world and the link between housing and asthma has been well established (Howden-Chapman).

IS THE DOOM OVER NEW ZEALAND'S ENERGY SUPPLY ALL A PACK OF LIES?

8.0 Madame Chair asked the question if all the doom over New Zealand's energy supply has been a pack of lies? The answer is not so much a pack of lies, but since these predictions new energy generation has increased beyond original predictions and the ability to conserve energy without the loss of amenity has increased. The next section of my evidence will address this question. I will endeavor to address the complexities of this succinctly as possible by using analogies with every day life.

8.1 New Zealand used to have an abundance of very cheap hydro electricity and this allowed the country to have inefficient energy use standards such as building performance and inefficient habits. A decade ago predictions for New Zealand's energy supply were that demand for energy was growing faster than growth in generation and transmission capacity. This triggered alarm bells and set in place many excellent initiatives to address energy consumption and increase generation. Current energy forecasting shows New Zealand is well on the way to achieving the required electricity supply except at peak locations, such as Auckland and at peak times. The largest current challenge is managing the distribution of the supply load with the peak demand required in Auckland. As mentioned by Dr Bennent there are conditions when there is too much energy generation south of the Waikato and hydro is spilled; this needs to be avoided to prevent waste.

ENERGY EFFICIENCY

8.2 The New Zealand Energy Strategy states the important principle, "to invest in energy efficiency whenever possible as this is cheaper in the long run than the cost including externalities, of new generation." This principle is repeated in different forms in the New Zealand energy strategy.

8.3 Energy efficiency is considered as the most promising source of freeing up energy capacity, and is capable of delivering substantial savings in overall energy consumption. In the past New Zealand has had the luxury to use its energy very wastefully. Two thirds of all electricity is consumed in some way in buildings and consequently energy efficiency programmes are focusing and achieving good results within the building sector.

8.4 Very substantial savings in energy consumption could be achieved for modesty little change to the building and no lose of amenity. Often energy efficiency measures lead to a vast improvement warmth and dryness of the home and health of the occupants (Howden Chapman, 2007).

8.5 The Home Energy Rating Scheme (HERS); incentives for industry and commercial facilities operators to optimise efficient use of energy; financial incentives for the installation of solar water heating; changes to the building code to mandate a level of solar utilisation and the BEACON sustainability programme are but a few such projects. These initiatives are either in their infancy or will come into operation in the next 12 months.

8.6 As discussed in the evidence by EECA, home insulation subsidies are available to all low income home owners. In addition to the subsidies, Contact energy, Trustbank, and many other insightful businesses are offering co-payments to top up the home insulation subsidies. As home heating accounts for 34% of the energy used in a home increases in insulation can have a dramatic reduction in the need for energy.

8.7 A further very simple measures that would cause no reduction in amenity for households but would save NZ a huge amount of energy. In the HEEP study Nigel Isaacs identified that households waste 112 + or – 4 W or 10% of the total average residential power demand in standby load. Standby load is the energy used by appliances such as TVs, DVDs, and computers while they are in standby mode and waiting to be used. Isaacs calculated this as costing NZ 160MW. This could easily be saved by turning appliances off at the appliance rather than via the remote (Isaacs, 2006).

8.8 Compact energy efficient fluorescent light bulbs use one fifth of the electricity of a conventional incandescent light bulb. The government has recently invested $3 million to extend a campaign that was successful in getting energy efficient compact fluorescents into 80% of homes. If 70% of New Zealand homes replace only four old bulbs with four energy efficient bulbs, the country's energy savings will exceed the capacity of New Plymouth's power stations and provide sufficient energy for either all of Hamilton or Dunedin. These four light bulbs retail for under $16, a very modest sum and much more cost effective way of increasing supply than simply building more generation (Parliamentary Commissioner for the Environment, 2006).

8.9 The Tertiary Education Commission has recently granted nearly $1M dollars to the National Energy Research Institute (NERI) which is a collaborative centre of excellence that stretches across 4 universities, to promote education at all levels (schools to tertiary institutes as well as general public) in smart energy technologies. Dr Peter Read and I are both members of NERI. Before investing in NERI the Tertiary Education Commission undertook a very rigorous peer review, including scrutiny that the project team could achieve the energy efficiency goals. Their investment is testament to their confidence that significant reductions in energy are achievable and this will translate into economic growth as well as brighter prospects for New Zealand's ability to meet its electricity needs.

8.10 The above initiatives are giving energy forecaster's confidence of a brighter future and there are more efficiency measures being proposed.

INCREASED GENERATION

8.11 Further, the generation market has responded and new generation has increased at a rate higher and faster than previously predicted.

8.12 The above factors are giving energy forecasters greater confidence in the surety of supply capacity. Evidence suggests that the energy supply threat has reduced and that the generation market is correcting to avoid a possible oversupply.

8.13 Mighty River has just cancelled plans to construct a new gas fired electricity generator at Marsden on the grounds that the new energy forecasts show it would produce more energy than New Zealand requires in the foreseeable future, and an oversupply would lead to price instability. Contact Energy has also deferred construction of Otahuhu C for the same reason.

8.14 Current predictions for the energy future have changed from "we need every possible GW" to "we need to address certain pinch points". The pressure to generate the total energy needs is relaxing, however there is still concern over the placement of the supply in relation to the large load centres and supply to meet peak periods.

8.15 These constraints or pinch points were explained in the presentations by Dr David Bennett and Dr Peter Read. It is worth noting that both Dr Bennett and Dr Read` are highly respected in their field and have no vested interest in energy generation.

8.16 The two biggest energy supply issues are;

- getting the load through the Waikato bottleneck in the transmission network to Auckland load centre and
- being able to meet the peak load.

8.17 Auckland is both the largest and the fastest growing load centre in New Zealand and concerns about energy supply for Auckland are still valid. All energy generated south of Waikato will face large loses during transmission. An analogy for this is pouring 100L of water into a leaking hose may only realise 90L by the time it arrives in Auckland. The longer the length of pipe, or electricity transmission line; the larger the transmission loss. The transmission network is very constrained by the capacity of the transmission lines in the Waikato. This has been documented by the Parliamentary Commissioner and the need for generation north of Waikato to avoid both transmission loses and the bottleneck are being advocated.

8.18 Construction of more wind farms in the Manawatu will not contribute greatly to the Auckland load.

PEAK SUPPLY LOADS

8.19 The commercial and industrial sectors typically demand electricity from 7:00am to 7:00pm 5 days per week. Nighttime and weekends loads are lighter than during the day, and lighter in summer than winter. The residential sector tends to have two distinct peaks, one around 6-8:00am for morning coffees and showers; with a larger peak that builds from late afternoon, peaking around 7pm and tailing into the evening. The winter load is substantially higher than the summer load. This is graphically represented in figure 7.

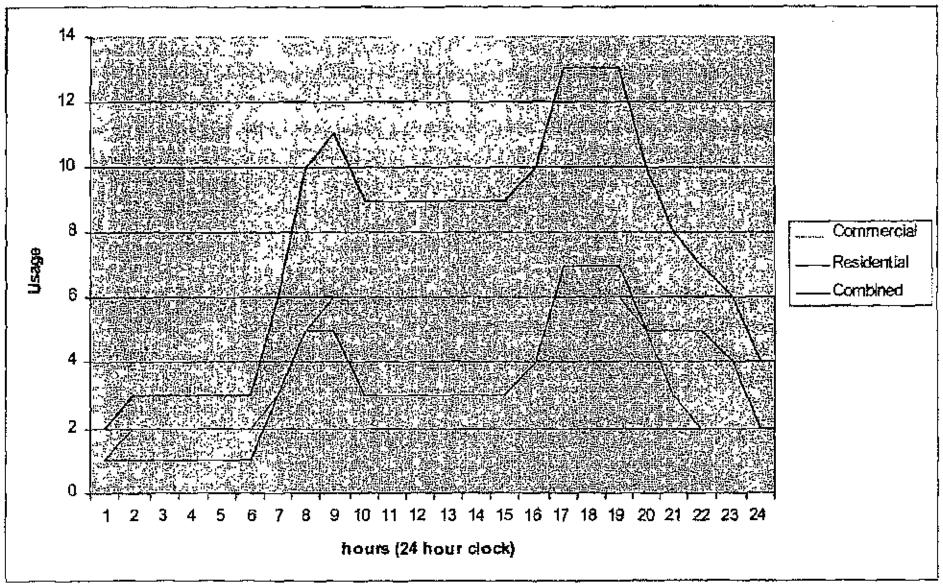


Figure 7 Peak load energy use

8.20 The peak supply loads occur when these sectors are demanding electricity simultaneously. Both electricity generation and transmission need to have sufficient capacity to meet the peak load but may have substantial excess capacity at non-peak period. New generation is most valuable if it can be guaranteed to be available to contribute to the peak load, with ideally any excess able to be stored for peak periods.

8.21 Assessment of any energy source without understanding its contribution to management of the peak demand period can be likened to running a catering business without being able to control the time the meals arrive. For example, the peak loads for a commercial kitchen will occur around 7:00am, midday and 6-7:00 with lull periods in between. To be efficient the kitchen needs to be able to produce sufficient meals and produce these meals at the times required by the diners. Meals produced during periods of low demand will be wasted unless they can be stored.

8.22 Managing the peak daily load is easy with hydro and gas as these can both be stored in periods of low demand and utilised in periods of high demand. Gas is accessible all year and storable until required. Energy supply from gas can not be turned on and off quickly and unless it is running in idle mode which still consumes energy. This "idling" wastage occurs if gas is used as a reserve for when wind energy generation drops during periods of light wind. For this reason the Electricity commission has cited hydro as the reserve for lulls in wind energy, not gas. This effectively changes the calculation of green house gas savings wind is offsetting a renewable energy not a fossil fuel. It can also lead to wasteful spilling of hydro as shown by Dr Bennet.

8.23 Wind energy does little to address the peak loads it is neither guaranteed to be available for peak electricity demand periods and can't be stored in light electricity demand periods. Therefore it can not be relied on to offset peak electricity load generation capacity.

8.24 Further Nigel Isaacs, Principal Scientist with BRANZ and a leading researcher in energy supply, has conducted various scenarios models using energy from different sources to determine ways to address the peak load. He has shown that moving to alternative fuels such as solar, gas or wood in a low emission wood burner for space heating, water heating and cooking will make a very significant contribution to reduction of the peak energy load. Reliance on electricity generation and transmission fails to address the peak load and will result in increasing demand for peak generation and transmission capacity (Isaacs, 2007)

SOLAR ENERGY AND ENERGY EFFICIENCY AS ALTERNATIVE SOLUTIONS

8.25 Much of the evidence presented at the hearing has assumed that wind energy is the renewal energy of choice. To present balance to the debate we need to introduce the discussion of other renewable energy sources. Hydro and wave power have been mentioned in passing. Surprising very little discussion has occurred on the role of solar energy in New Zealand.

8.26 New Zealand has an abundance of solar resource. Solar radiation in New Zealand delivers about 1kW per square meter, which is a virtually limitless free operational resource for much of New Zealand. Even the south of the south island has sufficient solar energy to provide the energy for about 70% of typical houses hot water requirements and about 90% of home space heating. As an example, Associate Professor Bob Lloyd has constructed a passive solar designed house near Dunedin at an additional $3000 above standard construction costs. He maintains his house at over 18 deg C and only needs to supplement the solar heat if there are 3 or more days with no sun, even in mid Dunedin winter.

8.27 New Zealand has a much higher solar resource than either Japan or Germany. Yet both these countries have a much higher uptake of solar energy utilization.

8.29 Solar energy can be used in three ways, solar water heating, photovoltaic panels and passive or active solar space heating. Although photovoltaic are used to generate electricity for many New Zealand homes, they are outside my expertise and I will not discuss them in this hearing. However solar water and passive solar are two renewable energies which, as EECA mentioned, have huge potential in New Zealand. The New Zealand update of solar technologies has in the past been ridiculously low in part due to the low performance criteria set in building standards, cheap hydro electricity and poor leadership. The main reason for lack of solar is that the energy is harvested and used directly by the household without passing through an electricity meter. As only the household profits from solar energy this is an unattractive option for generation companies.

8.30 The mandatory need to incorporate a significant amount of solar design for all new homes will commence in New Zealand from 2008 when the next revision of the Building Code comes into force. The code revision will address a massive waste of energy for space heating and water heating which accounts for 34% and 29% respectively of energy consumed in houses.

8.31 The HEEP study, conducted by BRANZ, (Isaacs 2006) which was a very detailed 10 year study on the energy use in New Zealand homes has found the energy use patterns shown in figure 8. Hot water and space heating account for 63% of energy used and it is possible to use solar harvested on site instead of electricity generated at a remote site for the vast majority of both space heating and water heating. This is important as residential energy use is currently the fastest growing electricity sector and the latest changes to the Building Code will arrest this growth.

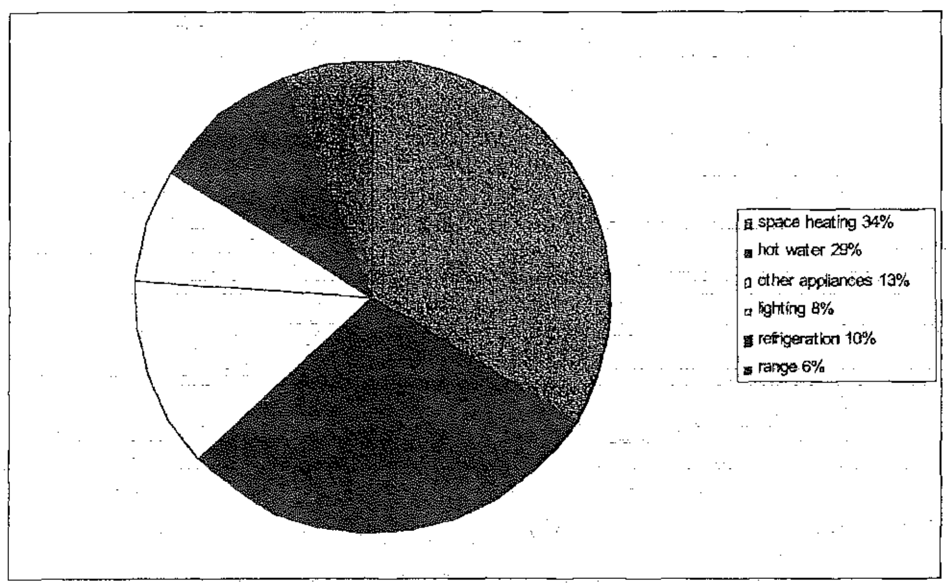


Figure 8 Household energy uses (Isaacs, 2006)

8.32 With support from EECA, solar water heating is coming of age in New Zealand. To harvest the suns free energy for hot water heating all that is required is a sloped surface facing north, a roof is ideal and the only additional requirement is a solar collector and some plumbing.

8.33 There is a long list of features that solar water heating doesn't have. These include:

- No emissions of noise
- No visual pollution
- No transmission losses or distribution network required
- No traffic problems associated with either erection or operation
- No earthworks

- No green house gas emissions
- No footprint
- No price shocks
- No imported fuels
- No purchases of expensive oversees components and impact on foreign exchange
- No dividends to foreign investors.

It does provide free hot water for about 80% of a household's requirements. It does provide security of supply, as well as work for tradespeople. Once installed there is very little maintenance required.

8.34 Solar water heating removes load from the peak electricity demands. Recent energy modeling by Nigel Isaacs Principle Scientist with BRANZ (Isaacs, 2007) has shown that the peak load is the driver for both generation and transmission and they are commending energy sources which shift the load away from electricity which will reduce the need for both peak generation and network capacity.

8.35 Solar hot water also puts extra disposable income in the pockets of average New Zealanders. This has an economic multiplier effect so will feed economic development.

8.36 The cost of one wind turbine is approximately the same cost of solar hot water for 1600 homes with consideration of the financial assistance available from EECA.

8.37 New Zealand's low land use density and rolling land means most homes are blessed with the ability to have glazed wall facing north of sufficient area for solar space heating. In a simplistic sense this, plus some exposed thermal mass eg polished concrete, or tiles or slate over concrete to store the heat and plenty of insulation to retain the solar heat, are all that is required for a passive solar home.

8.38 Most new homes constructed have these and code changes will bring code required insulation closer to a solar home standard bridging the financial difference between these constructions. In addition a higher level of thermal insulation is required. Solar space heating features includes:

- No emissions of noise
- No visual pollution
- No transmission losses or distribution network required
- No traffic problems associated with either erection or operation
- No earthworks
- No green house gas emissions
- No footprint
- No price shocks
- No imported fuels

- No purchases of expensive oversees components and impact on foreign exchange
- No dividends to foreign or corporate investors.

8.39 It does provide house warming for about 80% of a household's heating requirements (Phipps 1996; Phipps 2000). It provides a home that is warmer and dryer, with less mould, dustmites. This has been shown to reduce health costs, hospitalization, days off school and work and provide a drier, warmer home. The economic and social benefits of this are huge. It does provide security of supply. It provides some work for house designers with expertise in passive solar design. Once installed there is no maintenance required and it will be effective for the life of the home. A New Zealand home lasts for 100 or more years, it has a pay back of around 5 years meaning the house will receive 95 years heating for free. If health benefits are included it could have a payback of 1 year. It removes peak load from generation and transmission.

8.40 Passive solar space heating removes load from the peak electricity demands. As above, recent energy modeling by BRANZ has shown that the peak load is the driver for both generation and transmission and they are commending energy sources which shift the load away from electricity which will reduce the need for both peak generation and network capacity.

8.41 It puts extra disposable income in the pockets of average New Zealanders. This has a significant economic multiplier effect so will feed economic development. The cost of one wind turbine is approximately the same cost of solar passive heating for 670 homes.

8.42 Mandating that all new homes move towards solar design will make a massive reduction in the growth in electricity demand. It has been calculated that alone, this change to the building code will save nearly 2000MW per new home which equates to 70GW per year. This is an efficient totally renewable resource with no adverse amenity or health effects, and does not have the prejudice of wind power.

9.0 REFERENCES

American National Standard Institute (1979). The American National Standard Guide to the Evaluation of Human Exposure to Whole Body Vibration ANSA S3.18-1979.

Batho, W. J. S. C. (1990). Report of the Noise Review Working Party, Department of the Environment.

Belojevic, G. S.-T., M. (2002). "Prevalence of arterial hypertension and myocardial infraction in relation to traffic noise exposure." Noise and Health **4**: 33-37.

Berglund, B. L., Thomas.; Schwela, D.H. (1999). Guidelines for Community Noise. World Health Organisation. Geneva.

Berglund, B. L., Thomas.; Schwela, D.H. (2000). Guidelines for Community Noise. Geneva, World Health Organisation.

Branco, M. A.-P., M. (2004). "Vibroacoustic disease." Noise and Health **6**(23): 3-20.

Carter, N. L., Ingham, P., Tran, K., (1994). "Environmental noise and sleep - A study of arousals, cardiac arrhythmia and urinary catecholamines." Sleep **17**: 49-55.

Casella, S. (2001). Low Frequency Noise Update. DEFRA Noise Programme, Department of the Environment, Northern Ireland Scottish Executive National Assembly for Wales: 1-11.

Chen, Y. H., S. (2004). "An investigation on the physiological and psychological effects on infrasound on persons." Journal of Low Frequency Noise, Vibration and Active Control **23**(1): 71-76.

EnHealth (2004). The Health Effects of Environmental Noise - Other than Hearing Loss. Canberra, Australia, EnHealth Council, Department of health and Aging, Commonwealth of Australia: 1-71.

EPA (2003). Wind Farms: Environmental Noise Guidelines. Adelaide, Australia, Environmental Protection Authority: 1-22.

Evans, G. W., Lepore, S.J. (1993). "Non-auditory effects of noise on children." Journal of Children's Environment **10**: 31-55.

Gander, P. H. M., N. S.; Harris, R. B.; Reid, P. (2005). "Sleep, sleepiness and motor vehicle accidents: a national survey." Australian and New Zealand Journal of Public Health **29**(1): 16-21.

Goldstein, M. (1994). "Low -frequency components in complex noise and their perceived loudness and annoyance." Work and Health **2**.

Guest, H. (2003). "Inadequate standards currently applied by local authorities to determine statutory nuisance from LF and infrasound." Journal of Low Frequency Noise, Vibration and Active Control **22**(1): 1-7.

Heines, M. S., SA.; Job, RFS.; Berglund, B. (2001). "A follow up study of the effects of aircraft noise exposure on child stress responses and cognition." International Journal of Epidemiology **30**: 839-45.

Howden-Chapman, P. M., A.; Crane, J,;Viggers, H.; Cunningham, M.; Blakely, M.; Cunningham, C.; Woodward, A.;Saville-Smith, K.;O'Dea, D.;Kennedy,M.; Baker M.;, Waipara, N.;Chapman, C.;Davie G "Effect of insulating existing houses on health inequality: cluster randomised study in the community." British Medical Journal **bmj.39070.573032.80v1**.

Hudspeth, A. K., M (2000). "Auditory Neuroscience: Development , Transduction and Integration." National Academy of Sciences **97**(22): 11690-11691.

Isaacs, N. C. M. F., L. ; Pollard, A.; Saville-Smith K.; Fraser. R.; Rossouw P.; Jowett, J. (2006). Energy use in New Zealand households - HEEP year 10 report. Wellington, BRANZ.

Jakobsen, J. (2005). "Infrasound Emission from Wind Turbines." Journal of Low Frequency Noise, Vibration and Active Control **24**(3): 145-155.

Joubert, D. (2001). Whole body vibration and health. Queensland, Australia, Central Queensland University.

Kjellberg, A., Goldstein, M.,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.

Landtransport (2005). Factsheet 24 - Fatigue: Staying alert while you're driving, Landtransport.

Netherlands, H. C. o. (1994). Noise and Health. Hauge.

New Zealand Standards (1998). "New Zealand Standard NZS6808:1998 Acoustic - The Assessment and Measurement of Sound from Wind Turbines Generators."

Parliamentary Commissioner for the Environment (2006). Wind power, people and place. Wellington, Parliamentary Commissioner for the Environment: 144.

Pederson, E. W., Kerstin Persson (2005). Human Response to Wind Turbine Noise - Annoyance and Moderating Factors. Wind Turbine Noise: Perspectives for Control, Berlin, INCE/European Conference.

Pederson, E. W., KP (2007). "Wind turbine noise, annoyance and self reported health and wellbeing in different living environments." Journal of Occupational and Environmental Medicine.

Phipps, R. A. (1996). Passive Solar in Buildings:. New and Emerging Renewable Energy Technologies in New Zealand., Jointly published by the Energy Efficiency and Conservation Authority and the Centre for Advanced Engineering.

Phipps, R. A. (2000). Passive Solar Design in New Zealand Homes. Report prepared for EECA. Energy -Wise Renewable - 11., EECA.

Seidel, H. H., R. (1986). "Long-term effects of whole-body vibration: a critical survey of the literature." International Archives of Occupational and Environmental Health. **58**(1): 1-26.

Stanton, N., ; Hedge, A.; Brookhuis, K,;Salas, E.;Hendrick, H.W. (2004). Handbook of Human Factors and Ergonomics Methods, CRC Press.

Stewart, J. (2006). Location, Location, Location - An Investigation into the Windfarms and Noise. London, UK, The Noise Association: 1-32.

Thorne, B. (2007). Noise Assessment Report Proposed Motorimu Windfarm Palmerston North. Brisbane, Australia, Noise Measurement Services: 1-57.

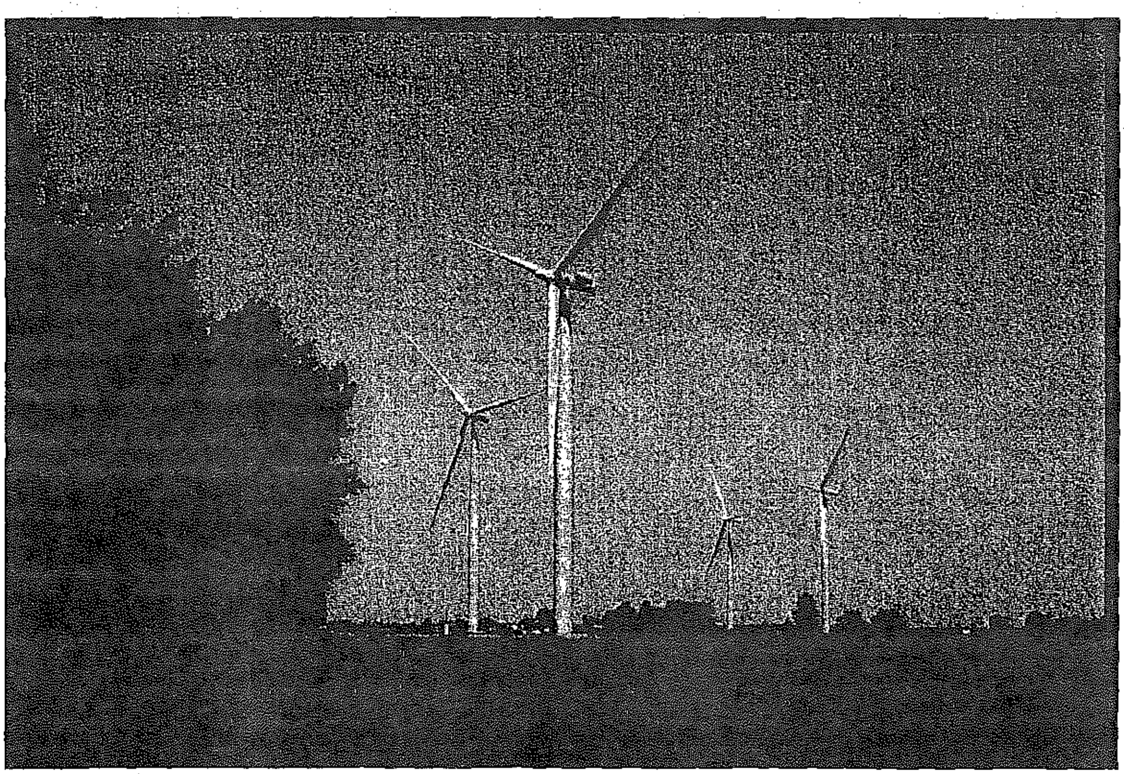
van den Berg, G. P. (2004). Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, the Netherlands, http://www.viewsofscotland.org/library/docs/LF_turbine_sound_Van_Den_Berg_Sep04.pdf.

van den Berg, G. P. (2004). "Effects of the Wind Profile at Night on Wind Turbine Sound." Journal of Sound and Vibration **277**: 955-970.

van den Berg, G. P. (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.

van den Berg, G. P. (2006). The Sounds of High Winds: the effects of atmospheric stability on wind turbine sound and microphone noise. Rotterdam, University of Groningen: 1- 200.

Wasserman, D. E. W., J.F. (2005). Occupational vibration: a brief overview.



Chatham-Kent 2008

The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature

Chatham-Kent Public Health Unit

June 2008

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Prepared by:

Chatham-Kent Public Health Unit
435 Grand Ave West
Chatham, ON N7M 5L8
519-352-7270

Prepared for:

Chatham-Kent Municipal Council
Chatham Ontario

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Introduction

On May 5, 2008, during the regular meeting of the Chatham-Kent Municipal Council, the following notice of motion was moved by Councillor Parsons and seconded by Councillor Sulman:

"That Council request a report from the Board of Health identifying any health impacts and recommended mitigation measures for placement of wind turbines in proximity to residences, public facilities that house individuals, and school properties."

The following report addresses the health and safety issues of wind turbines identified within current Canadian, American, European and Australian literature, and correspondence with key health officials from Ontario, Nova Scotia, and Prince Edward Island. The report presents findings and recommendations from impact assessments, research studies, and opinions of individuals and organizations for and against wind power. New information, research studies, and further impact assessments will continue to be generated; despite the utilization of extensive search techniques, documents will have inadvertently been missed. This report will enable the Chatham-Kent Board of Health to make an evidence-based decision regarding the known health impacts of wind turbines from the current literature and will assist the Board of Health with their recommendations to Chatham-Kent Council.

Using key words, two North American accredited university electronic library search engines provided dissertation papers and published research on wind turbines. An internet search revealed numerous white and grey literature. A posting on the Association of Local Public Health Agencies (alPHa) list serve resulted in documents prepared for two of the thirty-six health units in Ontario that received similar requests for health information surrounding wind turbines. Searching continued until saturation was achieved. Wherever possible, peer reviewed journals were utilized as the first information source in efforts to reduce potential bias.

Wind Power and Health

Wind power has been identified by the United Nations and the World Health Organization as a clean renewable energy source that has no impact on global warming, and no known emissions, waste products, or harmful pollutants.[1,2] One modern wind turbine will save over 4,000 tonnes of carbon dioxide emissions annually.[3] Climate change and global warming are discussed in the news daily and are often cited as the leading cause for major droughts, flooding, and disease crises, that affect the health of populations the world over. Renewable sources of energy are required to ensure the health and safety of future generations. On the opening of the First Session of the Thirty-Ninth Parliament of the Province of Ontario, the Honourable David C. Onley, Lieutenant Governor of Ontario, ensured all Ontarians that the current government was committed to seeing a greener Ontario within its mandate with a goal of reducing emissions that contribute to climate change 6% by 2014 and 50% by 2050.[4]

The Chatham-Kent Official Plan articulates clearly the position of wind farms within the Municipality. Section 2.5.1.1 states,

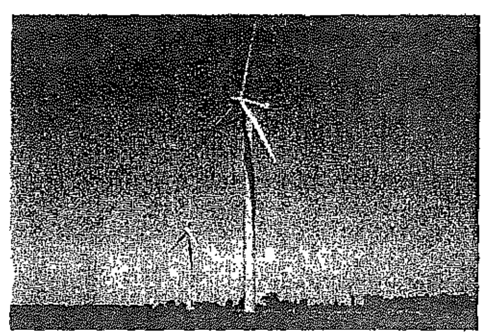
"It shall be the objective of Chatham-Kent to: encourage the development of wind energy systems for electricity production, as a source of renewable energy for the economic and environmental benefit of Chatham-Kent and the Province of Ontario".[5]

However, any new technology brings questions and concerns regarding health and safety implications that must be assessed, and the impact of such, publicly acknowledged.

Human Health Impacts versus Human Safety

The Public Health Agency of Canada (PHAC) defines health impact as an immediate effect of a program, policy, or process on health. It further defines health outcome as a distant or ultimate effect on health of a program, policy, or process.[6] A health impact assessment seeks to determine if a policy or program positively or negatively affects the health of a population. William Lowrence defines human safety as "a judgement of the acceptability of risk, and risk, in turn, as a measure of the probability and severity of harm to humans" he continues, "a thing is safe if its risks are judged to be acceptable".[7] Driving a car is an example of an acceptable risk that most individuals experience on a daily basis.

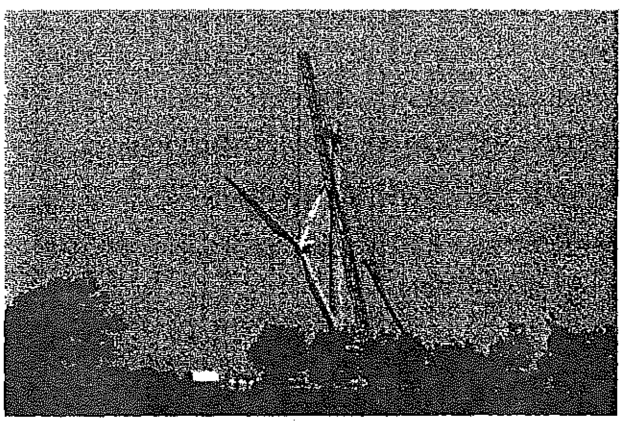
The Workplace Safety and Insurance Board of Ontario define a health hazard as something that results in an injury, illness, or disease. The agency specifies five types of health hazards: chemical agents in the forms of solids, liquids, or gases; physical agents that are forms of energy or force; biological agents including microorganisms in plant, animal, or human tissue; ergonomic hazards; and stress hazards.[8] Health outcomes result from exposure over time; safety concerns usually result from a specific incident. This review attempts to identify the impact of wind turbines on both human health and human safety. Despite extensive searching of the current literature, limited information is available on health concerns relating to wind turbines. It is premature to assume that the limited research available is indicative of the recent influx of wind power to North America; for decades, wind turbines have existed throughout the world with stringent procedures ensuring adherence to established safety regulations. Potential health and safety issues identified and recommended for scrutiny within the impact assessments reviewed include:



* Turbine blade and structural failure
* Icing issues in northern climates
* Sound emissions and noise concerns
* Shadow flicker
* Construction injuries

Aesthetic issues, wildlife concerns, flora and fauna impact, and communication and aviation navigation issues are well documented but beyond the scope and purpose of this review.

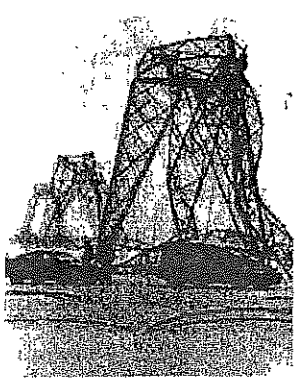
Turbine Blade and Structural Failure



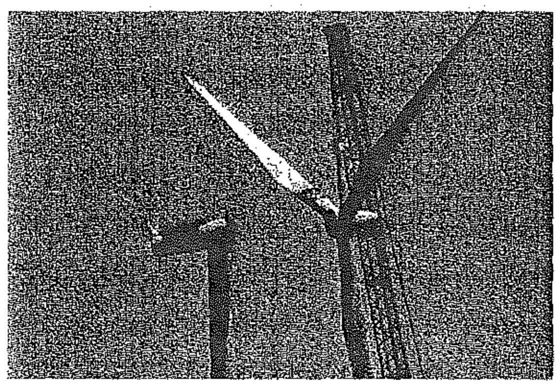
It is estimated that 68,000 wind turbines have been installed worldwide over the last 25 years. Cape Wind, Prince Edward Island, opened in 2001 doubling the number of wind turbines by 2004 and now supplies 6% of the province's power.[9] Nova Scotia's first wind farm opened in 2005 at Pubnico Point.[10] To date, there is no recorded evidence of injury to the public caused by a wind turbine.[11] Modern wind turbines must meet strict international engineering standards, and documented injuries to construction crews occurring only when construction and operating instructions were not adhered to.[12,13] In Ontario, four documented turbine failure issues were found within the literature, all due to lightening strikes requiring the turbine to be shut down for repairs.[14] In 1945, the first commercial wind turbine threw an 8-ton blade 225 meters.[15] Today, wind turbine safety standards meet wind strengths equivalent to hurricane forces.[16] The current Canadian Wind Energy Association's minimum setback requirement for wind turbines is one turbine blade length plus 10 metres.[17] The research supports lightning strikes as posing the greatest potential for blade or turbine breakage. To date, no injuries or fatalities have occurred in North America due to blade or turbine breakage and/or collapse, or with fragments and pieces found between 100-200 meters from the turbines.[18] The American Wind Energy Association identifies the leading causes of blade failure as vandalism, improper assembly, or exceeding design limits.[19]

The current Chatham-Kent minimum wind turbine setback requirement of 600 metres from any residential or institutional zone, which would include schools, provides ample setback in the unlikely event of a turbine failure. In May 2007, Garrad Hassan Canada released an independent report on *Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario.* Ontario wind turbines now receive certification through Statements of Compliance and a Type Certification including a Statement of Compliance for Design Assessment. Turbine failure has decreased dramatically with the introduction of International Electrotechnical Commission standards and continue to be caused mainly by human interference, lightening strikes, or manufacturing defects.[20] The 74 known European turbine failures since 2000, have thrown whole blades up to 150 meters and blade pieces up to 500 meters; as indicated previously, no injuries have been documented in Ontario because of a wind turbine failure.[21]

Icing Issues in Northern Climates



Compared to the rest of Canada, Chatham-Kent enjoys a relatively mild climate. However, weather history demonstrates that from October through to April there are days when the average daily temperature can drop below freezing.[22] Potential injuries resulting from ice build up on wind turbines occurs two different ways, ice throw during turbine operation or ice shed when the turbine is off or idling.[23,24,25] For human injuries to result from wind turbine ice throw, several conditions must exist simultaneously:



- a sustained weather condition conducive to icing,
- the ice dislodges from the turbine or turbine blade,
- ice pieces are large enough to remain intact through the air,
- the ice travels in a particular direction past setback guidelines, and
- someone is in the path of the ice as it lands.[26]

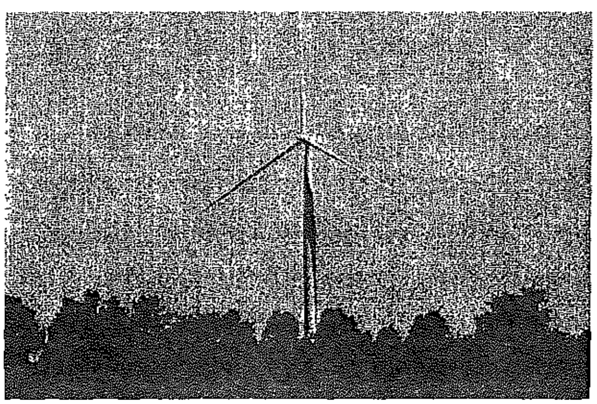
Ontario Hydro monitored its first wind turbine (Huron County Wind Farm) during the first six years of operation. Ice throw occurred thirteen times, with the furthest ice fragment found less than 100 m from the turbine.[27] Tammelin and Seifert investigated the introduction of wind turbines in the Northern Austrian Alps to determine power losses resulting from ice build-up on the rotor blades. While not investigating safety impacts, they recommend a setback distance of turbine height plus rotor diameter wherever the potential of ice throw occurs and the wind turbine is in proximity to buildings, resorts, roads, or ship routes.[28]

Computer modelling was used to estimate the number of potential residential, vehicle, and person ice strikes within a typical wind farm environment in Southern Ontario. With a setback distance of 300 meters for buildings, 200 for vehicles, and 300 for individuals on the ground, the potential number of ice strikes to buildings is 1/500,000 years, vehicles 1/260,000 years, and 1/137,500,000 years for individuals on the ground.[29] The minimum setback regulation in Chatham–Kent is 250 meters from an on-site residential dwelling and 600 meters from residential or institutional zones. This distance is within the generally accepted safety zones and concurs with safe levels of incident probability.

AMEC Earth & Environmental released an environmental assessment in April 2008. The Public Health Department of Prince Edward Island provided the assessment to

Chatham-Kent Public Health despite its pending national public availability.[30] The assessment concurs with data and impact assessments released previously, stipulating that while ice throw is a normal operating process and likely to occur, setbacks of greater than 400 meters provide ample distance in the event of an icing incident in PEI's climate. The impact of turbine icing is greatest for construction workers when the turbine is at rest and not rotating. AMEC approaches the concerns generated from wind turbine icing by recommending mandatory icing training of all construction workers, maintenance and enforcement of setback by-laws, and signage of the potential for icing.[31] Illinois Institute Department for Rural Affairs' Wind Energy Handbook recommends placing tourist information kiosks far enough away from the turbine to prevent a potential hazard from falling ice and encourages adherence to local set back by-laws.[32] Impact assessments concur that ice shedding is of greatest impact during construction and subsequently to the operators of the wind turbines in the event individuals are in the way of falling ice.

Sound and Noise Concerns



Wind turbines produce noise from two distinct sources; the sound of rotor blades as they rotate (aerodynamic effect) in the wind and the motor noise from within the turbine unit itself (mechanical operations). The sound wind turbines emit is described as audible or as infrasound, that which is inaudible to the human ear. The health impact of the noise created by wind turbines has been studied and debated for decades with no definitive evidence supporting harm to the human ear.[33,34,35,36,37,38] It is unrealistic to expect any type of machinery to be noiseless; the community does not demand this from other administrative, industrial, commercial or farming operations. Although noise tolerance is very subjective, care should be taken to ensure a reasonable noise level exists in relation to normally occurring sounds within the environment.

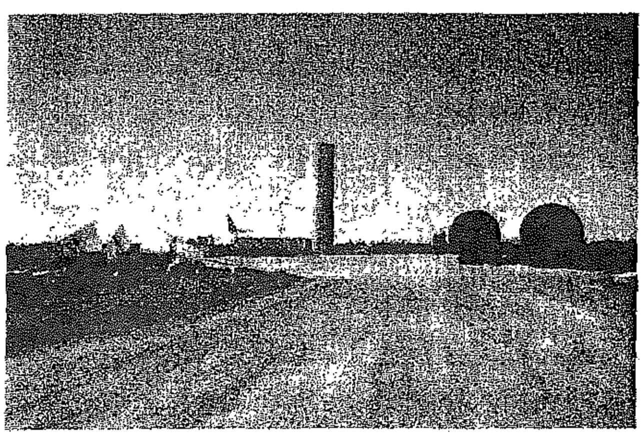
The Ontario Ministry of the Environment defines noise simply as "unwanted sound".[39] Noise is measured in decibels (dB), however, environmental noise is adjusted to include the sensitivity of the human ear and is measured in dB(A). The audible sound created by a wind turbine, measured at 350 meters, is approximately 35-45 dB(A). In comparison, rural night-time background noise is 20-40 dB(A), a jet airplane at 250 meters is 105 dB(A), and an urban residential environment is 58-62 dB(A). Wind on its own, as it interacts with the environment, produces levels up to 35 dB(A).[40] The Ministry of the Environment has published technical guidelines for the protection of the environment; prior to construction, wind turbines must receive a Certificate of Approval (Air) that includes sound impacts and their effect on the environment.[41] Again, these fall well within Chatham-Kent setback limits.

Modern wind turbine construction has drastically decreased the noise complaints that resulted from the thumping sound created by a downwind rotor placement.[42,43,44,45] The Canadian Wind Association and the Ministry of the Environment indicate that current turbine technology requires a setback placement of at least 250 meters to meet separation distances for noise.[47,48] While noise and sound can be annoying, the audible noise created by a wind turbine, constructed at the approved setback distance does not pose a health impact concern. A wind turbine setback at 750 meters emits noise comparable to a kitchen refrigerator.[49,50,51] Greenpeace, in the September 2006 report *Global Wind Energy Outlook*, advise that wind turbine noise is comparatively lower than road traffic, trains, construction activities, and industrial noise.[52]

Howe Gastmeier Chapnik Limited (2007) recommends several best practice guidelines with respect to wind turbine sound by, identifying the potential receptors of turbine noise, acknowledging the noise generated (wind turbines are not silent), following established setbacks, acknowledging the impact of ambient sound, and dispelling the rumours regarding infrasound which have not been supported by research.[53]

Inaudible noise, also known as infrasound is described as noise generated that humans cannot hear.[54,55,56] Early wind turbines, those installed in the 1980s, were *downwind* models meaning the wind had to pass by the tower before reaching the blades, subsequently creating a low frequency repetitive or constant thumping that created concerns and complaints from individuals located in close proximity to early wind farms.[57] In 2006, Howe Gastmeier Chapnik engineering completed an independent study on infrasound associated with Canadian wind farms.[58] This study determined that wind farms do generate infrasound however, it is not at a level perceptible to the human ear. Studies around the world have also indicated that infrasound generated by wind turbines is not known to be harmful to human health.[59,60,61,62,63]

Huron County Health Unit completed an assessment of human health impacts from wind turbines in 2006. Noise was the only issue identified as requiring complete assessment and modeling prior to wind farm development.[64] The Kingston, Frontenac, Lennox & Addington Health Unit provided a summary of the information presented to



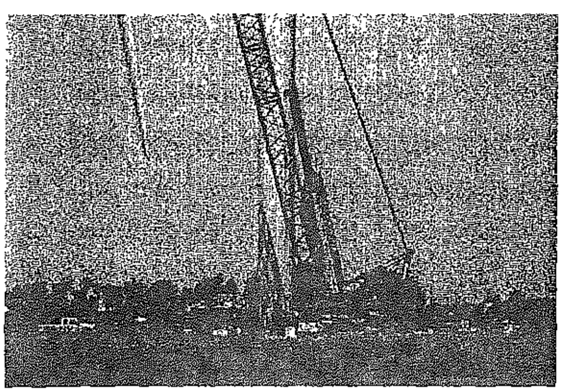
the local Board of Health, municipal government, and community stakeholders, concluding that current evidence failed to demonstrate a health concern associated with wind turbines and would be taking no further action at this time.[65] Even noise that falls within known safety limits is subjective to the recipient and will be received and subsequently perceived positively or negatively. However, noise is one of the few health issues surrounding wind turbines that can be measured and has guidelines that must be adhered to.

Shadow Flicker

Shadow flicker occurs when the sun is located behind a wind turbine casting a shadow that appears to flick on and off as the wind turbine blades rotate.[66] Modern wind turbines rotate at a frequency between 1 and 1.75 hertz. Atlantic Canadian turbines rotation frequencies range from .45 to 1.61Hz. Shadow flicker from all causes, has been demonstrated to negatively affect about 5% of individuals who suffer from epilepsy however, the frequency known to affect individuals with epilepsy is above 2.5 to 3 hertz.[67,68] The frequency of wind turbines is well below the current known documented threshold for triggering epilepsy symptoms.

Jones Consulting Group, (2007) in the planning study completed for Essex County recommended a limit of 30 hours per calendar year of shadow flicker exposure in any one location.[69] Pheonix Engineering released a shadow flicker assessment on the Enbridge Ontario Wind Farm (Bruce County) housing 110 turbines with 336 residences affected by shadow flicker. Only one third of houses were affected by shadow flicker, 5% experienced more than 10 hours per year with the maximum exposure of 21.5 hours per year.[70] Government standards do not exist for shadow flicker caused by wind turbines however, best practices from the available research, and usage history in Europe and the United States, have determined shadow flicker not to be a health concern when setbacks are enforced.[71,72,73] Chatham-Kent setback limits are consistent with current best practice recommendations.

Construction Injuries



A wind farm development is a large construction site that must comply with Canadian occupational health and safety guidelines.[74] Few documents were found addressing construction hazards or injuries occurring during building and/or maintenance of wind turbines. Strict adherence to construction guidelines and occupational health and safety laws will decrease the potential impacts to health and safety of construction crews. The few construction injuries identified during this search were caused by human error, failure to adhere to required safety measures, and lack or misuse of protection equipment.[75,76,77] A recent settlement awarded against an employer following the death of a worker was determined to be caused by the company's failure to adhere to known safety regulations.[78] This is consistent with all other construction project guidelines.

Concerns Presented by Those Opposed to Wind Power

In February 2008, Chatham-Kent Municipal Council received a package of documents titled *Wind Energy and Human Health Research Brief Volume 1, 2, and 3.*[79,80,81] The volumes consist of numerous entries from curriculum vitas to newspaper articles. Nina Pierpont, writes several of the articles. The literature search utilized by Chatham-Kent Public Health for the Chatham-Kent report, revealed no articles or research papers by Nina Pierpont published in scientific or peer reviewed journals. Several of the studies Dr. Pierpont has conducted are case studies, meaning they are a documentation of an individual's account of a situation or experience. One cannot discount the information, yet it is prudent that generalizations from such limited data are avoided. Several of the articles, all of Volume 3, have nothing to do with wind power or the health effects of wind farms and the intent of these articles remains unclear.

The main opposition concerns presented in the documentation appear to be noise and shadow flicker's potential impact on epilepsy. The evidence on shadow flicker does not support a concern. As noted previously, wind turbines in Canada do not rotate at a speed high enough to trigger epileptic seizures.[82] Noise remains a subjective issue; when setback guidelines are adhered to, the resulting noise impact is minimal. A survey conducted on public attitudes toward wind farms concluded that the majority of individuals are supportive of wind power as long as the turbines were not in their neighbourhood. [83]

Recommendations

The following table lists the discussed health and safety issues and suggested mitigation activities. It provides recommendations one would expect from any construction project of this magnitude.

Health & Safety Issue	Suggested Mitigation Activities
Structural Failure • blade failure • turbine failure	Ensure design and construction activities are completed by a known, reputable manufacturer and builder Ensure and enforce adherence to Chatham-Kent municipal setbacks – including visitor information centres Turbine design must be equipped with lightening protection systems Turbine design adheres to navigational regulations Shut-down occurs during high wind episodes Quality assurance protocols are within the projects safety plan Fencing at turbine base prevents access and potential vandalism
Icing Issues • ice drop • ice throw	Ensure and enforce adherence to Chatham-Kent municipal setbacks – including visitor information centres Education of construction crew and maintenance staff regarding icing potential, policies and procedures (shut-down and system reactivation) Signage/warning flag or other potentially proven system available in areas where icing potential exists Ensure automatic shut-off in times of icing is a design

	feature of turbine Obtain a management plan for icing emergency
Noise Concerns • Construction noise • Blasting, grading, materials delivery • Operational noise	Ensure and enforce adherence to Chatham-Kent municipal setbacks Construction occurs during times of least disruption to neighbouring lands – day time Landscape screening is preserved or designed after installation of wind turbines to decrease sound impact to neighbouring land Complaint resolution procedures are in place, documented, addressed, and resolved Sound assessment by an acoustical consultant is obtained on a need basis
Shadow Flicker • Low angle sunlight	Landscape screening is preserved or designed after installation of wind turbine to decrease flicker impact to neighbouring land Window treatments as required for neighbouring lands
Construction • Workplace injuries • Heavy Equipment • Local infrastructure to support turbine (roads, site)	No public on site during construction phase Fencing and security access during construction Minimize impacts on other land uses Roads not originally designed to handle weight during construction assessed prior to construction Safety plans are posted and accessible during construction

Conclusion

Wind power has been in use around the world for decades with very little human impact. Research occurs when issues create enough interest or concern to compel researchers and scientists into study. Governments fund research but often on a need to know basis. Stakeholders from community groups to turbine manufacturers, rely on expert opinions both for and against wind power, potentially allowing bias to enter the equation.

This document presents the current available white, grey, and published literature on the health effects of wind turbines. Despite copious literature from experts in government, manufacturers of wind turbines, and support groups both for and against wind power, very little scientific evidence exists on the health effects of wind turbines.

This paper concludes and concurs with the original quote from Chatham-Kent's Acting Medical Officer of Health, Dr. David Colby,

> *"In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed, it is my opinion that there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence."*

References

1. United Nations, Environment and Sustainable Development Division. (2007). Capacity Building on Renewable Energy. Available at http://www.unescap.org/esd/energy/cap_building/renewable/

2. World Health Association. (2004) Energy, Sustainable Development and Health. Fourth Ministerial Conference on Environment and Health. Budapest, Hungary. Available at http://www.euro.who.int/document/eehc/ebakdoc08.pdf

3. Canadian Wind Energy Association (CanWEA). (2008). Wind Energy. Available at http://www.canwea.ca/wind-energy/myths_e.php

4. Government of Ontario. (2007). Moving Forward the Ontario Way. Speech from the Throne: Address of the Honourable David. C. Onley. November 29, 2007.

5. Municipality of Chatham-Kent. Chatham-Kent Official Plan Section 2.5.1.1. Available at http://www.chatham-kent.ca

6. Public Health Agency of Canada. (1997). Health Impact Assessment as a Tool for Population Health Promotion and Public Policy. Available at http://www.phac-aspc.gc.ca/ph-sp/phdd/impact/hiatp2.html

7. Lowrence, W. (1976). *Of Acceptable Risk* quoted in Bryce Fisher, Transport Canada http://www.icao.int/icao/en/jr/2006/6106_en.pdf

8. Workplace Safety & Insurance Board. (2006). Basic Certification Training Program. Canadian Cataloguing in Publication Data: Canada.

9. Environment & Energy. (2004). Province Doubles Wind Energy Capacity. Government of Prince Edward Island. Available at http://www.gov.pe.ca/news/getrelease.php3?number=3447

10. Renewable Energy World. (2005). Nova Scotia's First Wind Farm Opens. Available at http://www.renewableenergyworld.com/rea/news/story?id=31427 - NS

11. Canadian Wind Energy Association (CanWEA). (2008). Wind Energy. Available at http://www.canwea.ca/wind-energy/myths_e.php

12. Department of Trade and Industry. (2006). "Community Benefits from Wind Power" A Study of UK Practice & Comparison with Leading European Countries. URN number 05/1363.

13. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

14. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

15. Warburton, A. M. (2004). Examining Utility Scale Wind Energy Development in Nova Scotia: A Planning Perspective. Dalhousie University. Halifax, Nova Scotia

16. American Wind Energy Association. (2008). Wind Power Myths versus Facts. Available at http://www.awea.org/pubs/factsheets/050629_Myths_vs_Facts_Fact_Sheet.pdf

17. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

18. AMEC Earth & Environmental, A Division of AMEC Americas Limited. (2008). Environmental Impact Assessment City of Summerside Wind Farm: Final Report Submitted to the City of Summerside, Prince Edward Island. Fredericton, New Brunswick.

19. Tetra Tech EC, Inc. & Nixon Peabody LLP. (2008). Wind Energy Siting Handbook. Available at http://www.awea.org/sitinghandbook/

20. LeBlanc, M. P. (2007). Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario. Garrard Hassan Canada.

21. LeBlanc, M. P. (2007). Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario. Garrard Hassan Canada.

22. The Weather Network http://www.theweathernetwork.com

23. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

24. Atlantic Wind Power Corporation. (2003). Pubnico Point Wind Farm Environmental Assessment. CBLC Land Use and Environment Division: Halifax, Nova Scotia. Available at http://www.gov.ns.ca/nse/ea/pubnicowind/Pubnico_TOC_Chp1-2.pdf

25. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

26. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

27. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

28. Tammelin, B & Seifert, H. (2001). *Large Wind Turbines Go Into Cold Climate Regions.* European Wind Energy Conference. Copenhagen.

29. LeBlanc, M. P. (2007). Recommendations for Risk Assessments of Ice Throw and Blade Failure in Ontario. Garrard Hassan Canada.

30. AMEC Earth & Environmental, A Division of AMEC Americas Limited. (2008). Environmental Impact Assessment City of Summerside Wind Farm: Final Report Submitted to the City of Summerside, Prince Edward Island. Fredericton, New Brunswick.

31. Daniels, L. M., Johnson, S. E. & Slaymaker, W. (2004). Harvest the Wind: A Wind Energy Handbook for Illinois. Available at http://www.windustry.org/harvest-the-wind-a-wind-energy-handbook-for-illinois

32. Tetra Tech EC, Inc. & Nixon Peabody LLP. (2008). Wind Energy Siting Handbook. Available at http://www.awea.org/sitinghandbook/

33. Leventhal, G. (2006). *Infrasound from Wind Turbines – Fact, Fiction or Deception.* Canadian Acoustics 24(2).

34. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

35. American Wind Energy Association. (2008). Facts about Wind Energy and Noise. Available at http://www.awea.org/pubs/factsheets/WE_Noise.pdf

36. The British Wind Energy Association. (2000). Noise from Wind Turbines: The Facts. Available at http://www.bwea.com

37. Warburton, A. M. (2004). Examining Utility Scale Wind Energy Development in Nova Scotia: A Planning Perspective. Dalhousie University. Halifax, Nova Scotia

38. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

39. Ministry of the Environment. (2004). Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators. Government of Ontario. Available at http://www.ene.gov.on.ca/envision/gp/4709e.pdf

40. AMEC Earth & Environmental, A Division of AMEC Americas Limited. (2008). Environmental Impact Assessment City of Summerside Wind Farm: Final Report Submitted to the City of Summerside, Prince Edward Island. Fredericton, New Brunswick.

41. Ministry of the Environment. (2004). Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators. Government of Ontario. Available at http://www.ene.gov.on.ca/envision/gp/4709e.pdf

42. American Wind Energy Association. (2008). Facts about Wind Energy and Noise. Available at http://www.awea.org/pubs/factsheets/WE_Noise.pdf

43. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

44. The British Wind Energy Association. (2000). Noise from Wind Turbines: The Facts. Available at http://www.bwea.com

45. Department of Trade and Industry. (2001). Wind Power: Environmental and Safety Issues. Wind Energy Fact Sheet 4. Available at http://www.berr.gov.uk/files/file17777.pdf

46. Ministry of the Environment. (2004). Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators. Government of Ontario. Available at http://www.ene.gov.on.ca/envision/gp/4709e.pdf

47. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

48. Ministry of the Environment. (2004). Interpretation for Applying MOE NPC Technical Publications to Wind Turbine Generators. Government of Ontario. Available at http://www.ene.gov.on.ca/envision/gp/4709e.pdf

49. Atlantic Wind Power Corporation. (2003). Pubnico Point Wind Farm Environmental Assessment. CBLC Land Use and Environment Division: Halifax,

Nova Scotia. Available at
http://www.gov.ns.ca/nse/ea/pubnicowind/Pubnico_TOC_Chp1-2.pdf

50. Canadian Wind Energy Association. (2007). Canadian Wind Energy Association Position on Setbacks for Large-Scale Wind Turbines in Rural Areas (MOE Class 3) in Ontario. Available at http://www.canwea.ca

51. Sustainable Development Commission. (2005). Wind Power in the UK: A Guide to the key issues surrounding onshore wind power development in the UK. Available at http://www.sd-commission.org.uk/publications/downloads/Wind_Energy-NovRev2005.pdf

52. Greenpeace & Global Wind Energy Council. (2006). Global Wind Energy Outlook 2006. Available at
http://www.gwec.net/fileadmin/documents/Publications/GWEC_A4_0609_English.pdf

53. Howe, B. (2007). Wind Turbines and Sound: Review and Best Practice Guidelines. Howe Gastmeier Chapnik Limited. Mississauga, ON. Available at http://www.canwea.ca/images/uploads/File/CanWEA_Wind_Turbine_Sound_Study_-_Final.pdf

54. Leventhal, G. (2006). *Infrasound from Wind Turbines – Fact, Fiction or Deception*. Canadian Acoustics 24(2).

55. Howe, B. (2006). Wind Turbines and Infrasound. Howe Gastmeier Chapnik Limited. Mississauga, ON. Available at
http://www.canwea.ca/images/uploads/File/CanWEA_Infrasound_Study_Final.pdf

56. The British Wind Energy Association. (2000). Noise from Wind Turbines: The Facts. Available at http://www.bwea.com

57. Howe, B. (2006). Wind Turbines and Infrasound. Howe Gastmeier Chapnik Limited. Mississauga, ON. Available at
http://www.canwea.ca/images/uploads/File/CanWEA_Infrasound_Study_Final.pdf

58. Howe, B. (2007). Wind Turbines and Sound: Review and Best Practice Guidelines. Howe Gastmeier Chapnik Limited. Mississauga, ON. Available at http://www.canwea.ca/images/uploads/File/CanWEA_Wind_Turbine_Sound_Study_-_Final.pdf

59. Enterag UK Limited. (2008). Noise and Vibration. Available at http://www.enteraguk.com/technical/noise-and-vibration.html

60. Pederson E & Persson Waye K. (2004). *Perception and annoyance due to wind turbine noise – a dose-response relationship.* Journal of the Acoustical Society of America. 116(6): 3460-3470.

61. Viollon S, Lavandier C & Drake C. 2002. *Influence of visual setting on sound ratings in an urban environment.* Applied Acoustics. 63: 493-511.

62. Jakobsen J. 2005. *Infrasound Emission from Wind Turbines. Journal of Low Frequency Noise,* Vibration and Active Control. 24(3): 145-155.

63. Tetra Tech EC, Inc. & Nixon Peabody LLP. (2008). Wind Energy Siting Handbook. Available at http://www.awea.org/sitinghandbook/

64. Savage, R. (2006). Epidemiology Report: The Effects of Wind Turbines on Human Health. Huron County Health Unit.

65. Moccio, P. (2008). Health Effects of Wind Turbines. KFL&A Public Health.

66. Enterag UK Limited. (2008). Shadow Flicker. Available at http://www.enteraguk.com/technical/shadow-flicker.html

67. Department for Business Enterprise & Regulatory Reform. (2008). Onshore Wind: Shadow Flicker. Available at http://www.berr.gov.uk/energy/sources/renewables/planning/onshore-wind/shadow-flicker/page18736.html

68. Warburton, A. M. (2004). Examining Utility Scale Wind Energy Development in Nova Scotia: A Planning Perspective. Dalhousie University. Halifax, Nova Scotia.

69. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

70. Phoenix Engineering Inc. (2007). Enbridge Ontario Wind Power Project Shadow Flicker Assessment: Procedures and Calculation Results. Available at http://www.enbridge.ca/ontariowindpower/about-project/pdf/attachment3-revisedshadowflicker-2006.pdf

71. Warburton, A. M. (2004). Examining Utility Scale Wind Energy Development in Nova Scotia: A Planning Perspective. Dalhousie University. Halifax, Nova Scotia

72. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

73. Phoenix Engineering Inc. (2007). Enbridge Ontario Wind Power Project Shadow Flicker Assessment: Procedures and Calculation Results. Available at http://www.enbridge.ca/ontariowindpower/about-project/pdf/attachment3-revisedshadowflicker-2006.pdf

74. Workplace Safety & Insurance Board. (2006). Basic Certification Training Program. Canadian Cataloguing in Publication Data: Canada.

75. AMEC Earth & Environmental, A Division of AMEC Americas Limited. (2008). Environmental Impact Assessment City of Summerside Wind Farm: Final Report Submitted to the City of Summerside, Prince Edward Island. Fredericton, New Brunswick.

76. Jones Consulting Group (2007). Windpower & Renewable Energy Planning Study: Background Research Paper. County of Essex.

77. Atlantic Wind Power Corporation. (2003). Pubnico Point Wind Farm Environmental Assessment. CBLC Land Use and Environment Division: Halifax, Nova Scotia. Available at http://www.gov.ns.ca/nse/ea/pubnicowind/Pubnico_TOC_Chp1-2.pdf

78. Portland Oregon News KOIN http://www.koin.com/content/news/topstories/story.aspx?content_id=e1cc6808-1b5a-4889-8e6b-fa969086fbe3

79. No Editor (2008). Wind Energy and Human Health Research Brief No. 1 Volume 1. Prepared for Chatham-Kent Municipal Council. February 11, 2008

80. No Editor (2008). Wind Energy and Human Health Research Brief No. 1 Volume 2. Prepared for Chatham-Kent Municipal Council. February 23, 2008

81. No Editor (2008). Wind Energy and Human Health Research Brief No. 1 Volume 3. Prepared for Chatham-Kent Municipal Council. February 25, 2008

82. Phoenix Engineering Inc. (2007). Enbridge Ontario Wind Power Project Shadow Flicker Assessment: Procedures and Calculation Results. Available at http://www.enbridge.ca/ontariowindpower/about-project/pdf/attachment3-revisedshadowflicker-2006.pdf

83. Damorg, S. (nd). Public Attitudes Towards Wind Power. Danish Wind Industry Association. Available at http://www.windpower.org/media(485,1033)/public_attitudes_towards_wind_power.pdf

Additional Resources

Frey, B. J. & Hadden, P. J. (2007). Noise Radiation from Wind Turbines Installed Near Homes: Effects on Health. Available at http://www.windturbinenoisehealthhumanrights.com/wtnhhr_june2007.pdf

Morgan, C. & Bossanyi, E. (n.d.) Wind Turbine Icing and Public Safety – A Quantifiable Risk? Gharrad Hassas and Partners Limited Bristol, UK. Available at http://www.easthavenwindfarm.com/filing/feb/ehwf-ml-reb4.pdf

CBCL Limited. (2007). Wind/Hydro Energy Project: Environmental Assessment Registration & Project Description. Available at http://www.gov.ns.ca/nse/ea/CBWindHydro/CBWindHydroRegistration.pdf

Acciona Telecommunication Engineering Projects. (2008). Study of Radioelectric Interferences in the Amherst Wind Farm. Nova Scotia, Canada. Available at http://gov.ns.ca/nse/ea/amherst.wind.energy.project/AmherstWindEnergyProject_AppendixG.pdf

Gipe, P. & Murphy, J. (2005). Ontario Landowner's Guide to Wind Energy. Ontario Sustainable Energy Association. Toronto, ON

Campbell, D. (2007). *Harvesting the Prairie Wind.* Rural Cooperatives. NOV/Dec. 2007.

Yes2Wind. (2008). Wind Energy and Health. Available at http://www.yes2wind.com/41.faq.html

Yes2Wind. (2008). Frequently Asked Questions. Available at http://www.yes2wind.com

County of Bruce, Planning and Economic Development Department. (2007). File:OPA #99-Wind Policies. Available at www.brucecounty.on.ca/downloads/planning/Staff-Wind_Report_ATP_%20OPA_99_%20July_26_2007.pdf

Government of Ontario (2003). Benefits of Wind Energy: Info Sheet. http://www.energy.gov.on.ca/english/pdf/conservation/2131027_windturbines.pdf

Chatham-Kent Draft Zoning By-Law (Extract) Available at http://www.chatham-kent.ca

Chatham-Kent Municipal Checklist for Wind Energy Environmental Assessment Studies. Available at http://www.chatham-kent.ca

Photo on page 8 from http://www.energyquest.gov.ca

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DISCONNECT BETWEEN TURBINE NOISE GUIDELINES AND HEALTH AUTHORITY RECOMMENDATIONS

John P Harrison
Professor Emeritus, Physics Department, Queen's University
Kingston, ON K7L 3N6
harrisjp@physics.queensu.ca

INTRODUCTION

There is a disconnect between the setbacks of modern up-wind blade wind turbines from homes as recommended by health authorities and as determined from the noise guidelines of various jurisdictions. Typically, health authorities recommend 1.5 to 2 km while noise guidelines allow setbacks of 400 to 500 metres. The resolution lies in the inadequacy of noise guidelines. There are a number of reasons for the inadequacy: The typical allowance of 10 dBA above background noise; the characteristic periodic or impulsive sound of a turbine; the continuing use, in Ontario and New Zealand, of masking from ground-level wind noise to allow permissible turbine noise to increase with wind speed; the absence of turbulent inflow noise in noise guidelines and assessments; the absence of coherent sound reflection from the ground in the calculation of turbine noise at a receptor.

HEALTH AUTHORITY RECOMMENDATIONS

Wind turbine noise causes annoyance and health problems. These problems include sleeplessness, anxiety, headaches and migraine, depression, and accentuation of learning disabilities[1-3]. The annoyance also has an impact on concentration and work performance[2, 4-6]. Different people have different reactions to noise and, as expected, the health problems are chronic for those who are noise-sensitive. The annoyance caused by wind turbines is higher than for traffic noise at the same sound pressure level[6] because of the predominance of low frequencies in the sound spectrum and because of the amplitude modulation that results from the blade passage past the tower. Looking at ⅓-octave sound pressure levels, turbulent boundary layer noise, arising from motion of the blades through steady wind, peaks at 1 kHz and falls slowly below that. Turbulent inflow noise, arising from the motion of the blades through turbulent wind, has no peak but instead increases with decrease in frequency. By contrast, traffic noise tends to be white noise. The annoyance from the periodic or impulsive character of turbine noise, associated with the amplitude modulation, is enhanced by the visual annoyance of the rotating blades.

Harry[2], in the UK, followed up on complaints of annoyance from 39 people living between 300 and 2000 metres from one or more wind turbines. The questionnaires showed that 80% experienced health problems with migraine and depression being the main health symptoms. 75% of the 39 respondents had sought help from a doctor. 75% reported sleeplessness. Harry recommended a 1.5 mile (2400 metre) set-back from homes and criticized ETSU-R-97, the basis for setbacks in the UK, as inappropriate for modern turbines 5x the size (power) of those common in 1997.
Frey and Hadden[3], in a remarkably thorough literature survey of the impact of wind turbine noise on people living within 2 km of wind turbines, present over 50 separate items on the impact of the noise. These include statements from residents describing their annoyance and health problems, comments from doctors and from wind energy developers and lists a number of people living up to a kilometre away who just had to

move out. This section of their paper is largely anecdotal but nevertheless it makes for very disturbing reading and should be mandatory reading for all wind energy developers and regulatory authorities. Hadden and Frey also review the nature of turbine noise, emphasize the dominance of low frequency noise with its low attenuation in the atmosphere and by structures, and point to the limitations of ETSU-R-97, the basis for the UK noise regulations. Another section of their report presents a comprehensive summary of the peer reviewed literature on the impact of noise. This includes sociological studies of annoyance and impact on mental performance, the impact on sleep and the effects of sleep disturbance, as well as biological effects such as the hormonal changes associated with annoyance/stress. Frey and Hadden conclude that no wind turbines of up to 2 MW should be sited within 2 km of dwellings and that much more research is needed on understanding why turbine noise does penetrate above ambient noise up to 2 km and more.

Stewart, an acoustician with the UK Noise Association made a study of turbine noise and the annoyance caused by the noise, described in the famous report: Location, Location, Location[7]. He concludes that turbines are causing significant noise problems for some people, that the evidence is persuasive that the noise problems can be exacerbated by the rotating blades and dancing shadows of the turbines and that the main problem is the swish, swish, swish of the blades (amplitude modulation). On behalf of the Noise Association, he recommends that no turbine should be sited closer than 1 mile (1.6 km) from the nearest dwelling.

Pedersen and Perrson Waye made a sociological study of wind turbine annoyance[8]. 351 respondents living in the vicinity of turbines in rural Sweden completed questionnaires. For turbine noise in the range 37.5 – 40 dBA, 51% were annoyed (20% very annoyed); above 40 dBA, 56% were annoyed (36% very annoyed). These numbers compare with earlier measurements, quoted by Pedersen, of 2 – 4% annoyed by transport and industrial noise in the same noise level range[9]. Shepherd et al[10] performed laboratory tests to determine detection threshold and annoyance levels. They found that for noise levels 10 dBA above threshold, they would predict widespread complaints. However, this work cannot compare with the field studies of Pedersen and Persson Waye.

In 2006, the French National Academy of Medicine issued a report[11] on wind turbine noise and health, concluding with a recommendation to halt wind turbine construction closer than 1.5 km from residences. The World Health Organization[12] recommends that the noise level in a bedroom be a maximum of 30 dBA to avoid sleep disturbance. It also uses a rather large and unrealistic 15 dBA sound pressure level drop across a wall, leading to a limit of 45 dBA outside a bedroom. The International Standards Organization (ISO) 1996-1971 Recommendation for Community Noise Limit in Rural Areas is 35 dBA day-time, 30 dBA evening, and 25 dBA night-time (presumably in the bedroom). ISO 9613, the accepted methodology for evaluating sound propagation, suggests 7 dBA sound pressure level drop across a wall. Therefore, using the ISO recommendation, the sound pressure level at night outside a bedroom should be 32 dBA. Finally, the Sierra Club, a responsible proponent of renewable energy, has the following advice on the siting of wind plants: "We suggest that wind developers restrict their impact on involuntary neighbours to near ambient levels at the closest residence[13].

In summary, the consensus is that turbines should be separated from residences by about 1.5 km or that the sound pressure level at a residence should be near ambient which is close to 30 dBA in rural areas at night.

NOISE GUIDELINES

Regulations for wind turbine siting relative to residences vary world-wide and even vary within countries with local environmental protection jurisdictions. Some regulations specify setback distances and others specify noise limits. The following table shows a selection of international night-time noise limit regulations extracted from a recent review written for the Ontario Ministry of the Environment[14]. The setbacks are estimated from the ISO-9613 procedure for calculating noise at a receptor as a function of distance from a turbine, in this case a typical fixed-speed up-wind turbine with a turbine noise of 105 dBA.

Table 1: Selection of Noise Limits and Estimated Equivalent Setbacks

Jurisdiction	Noise Limit (dBA)	Setback (m)
Oregon, Germany, Australia	35 - 36	800
Alberta, British Columbia, Quebec, Denmark and Netherlands	40	450
Ontario, New Zealand	40 with wind speed adjustment	450 and below
U.K. and Ireland	43	350 metres
Various U.S.	50 and up	200 metres

Clearly, the setbacks allowed by these noise limits are far smaller than those recommended by the variety of health experts. There are several reasons for this disconnect; they will be reviewed in the rest of this paper.

NOISE INTRUSION

In rural areas, background noise levels can be 25 – 30 dBA at night. Therefore, the noise limits in most jurisdictions represent a night-time intrusion of 10 to 20 dBA above background. An intrusion of 3 dBA is noticeable and an intrusion of 10 dBA causes widespread complaints as noted above. The intrusion level is quite arbitrary and is imposed on the rural population; there are no studies that show no problems with the 10 to 20 dBA intrusion. Some jurisdictions specify limits such as background plus 10 dBA or 45 dBA, whichever is the higher, allowing the 10 dBA to be a

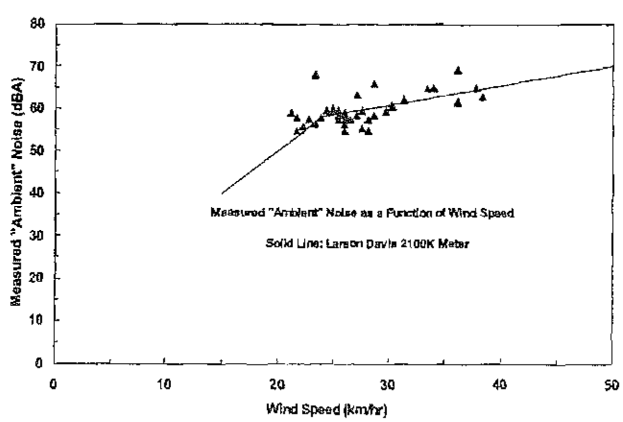

Figure 1. An erroneous measurement of ambient noise.

minimum intrusion. A problem here is that background noise is not easy to measure when there is a wind blowing. The figure shows one consultant's measurement of background noise that I have converted to a plot of background noise as a function of wind speed. Superimposed is the manufacturer's specification for the wind noise in the microphone of a noise meter. For obvious reason, this will remain anonymous.

AMPLITUDE MODULATION

Wind turbines emit a characteristic sound. There is an abundance of low frequency noise that travels with little attenuation in the atmosphere and it is modulated at the blade passage frequency, about 1 Hz. The amplitude modulation is of the order of 5 dBA[15]. The problem here is that all jurisdictions use L_{eq}, in setting their noise limits and this averages out the modulation. The ear responds on a fast time scale and does not average the noise peak away. It is this periodic noise that causes the widespread annoyance. From above, over 50% of those in the vicinity of turbines were annoyed at noise levels of 40 dBA with about 30% very annoyed. Van den Berg has investigated this annoyance from an acoustic perspective. He showed that at night, the amplitude modulated noise from several nearby wind turbines can drift in and out of synchronization. When synchronized, the modulation is the full 5 dBA of a single turbine but the noise level is higher than for a single turbine and so more audible. When unsynchronized, the amplitude modulation is smaller. Noise limits need to include a 5 dBA penalty for amplitude modulated noise so that the limit reflects the sound perceived by people. Ontario does have such a penalty but it has not been enforced.

MASKING NOISE

Just two jurisdictions, Ontario in Canada and New Zealand, make an allowance for masking of turbine noise by wind noise at ground level but this is two too many. It was van den Berg[16] who showed that, at night-time, masking noise is largely a myth. He started by investigating noise complaints from residents living near the Rhede wind plant who had been led to believe that they would not be impacted. He showed, particularly for the night-time, that the sound level from the wind plant was indeed very noticeable and, by sound pressure level measurement, in excess of what was expected from concurrent measurements of wind speed. He postulated that the cause was higher wind speed at the height of the turbine hubs (98m) than that expected from the standard neutral atmosphere model. Follow up work with records from the Cabauw meteorological research station and from a literature survey of work elsewhere showed that night-time average values of the ratio of wind speed at 80m to that at 10m, which is used as a proxy for the wind speed at ground level, were invariably higher than supposed for a neutral atmosphere. The most extensive measurements have come from the National Renewable Energy Laboratory in the USA for a variety of sites in the mid-west[17,18]. This laboratory was established by the DOE to support the wind industry in the USA. Masking noise was not one of their interests; they were concerned that unexpected large wind speed gradients could cause turbine failure and intrigued that the large wind speed gradients would lead to enhanced power generation. Table 2 collects together all available measurements of wind speed gradient data that includes both average and night-time averages. This data set includes those referenced in van den Berg's thesis and others that are more recent. The original references give the gradients in terms of a wind shear coefficient α defined by: $v_A/v_B = (h_A/h_B)^{\alpha}$ where v_A and v_B are the wind speeds at heights h_A and h_B with h_A representing the turbine height and h_B =10 metres representing ground level. A neutral atmosphere, is defined to have $\alpha = 0.14$; this corresponds to a wind speed ratio $v_{turbine}/v_{ground} = 1.35$ for an 80m high turbine tower. Noise limits are based upon this number. Table 2 presents the measurements in terms of the more accessible ratio of wind speed at 80m to that at 10m.

Table 2: Average and night average ratios of the wind-speed at 80m to that at 10m.

Region	Source	Average	Night Average
Neutral Atmosphere	$\alpha = 0.14$	1.35	1.35
Netherlands (Cabauw)	Van den Berg[16]	1.4	1.9
Big Spring TX	NREL[17]	1.55	1.85
Algona IA	NREL[17]	2.0	2.45
Springview NE	NREL[17]	1.6	1.85
Glenmore WI	NREL[17]	1.8	2.1
Ft. Davis TX (1860m)	NREL[17]	1.25	1.4
Berlin	Harders[19]	1.3	1.9
Australia 1 (Flat)	Botha[20]	1.5	1.8
Australia 2 (Flat)	Botha[20]	1.5	1.7
N Z (Complex Terrain)	Botha[20]	1.25	1.25
N Z (Complex Terrain)	Botha[20]	1.25	1.25
Kincardine – 30-50m	OMB[21]	1.85	2.55
Sumner KS	NREL[18]	1.7	2.3
Washburn TX	NREL[18]	1.4	1.7
Lamar CO	NREL[18]	1.35	1.6
Crow Lake SD	NREL[18]	1.55	1.8
Kingsbridge ON	Palmer[22]	1.6	1.75 (summer 2.25)
Amaranth ON	Palmer[22]	1.75	2.45 (summer 2.75)
USA 10 Stations	Archer[23]		2.1 ± 0.3

Looking at all of the results, we see that the average ratio is 1.4 ± 0.2 and the night-time ratio is 1.9 ± 0.4, higher by 35%.

To see the significance, consider an application to south-western Ontario. Making use of the 3 results from Table 1 and numbers from the Ministry of Natural Resources wind atlas, a daily average ratio of 1.75 is predicted. The wind atlas gives only annual average wind speeds as a function of height above ground level. The higher averages are expected because of the presence of large bodies of water. With the same 35%, the night-time average ratio will be 2.3. Consider the case that the wind speed at 80m is 10 m/s. The assumed neutral atmosphere wind speed ratio of 1.35 gives the wind speed at the ground equal to 7.5 m/s. The Ontario noise limit for this wind speed is 44 dBA, which includes a masking allowance of 4 dBA above the basic 40 dBA. However, with a more accurate night-time ratio of 2.3, the wind speed at the ground is 4.5 m/s. For this ground-level wind speed, there is no masking noise. As another example, for a wind speed at the turbine hub of 14 m/s, the 12 dBA of masking noise is reduced to 1 dBA. Clearly, for night-time operation of wind-turbines, masking noise is a myth. Authorities in the Netherlands have now accepted this and no longer include masking noise in their noise limit.

TURBULENT INFLOW NOISE

At present, noise generated by the inflow of turbulent air into the turbine (turbulent inflow) is not included in noise guidelines. Turbulent inflow was a particular problem with down-wind rotor turbines because of the turbulence created by the tower. However, with modern up-wind rotors the problem remains because of atmospheric turbulence. Wagner et al[24] did some modeling of turbulent inflow to airfoils but did not apply this to wind turbines. Since then there have been more semi-empirical models of turbulent inflow aerodynamic noise and, from NREL, a comparison of actual turbine measurements with these models[25,26]. The significance here is that turbulent inflow, when present, dominates the aerodynamic noise in the frequency range below 1 kHz, the frequency range where sound propagates with little absorption in the air.

Figure 16 from reference 24, reproduced below, shows a comparison of calculations of various aerodynamic noise sources with measured noise for the National Wind Technology Centre research turbine. It is a 37m tower with a 42m upwind rotor diameter. The wind speed measurement tower is close by. The turbulence intensity, measured over a 1 minute time interval, was a high 46%. The wind speed was 5.7 m/s. The noise measurements were made 58m downwind. The figure is a plot of noise (sound pressure level) in 1/3 octave bands as a function of frequency.

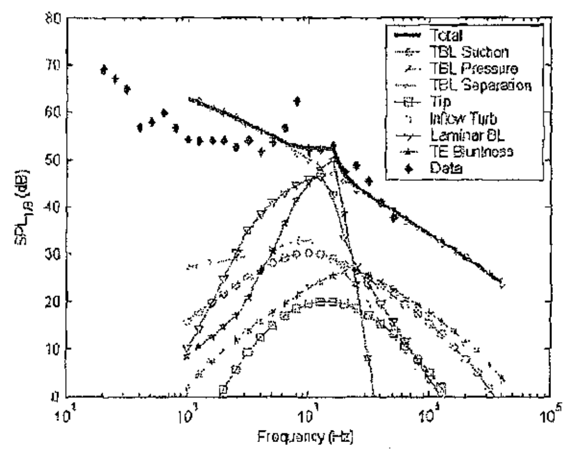

Figure 2: Calculation of aerodynamic contributions to turbine noise level.

TBL is turbulent boundary layer, TE is trailing edge. Note that the character of the measured sound reflects that of turbulent inflow, although the calculation over-estimates the turbulent inflow noise. The authors realized that 1 minute is too long a time for determining the turbulence intensity and that good agreement would have resulted from a 30 sec interval. Turbulent inflow noise can now be estimated on the basis of turbulence intensity measurements, which require wind-speed measurements measured on a fast time scale with the average and standard deviation calculated for 30 second intervals. Before any wind plants are approved, turbulence intensity measurements need to be made and turbulent inflow noise estimated.

COHERENT REFLECTION

Wagner et al[24] knew that sound reflects from the ground. Generally the path difference between the direct and reflected sound waves will be much larger than the sound wavelength and it makes sense to add the sound intensities. This is included in ISO-9613[27]. However, when the sound reflects specularly, as it will from a solid surface such as the ground, and the wavelength is comparable to the path difference, the direct and reflected sound waves will add coherently. For frequencies below about 200 Hz and distances of several hundred metres from a turbine this can add an extra 3 dBA to noise at the receptor. Although 200 Hz seems low compared to the spectral peak, low frequencies propagate with less absorption in the atmosphere and through walls. Furthermore, figure 2 shows how low frequencies dominate when the wind is turbulent. Turbine manufacturers know about coherent reflection; they subtract 6 dBA, not 3 dBA, from the measured sound when determining the turbine noise at the hub.

SUMMARY

Universally, turbine noise limits at residences allow an intrusion of 5 to 20 dBA above background noise level in rural areas. This can only be justified if there is no alternative. In Europe population density is large and the alternative is to go to off-shore sites. This is now in process. In the USA, Canada, Australia and New Zealand, population densities are low and turbines can be kept away from residences. In general they are not. Even when the annoyance from amplitude modulation is accepted, the 5 dBA penalty is not enforced. Two jurisdictions still allow for masking of the turbine noise by wind noise at ground level. Van den Berg drew attention to the fallacy of the masking at night-time. Extensive measurements from the National Renewable Energy Laboratory in the USA and elsewhere confirm the work of van den Berg and prove unequivocally that masking wind noise at night is a myth. The additional aerodynamic noise arising from the rotation of turbine blades in turbulent wind is not yet included in the noise limits of any jurisdictions. Calculation and measurements from the National Renewable Energy Laboratory demonstrate that this additional noise can add substantial low frequency noise, which is weakly absorbed by the atmosphere and walls. Regulating authorities need to request turbulence intensity measurements and associated noise estimates in the impact assessments required before approval of wind plants. At distances of 500m and more from a turbine, the combination of direct sound and that reflected from the ground can produce an extra 3 dBA of noise at a height of 1m from the ground for frequencies below 200Hz.

In order to see the effect of these deficiencies, consider a typical modern fixed-speed, up-wind rotor 2.3 MW turbine with an 80 m tower and a noise level of 105 dBA: With the 5dBA penalty for amplitude modulation, the standard 0.005 dBA/m for sound absorption in the atmosphere, Figure 6.9 from Wagner et al[24] for ground effect, the following sound levels at a receptor are found:

Table3: Noise Levels Calculated with an Amplitude Modulation Penalty

Distance from Turbine (m)	500	1000	1500
Noise Level (dBA)	43	40	31

If the 40 dBA allowance is reduced to below 35 dBA for rural areas in accord, with references 8 and 9, ISO 1996-1971 and the Sierra Club recommendation, then a set-back from a single turbine of 1 to 1.5 km is required. The additional noise from turbulent inflow and coherent reflection for low frequency sound will push this minimum setback to 1.5 km and more. Masking noise is a myth and so this minimum will hold for all wind speeds. Now it is clear why there have been extensive reports of annoyance and health problems suffered by those living within 1.5 km of a modern turbine. The health authorities were quite correct with their recommendations and residents are vindicated in registering their annoyance and health problems.

REFERENCES

1. N. Pierpont, Wind Turbine Syndrome – Testimony before the New York State Legislature Energy Committee (2006); available at www.ninapierpont.com. This reference, written by a respected physician, has a comprehensive literature review of the health effects of wind turbines. A forthcoming report from Dr. Pierpont will be submitted for publication.
2. A. Harry, Wind Turbine Noise and Health (2007).
3. B. J. Frey and P. J. Hadden, Noise Radiation from Wind Turbines Installed Near Homes: Effects on Health (2007). www.windturbinenoisehealthhumanrights.com
4. K. P. Waye, J. Bengtsson, A. Kjellberg and S. Benton, Noise Health, **4**, 33-49 (2001).
5. K. P. Waye, J. Bengtsson, F. Hucklebridge, P. Evans, and A. Clow, Life Sci. **70**, 745-758 (2002).
6. E. Pedersen and K. Persson Waye, Occupational and Environmental Medicine, **64**, 480-486 (2007);
7. J. Stewart, UK Noise Association Report (2006), available at http://www.countryguardian.net/Location.pdf
8. E. Pedersen and K. Persson Waye, J. Acoustical Soc. America, **116**, 3460 – 3470 (2004); E. Pedersen, Thesis, Göteborg (2007), available at https://gupea.ub.gu.se/dspace/handle/2077/4431
9. H. M. E. Miedema and H Vos, J. Acoustical Society of America, **116**, 334-343 (2004).
10. K.P. Shepherd, W. G. Ferdinand and D. G. Stephens, Noise Control Engineering Journal, **21**, 30 (1983)
11. C-H. Chouard, Repercussions of Wind Turbine Operations on Human Health (in French), Panorama du médecin (2006).
12. W.H.O. Guidelines (1999): http://www.who.int/docstore/peh/noise/Comnoise-4.pdf
13. Sierra Club Wind Siting Advisory Document Version: November 25, 2003, http://www.wind-works.org/articles/scsitingadvisory.html
14. R. Ramakrishnan, Wind Turbine Facilities Noise Issues, Aiolos Report Number 407/1/2080/AR155Rev3, pages 26-29 (2007). Available at: http://www.ene.gov.on.ca/envision/env_reg/er/documents/2008/Noise%20Report.pdf
15. G. P. van den Berg, J. Low Frequency Noise, Vibration and Active Control, **24**, 1-24 (2005); The Sound of High Winds, Thesis, The University of Groningen (2006).
16. G. P. van den Berg, J. Sound and Vibration, **277**, 955-970 (2004); The Sound of High Winds, Thesis, The University of Groningen, (2006).
17. K. Smith, G. Randall, D. Malcolm, N. Kelley and B. Smith, NREL/CP-500-32492, AWEA WindPower Conference (2002).
18. M. Schwartz and D. Elliott, NREL/CP-500-40019, AWEA WindPower Conference (2006).
19. H. Harders and H.J. Albrecht, Proceedings of Wind Turbine Noise, Berlin (2005).

20. P. Botha, Proceedings of Wind Turbine Noise, Berlin (2005).
21. J. W. S. Young, Testimony before the Ontario Municipal Board hearing PL060986 regarding the Kincardine Enbridge Wind Development (2007).
22. W. Palmer, Wind Turbine Noise Conference WTN2007 (2007).
23. C. L. Archer and M. Z. Jacobson, J. Geophysical Research, 108, 1 – 20 (2003). This was an average of data from 10 stations in the USA. The average daytime ratio was 1.4 ± 0.2.
24. S. Wagner, R. Bareiss and G. Guidati, Wind Turbine Noise (Springer 1996).
25. P. Moriarty and P. Migliore, NREL Report NREL/TP-500-34478, (2003);
26. P Moriarty, Development and Validation of a Semi-Empirical Wind Turbine Aeroacoustic Code. (NREL Report, 2004);
27. Dr. Alan Lightstone, private communication.

A REVIEW OF THE SCIENCE, LITERATURE AND RECOMMENDATIONS CONCERNING PUBLIC SAFETY AND ICE THROWS FROM WIND TURBINES

Kenneth Jaffe, MD Meredith, NY June 2006

During a recent roundtable discussion concerning wind power projects at the Delaware County Historical Society a participant[1] affiliated with two local wind development companies stated that there were three issues where the health and safety impacts were predictable and avoidable---- ice throws, noise, and flicker. Since the statement was made in the presence of planners who are advising towns in the process of writing regulations to protect the health and safety of residents, I felt that a fuller discussion of the known science of these issues was important, and have prepared this report to that end.

This concern about misinformation and poor science was compounded by the recent presentation by the New York State Department of State. The talk was designed to provide information and guidance to help planners and town officials of Delaware County write ordinances. Unfortunately, in the areas of health and safety the presentation was filled with misleading and incorrect statements. It did not accurately present the health risks as described by public health bodies (including, among others, the World Health Organization) and did not mention stricter public health regulations that have been written elsewhere to conform to recommendations of those public health groups.

In fact, the science, engineering, and planning surrounding icing are not well established. Analysis of the literature does not provide us with enough real world information to permit the prediction and avoidance of community impact and risk. There is an absence of peer review literature on icing risk; most of the literature comes from industry magazines and reports that are not reviewed objectively for validity. The existing literature is scant and does not support our ability to predict or prevent negative impact on communities from either ice throws or noise.

Below is a discussion of the state of knowledge concerning the public safety issues created by ice throws. A discussion of the noise issues will follow at a later date.

ICE THROWS

It is safe to say that there are several areas of agreement on the part of all who have thought about icing

1. Icing is a safety issue.
2. Icing occurs frequently in upstate New York, and at the altitude of Delaware County.
3. There have been no reported deaths or injuries from wind turbine ice to date, except for workers.

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[1] Mr. Dermot McGuigan who is affiliated with both Delaware Wind Energy, LLC and Airtricity See page 12 of Delaware Co. Electrical Coop grant application to NYSERDA

4. The theoretical distance of thrown ice can be calculated from the height, angle and speed of the tip of the turbine blade.
5. Setbacks from homes, roads and public spaces are necessary to prevent injury or death and property damage.

There are also areas of uncertainty which have led to controversy. Essentially the controversy is over

1. how to quantify the safety risk to people and property from thrown ice.
2. how to determine the appropriate setbacks to minimize risk.

I will review the key literature on the areas of agreement and controversy.

Consensus on Icing Being a Public Safety Issue

In his December 2005 presentation[2] entitled 'Ice and Snow- and the Winds Will Blow" Ian Baring-Gould of the U.S. Department of Energy's National Renewable Energy Laboratory identified the following icing problems. These statements are quoted from his report:

1. "Ice is an issue."
2. "Increases safety risk for staff and the public".
3. "It's not a winter wonderland."
4. "The latest on ice throw—an inexact science".
5. "Little data has been collected in the US on impacts of cold and ice."
6. "Sites with severe weather require rethinking the current paradigm of measurement."
7. "In Europe, safety considerations are paramount in the siting of wind turbines in icing climates."
8. "Very little scientific study exists but as the issues grow in Europe more will be conducted."

Peer review literature demonstrates that New York State has the highest risk of ice storms in the lower 48 states. [3]

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[2] "Ice and Snow---and the Wind Will Blow, Ian Baring-Gould, National Renewable Energy Laboratory, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, NWCC Technical Considerations in Siting Wind Developments, Dec. 1-2, 2005.
At http://www.nationalwind.org/events/siting/presentations/baring-gould.pdf

[3] Characteristics of Wind Storms in the United States, Stanley A Changnon, Climatologist, Journal of Applied Meteorology, vol 42, p 630-639, 2003. See figures 3, 4, 5.

Ice throw distance---theoretical calculations

We know the theoretical distance that an object can fly when thrown from a known height, speed and angle. The physics of this calculation is settled science. For the turbines proposed for Delaware County, this theoretical distance is over one half mile. There is no real argument about this being the theoretical distance that an object can travel when thrown at the speed and height of a turbine blade. [4]

The problem with the theoretical distance calculation with respect to a determination of the real effect and safety is that two forces can act upon a thrown object----one to increase and one to decrease the distance an object travels. These forces are lift and drag. The effect of lift can be seen in gliders, Frisbees, and the discus and extends the theoretical distance. Drag occurs with non aerodynamic objects, and shortens the distance the object travels.

It is not known how often the ice formed on a turbine blade will fly further that the theoretical distance because the ice formed on a blade retains the shape of the blade which was designed to be aerodynamic; or whether the ice assume a shape that is less aerodynamic and have drag which reduces its theoretical distance.

In spite of a lack of information of lift and drag, we will see that the wind industry consultants and employees publish ice throw distance and risk calculations which ignore the impact of lift and assume a massive drag effect. Both assumptions will shrink the distance of thrown ice and tend to underestimate the safety risks.

ABSENCE OF ACCURATE DATA FROM ICE THROW SURVEILLANCE STUDIES

Given that there is general agreement that icing safety risks are inherent in large wind turbine technology, it would be useful to planners and regulators to have data from surveillance studies designed to accurately record the frequency, distance and mass of ice throws in areas which share with Delaware County a high risk of icing. This is particularly so since there is no certainty as to whether the theoretical distance calculations under estimate or overestimate actual the distance traveled by thrown ice in real world settings.

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[4] Calculation of Ice Throw Distances for Wachusettt Wind Power Site, Prof. Terry Matilsky. Also see in this report, item number 3, the ice speed at impact is over 200 mph. Found on pages 31-33 http://www.mollica.com/windfarm/ICE%20-%20WACHUSETT%20EENF%20COMM.pdf

In a discussion of a public health approach to environmental protection by Barry Levy, President, American Public Health Association surveillance is the first of 10 recommendations given.[5] He defines surveillance---

> *Surveillance,* the ongoing, systematic collection, analysis, and dissemination of data to prevent disease and .....We need surveillance for exposures of public health concern and for adverse health events. Despite many advances in our capabilities for environmental and occupational health surveillance, there is a disturbing trend that the local and state public health infrastructure across the country is deteriorating, especially for surveillance systems.

Unfortunately the literature on icing does not provide us with actual surveillance data for assessing the risk from icing nor does it permit quantification of the risk to persons at various setbacks based on empirical data from surveillance studies.

Both the presentation by Baring-Gould referenced above, and NYSERDA's publication "Public Health and Safety"[6] cite articles published by Morgan and Seifert as offering data which permits risk assessment. These articles are extremely important in the realm of safety and ice throws since they are the sources of most industry recommendations for safety and icing. We will review Morgan and Seifert's articles below.

NYSERDA deals with the issue of ice throws in its publication "Public Health and Safety". This NYSERDA publication refers to a single paper (by Morgan et. al) as the source for its discussion of ice throws, describing the paper as the 'most complete study' to date, which 'quantified the risk of possible strikes from ice throws, in terms of distance from the turbine'.

This paper by Morgan[7], its risk calculations, and the articles that Morgan cites to arrive at his risk conclusions are also the basis of much of the current industry advice on setbacks and the wind industry risk predictions. It is therefore worthwhile to evaluate the validity this series of papers and their models to get a sense of their usefulness in predicting risk.

Understanding the deficiencies of these papers is crucial for planners and others concerned and responsible for public safety from thrown ice. Unfortunately, a careful review of the data and techniques employed in these studies demonstrates that the studies do not provide a scientific basis for assessing risk to people and property from thrown ice. We will see

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[5] Barry Levy, MD, at the Symposium on a Public Health Approach to Environmental Health Risk Management, Commission on Risk Assessment and Risk Management, 1997. http://www.riskworld.com/Nreports/1997/risk-rpt/miscinfo/nr7mi003.htm

[6] Public Health and Safety, Power Naturally, NYSERDA, 2005. see pages 5-6 for discussion of 'ice shedding' and page 10 for references used to source the discussion. At http://www.powernaturally.org/Programs/Wind/toolkit/18_publichealthandsafety.pdf

[7] Assessment of Safety Risks Arising from Wind Turbine Icing, Colin Morgan, Ervin Bossanyi, Henry Seifert, Boreas IV, 1998. At http://virtual.vtt.fi/virtual/arcticwind/boreasiv/assessment_of_safety.pdf

1. As described in the words of one the study author himself (Dr. Henry Seifert), that the data presented *does not involve actual measurement* of distance and mass of thrown ice.
2. The studies *do not involve true surveillance* of thrown ice in the sense of actually seeking out evidence of ice fragments after icing events.
3. *The participation rate of the icing survey is too low* to conclude that the data is a representative sample of icing frequency and distance.
4. That the final safety *risk assessment is based not on observation but on calculations*. In doing these calculations the authors make assumptions concerning lift and drag. They assume zero lift and severe drag. These assumptions <u>are not</u> based on facts, and serve to dramatically reduce the calculated ice throw distance, and underestimate the public safety risk.

The fact that the papers by Morgan and Seifert are not peer review in part explains their publication with these deficiencies. They are funded by DEWI, the German Wind Energy Institute, and many are published in the company magazine "DEWI magazine", which is not a peer review journal.

Peer review, meaning a review of the paper by non partial experts in the field, is considered crucial in avoiding bias and securing validity especially when the paper is funded by a company sponsored entity, such as DEWI, which has a proprietary interest in the conclusion of the paper. For instance, when a pharmaceutical company funds research on one of its own medications the study findings are regarded with suspicion unless the research reports are published in a peer review journal. These papers by Morgan and Seifert were not reviewed by objective experts in the field prior to publication. In fact, a search of the literature on icing and wind turbines turned up no papers in peer review journals concerning icing, this in spite of the consensus of the public safety issues concerning ice throws.

The data presented by Morgan in his paper on risk assessment is not derived from a published study, peer review or otherwise. The data used for his risk assessment, (which in turn is referenced by NYSERDA as the basis for its own risk assessment of thrown ice) is from 'private communications' from Henry Seifert at DEWI [8].

Morgan himself recognizes the lack of useful information on icing when he states [9]

> "As regards the size of ice fragments shed from rotor blades their mass and the distance which they are cast, there is very limited objective and subjective information. The only objective source of information is that collected in the recently completed EU Joule project *Icing of Wind Turbines*. As part of this work, carried out by DEWI and FMI, a questionnaire was circulated to a large number of turbine operators as described by Seifert. The questionnaire asked for information on the occurrence of icing including mass and location of any observed ice debris flung off the rotor. "

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[8] See above paper, page 121, reference number 4, 'Private Communication from H. Seifert, DEWI, 1996'
[9] see above paper, page 116

The methodology and results of this questionnaire were not published. In his paper Morgan cites 'personal communication' concerning the EU Joule project as the source of his data from this survey. The sum total of this information used by Morgan in his papers on risk assessment is presented in a chart with 17 point of data.[10] Again, Morgan did not actually gather this data. These 17 points of data derived from a source that is not published but are the only data that forms the basis for Morgan's (and in turn NYSERDA's) recommendations concerning safety risk.

This is quite unusual. Typically, in valid studies the methods of the derivation of the data, the 'survey' used to derive the data, how the survey was administered, and the compliance rate of the survey would all be given. None of this is available for the study by Seifert that Morgan, and in turn NYSERDA rely on for risk assessment.

Evaluating the quality of this data which has an unpublished source is critical to understanding whether a risk assessment can accurately be derived from the information.

Since Henry Seifert was the source of the personal communications to Morgan, and Seifert's data remains unpublished, I communicated directly with Dr. Seifert to better understand the source of this critical data.[11]

It turns out Seifert's data is derived from a survey done in the early 1990s of operators of wind turbines.

In this survey

1. The response rate was 13% of operators.
2. Ice was discovered in the context of going to and from a turbine to repair or service the turbine in winter conditions.
3. Dr. Seifert acknowledges that snowy winter conditions tend to prevent thrown ice from being noticed.
4. There study was not designed to include a systematic examination of the area surrounding the turbine after icing events to catalogue the frequency and distance of the thrown ice. Therefore a pro-active search for thrown ice was not performed.
5. **The data, as described by Seifert himself, is inaccurate and did not involve actual measurement.**

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[10] see above paper, figure 2, page 116.

[11] Email stream between Henry Seifert, PhD and Kenneth Jaffe, MD concerning Dr. Seifert's Survey on Ice Throws, 2006.

Elaborating on the lack of actual measurement of ice throw distance and weight, Seifert describes the data on mass and distance of thrown ice as 'rough guesses' rather than measurements. His description of this process follows[12]

> "In most of the cases the numbers given in the questionnaires are rather inaccurate, meaning that the mass of the fragments as well as the distances were rough guesses rather than exact measurements. Normally you don't go to the site with a weighing machine and a tape measure."

Given these limitations and study biases, it is likely that the actual number and distance of the ice fragments are both greater than presented in this data.

The key point of this discussion is that we simply do not have empirical data to make predictions or judgments about icing risk to people and property. The 'studies' discussed above are really not an adequate basis for risk assessment or forming public policy.

RISK CALCULATIONS, BIASED ASSUMPTIONS

In spite of his lack of data on ice throws, Morgan makes an attempt to quantify the public safety risk. In doing so he resorts to a calculation based on a series of assumptions which are not based on data, and which dramatically minimize the distance traveled by thrown ice. This calculation is done in another of his papers which he uses as his source.[13]

Morgan assumes that drag on thrown ice is very high (leading to shorter throw distance) and the lift is non-existent (also leading to shorter throw distance). He assumes that the drag coefficient is 1.0. For context I have included a list of drag coefficients of various objects. Please note that the drag coefficient of an aircraft wing (shaped similarly to the turbine blade on which the ice is formed) approaches zero.[14] Morgan's own calculations show that as drag approaches zero, the throw distance is over 1500 feet for a 75 foot turbine blade --- 4 times the calculation using his assumptions.[15]

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[12] See above reference, page 1

[13] Wind Turbine Icing and Public Safety---A Quantifiable Risk?, Morgan and Bossanyi, 1996. Presented at the wind industry conference Boreas III.
At http://www.easthavenwindfarm.com/filing/feb/ehwf-ml-reb4.pdf

[14] Aerodynamic Database, Drag Coefficients, page 2, at http://www.aerodyn.org/Drag/tables.html

[15] see Figure 5, the top line in the graph, which is the 'no drag' line in Morgan's paper, reference no. 13,

A fuller discussion of the inappropriateness of Morgan's assumptions can be found in a paper by Dr. Terry Matilsky, a Professor of Physics and Astronomy at Rutgers University.[16]

> **Comments on inclusions of drag coefficients and risk assessment**
>
> 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. ...... 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. The procedure is to 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. Developers discount this because he "assumed that the ice 'fragments' were actually large flat slabs weighing perhaps 80 kg." Actually, he was modeling 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 tell, the MacQueen study is the ONLY peer reviewed analysis for throw possibilities. The rest are calculations done by wind company employees and/or consultants.

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[16] Analysis of Ice and Rotor Throw from Wind Turbines, Matilsky, see part II, 'comments on inclusion of drag coefficients and risk assessment. At http://xray.rutgers.edu/~matilsky/windmills/throw.html

Let me summarize the situation with the studies by Seifert and Morgan that are being used as the basis of wind industry information and for NYSERDA's policy on risk to people and property from thrown ice.

1. We do not have true measurements.
2. We do not have true surveillance.
3. We do not have an adequate survey response rate.
4. We do not have risk calculations based on assumptions that are appropriate to the physical properties of ice formed on turbine blades.
5. We do not have publication (10 years after the data was gathered) in a peer review journal, to ensure accuracy and impartiality.

Earlier the calculated theoretical distance that ice could travel given the height and speed of a turbine blade was discussed. Until an actual icing surveillance study is available as an empirical guide we are left having to use this calculated theoretical distance---of one half mile--- as the basis for creating policy designed to protect public safety.

ADDENDUM

On June 7th the New York State Department of State made a presentation in Delaware County which included a discussion of safety risks from ice throws. Unfortunately the information was misleading, did not use credible sources and factually incorrect. The information concerning sound was even more problematic, and will be discussed in my note on noise at a later date.

The totality of the information presented concerning ice throws and public safety as guidance for planners and town officials was

1. A chart purporting to show the distance traveled by thrown ice. This chart actually concerns **stationary turbines, not turbines with blades moving** at 150 to 200 mph. The chart which the DOS used (copied from a paper by Seifert[17]) is titled "<u>Typical result of an ice fall width calculation for a turbine at standstill</u>".

2. The DOS refers to two "Insurance Testimonials" on the NYSERDA website. These letters are from insurance brokers are in Palm Springs, California and Torrence, California, both desert areas of Southern California not subject to icing.

3. The main source used in the DOS presentation (described in the slide she showed and included in the handout) is a paper from Williams College. She states the "study reports icing in that climate typically 3 to 5 days a year and calculates the risk as acceptable". A few points about this report will help one understand its scientific quality and how it reflects on the decision to use it as the primary reference in a presentation to government decision makers.

   a) The Williams College "study" is not actually a study.[18]
   It is a report written by undergraduate students (see page 8) in an environmental course at Williams in support of a local wind turbine project.

   b) The Williams paper expresses concern about liability issues (page 22) being caused by injuries from thrown ice striking hikers using a trail near the proposed turbines and suggests moving the trails to avoid injury and liability issues.

   c) The nearest residence to the proposed turbines in the project discussed in the Williams students' paper is over one mile (as discussed in the report's discussion of noise, page 16-17).

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[17] see figure 5, page 6 of Risk Analysis of Ice Throw from Wind Turbines, Seifert et al, presented at Boreas 6 conference. At http://web1.msue.msu.edu/cdnr/icethrowseifertb.pdf

[18] Report of the Feasibility of a Wind Power Project on the Berlin Pass. http://www.williams.edu/CES/mattcole/resources/onlinepaperpdfs/papers/Wind.pdf

d) The students' paper cites a report by Schaffner[19] as the source of their statement "Although our turbines would have blade diameters of 80 m (260 ft), ice throw danger from ice throws from any turbine with blade diameters over 40 m (130 ft) is the same." In fact *Schaffner makes no such statement and does not even address the issue of ice throw distance.* Rather, Schaffner's paper is simply a report of a technology (SODAR) designed to sense when ice forms on turbines in remote locations.

e) The only information the Williams students use to form their risk assessment is discussed in my main report----Seifert's survey which did not use actual measurements to create his data (and presented as 17 points on a chart) and the paper by Morgan work (discussed above) which made a series of calculations that assumed thrown ice would not retain the shape of the turbine blade on which it was formed.

The point of this review is to indicate that the presentation by the NY State Department of State to officials in Delaware County did not give a true sense of the science concerning ice throws in the region, and did not provide adequate information or appropriate guidance for officials interested in protecting public safety.

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[19] Schaffner, Beat. "Wind Energy Site Assessment in Harsh Climatic Conditions: Long Term Experience in the Swiss Alps". Bern, Switzerland. At http://virtual.vtt.fi/virtual/arcticwind/reports/harsh_climate.pdf

Perception and annoyance due to wind turbine noise—a dose–response relationship

Eja Pedersen[a)] and Kerstin Persson Waye
Department of Environmental Medicine, Göteborg University, P.O. Box 414, SE-405 30 Göteborg, Sweden

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Installed global wind power increased by 26% during 2003, with U.S and Europe accounting for 90% of the cumulative capacity. Little is known about wind turbines' impact on people living in their vicinity. The aims of this study were to evaluate the prevalence of annoyance due to wind turbine noise and to study dose–response relationships. Interrelationships between noise annoyance and sound characteristics, as well as the influence of subjective variables such as attitude and noise sensitivity, were also assessed. A cross-sectional study was performed in Sweden in 2000. Responses were obtained through questionnaires ($n=351$; response rate 68.4%), and doses were calculated as A-weighted sound pressure levels for each respondent. A statistically significant dose–response relationship was found, showing higher proportion of people reporting perception and annoyance than expected from the present dose–response relationships for transportation noise. The unexpected high proportion of annoyance could be due to visual interference, influencing noise annoyance, as well as the presence of intrusive sound characteristics. The respondents' attitude to the visual impact of wind turbines on the landscape scenery was found to influence noise annoyance.
 [DOI: 10.1121/1.1815091]

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I. INTRODUCTION

Wind turbines generate renewable energy and thus contribute to sustainable development. However, disturbance from wind turbines may be an obstacle for large-scale production (Rand and Clarke, 1990; Ackerman and Söder, 2000). Few studies have so far been directed to the prevalence of disturbance, and existing knowledge of annoyance due to wind turbines is mainly based on studies of smaller turbines of less than 500 kW (Wolsink *et al.*, 1993; Pedersen and Nielsen, 1994).

Global wind power installed at the end of 2003 reached 39 GW according to American Wind Energy Association (2004), an increase of 26% in just one year. United States (7 GW) and Europe (29 GW) account for 90% of the cumulative capacity. In Sweden, more than 600 wind turbines are operating today with a total installed capacity of 0.4 GW, producing 600 GWh per year. They are placed in 84 of Sweden's 290 municipalities both along the coasts and in rural inland areas, concerning a number of people. The goal set up by the Swedish government for 2015 is 10 TWh, leading to an increase of 1600% from today. Most of these new turbines will probably be situated off shore, but as the cost for building on land is considerably lower, the development on land is expected to continue. Already, turbines are being erected near densely populated areas. Preliminary interviews conducted among 12 respondents living within 800 m of a wind turbine, and a register study of the nature of complaints to local health and environments authorities, indicated that the main disturbances from wind turbines were due to noise, shadows, reflections from rotor blades, and spoiled views (Pedersen, 2000).

All wind turbines in Sweden are upwind devices. The most common type is a 600 or 660 kW turbine with three rotor blades, rotor diameter 42–47 m, constant rotor speed 28 rpm (84 blade passages per minute, a blade passage frequency of 1.4 Hz), and hub height of 40–50 m. They often operate singly or in multiple units of 2 to 10. The noise emission at the hub is 98–102 dBA measured at wind velocity 8 m/s at 10 m height. Earlier turbines were often downwind devices and contained low-frequency noise (Hubbard *et al.*, 1983). In contrast to these, modern machines have the rotor blades upwind and the noise is typically broadband in nature (Fig. 1), (Persson Waye and Öhrström, 2002; Björkman, 2004). There are two main types of noise sources from an upwind turbine: mechanical noise and aerodynamic noise. Mechanical noise is mainly generated by the gearbox, but also by other parts such as the generator (Lowson, 1996). Mechanical noise has a dominant energy within the frequencies below 1000 Hz and may contain discrete tone components. Tones are known to be more annoying than noise without tones, but both mechanical noise and tones can be reduced efficiently (Wagner *et al.*, 1996). Aerodynamic noise from wind turbines has a broadband character. It originates mainly from the flow of air around the blades; therefore the sound pressure levels (SPLs) increase with tip speed. Aerodynamic noise is typically the dominant component of wind turbine noise today, as manufacturers have been able to reduce the mechanical noise to a level below the aerodynamic noise. The latter will become even more dominant as the size of wind turbines increase, because mechanical noise does not increase with the dimensions of turbine as rapidly as aerodynamic noise (Wagner *et al.*, 1996).

Previous international field studies of annoyance from wind turbines have generally found a weak relationship between annoyance and the equivalent A-weighted SPL (Rand

[a)]Electronic mail: eja.pedersen@set.hh.se

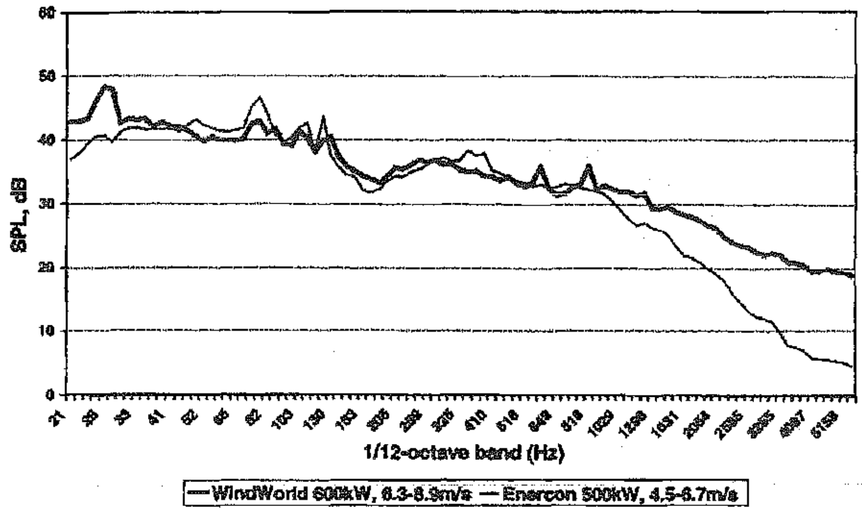

FIG. 1. Frequency spectra of two upwind three-bladed wind turbines recorded at down wind conditions; WindWorld 600 kW and Enercon 500 kW.

and Clarke, 1990; Wolsink *et al.*, 1993; Pedersen and Nielsen, 1994). It is possible that different sound properties, not fully described by the equivalent A-weighted level, are of importance for perception and annoyance for wind turbine noise. Support for such a hypothesis was given in a previous experimental study where reported perception and annoyance for five recorded wind turbine noises were different, although the equivalent A-weighted SPL were the same (Persson Waye and Öhrström, 2002). The results from that study and subsequent experiments suggested that the presence of sound characteristics subjectively described as lapping, swishing, and whistling was responsible for the differences in perception and annoyance between the sounds (Persson Waye and Agge, 2000). The descriptions swishing and whistling were found to be related to the frequency content in the range of 2000 to 4000 Hz (Persson Waye *et al.*, 1998) while the description lapping probably referred to aerodynamically induced fluctuations and was found to best be described by specific loudness over time (Persson Waye *et al.*, 2000). Sound characteristics such as described here could be of relevance for perception and annoyance, especially at low background levels.

It has been suggested that the perception of wind turbine noise could be masked by wind-generated noise. However, most of the wind turbines operating today have a stable rotor speed, and, as a consequence, the rotor blades will generate an aerodynamic noise even if the wind speed is slow and the ambient noise is low. Furthermore, noise from wind turbines comprises modulations with a frequency that corresponds to the blade passage frequency (Hubbard *et al.*, 1983) and is usually poorly masked by ambient noise in rural areas (Arlinger and Gustafsson, 1988).

It has also been shown in previous field studies that attitude to wind turbines is relevant to perceived annoyance (Wolsink *et al.*, 1993; Pedersen and Nielsen, 1994). Such a relationship, however, was not found in an experimental study where the participants were exposed to wind turbine noise (Persson Waye and Öhrström, 2002). The difference could be due to the fact that the subjects in the latter study had very little personal experience of wind turbines generally, or to their lack of visual impression during the noise exposure.

There is clearly a need for field studies to investigate the impact of wind turbines on people living in their vicinity and to further explore the presence of disturbances. In particular, dose–response relationships should be investigated to achieve a more precise knowledge of acceptable exposure levels. As noise annoyance may be interrelated to the presence of intrusive sound characteristics, ambient sound pressure level, and visual intrusion as well as individual variables, all these factors should be taken into account and their relative importance evaluated.

The aims of this study were to evaluate the prevalence of annoyance due to wind turbine noise and to study dose–response relationships. The intention was also to look at interrelationships between noise annoyance and sound characteristics, as well as the influence of subjective variables such as attitude and noise sensitivity.

II. METHOD

A. General outline

The investigation was a cross-sectional study comprising respondents exposed to different A-weighted sound pressure levels (SPL) from wind turbines. Five areas totaling 22 km^2 comprising in total 16 wind turbines and 627 households were chosen within a total area of 30 km^2 (Table I). Subjective responses were obtained through questionnaires delivered at each household and collected a week later in May and June 2000. The response rate was 68.4%. A-weighted SPLs due to wind turbines were calculated for each respondent's dwelling. Comparisons were made of the extent of annoyance between respondents living at different A-weighted SPLs.

B. Study area and study sample

The criteria for the selection of the study areas were that they should comprise a large enough number of dwellings at varying distances from operating wind turbines within a

TABLE I. Description of study areas.

Area	Square km	Wind turbines	Households	Study population	Responses	Response rate (%)
A	3.7	2	89	75	54	72.0
B	4.7	3	44	33	23	69.7
C	8.3	8	70	59	49	83.1
D	3.3	2	393	325	210	64.6
E	2.0	1	31	21	15	71.4
Total	22.0	16	627	513	351	68.4

comparable geographical, cultural, and topographical structure. Suitable areas were found in a municipality in the south of Sweden. More than 40 wind turbines are located in this region, either in small groups with two to five turbines or as single objects. The landscape is flat and mainly agricultural but small industries, roads, and railroads are also present. Most people live in privately owned detached houses in the countryside or in small villages. The wind turbines are visible from many directions. To define the study area, preliminary calculations of sound distribution were made so that the area would include dwellings exposed to similar A-weighted SPL irrespective of the number of wind turbines. Of the 16 wind turbines in the selected five areas, 14 had a power of 600–650 kW, the other two turbines having 500 kW and 150 kW. The towers were between 47 and 50 m in height. Of the turbines, 13 were WindWorld machines, 2 were Enercon, and 1 was a Vestas turbine. Figure 1 shows a $\frac{1}{12}$-octave band spectra of a WindWorld turbine sound recorded 320 m from a turbine in area A at 6.3–8.9 m/s and a spectra of an Enercon turbine sound recorded 370 m from the turbine in area E at 4.5–6.7 m/s. Both recordings were done under downwind conditions.

The study sample comprised one selected subject between the ages of 18 and 75 in each household in the area within a calculated wind turbine A-weighted SPL of more than 30 dB ($n=513$). The subject with birth date closest to May 20 was asked to answer a questionnaire.

C. Questionnaire

The purpose of the study was masked in the questionnaire; the questions on living conditions in the countryside also included questions directly related to wind turbines. The response of most questions was rated on 5-point or 4-point verbal rating scales. The key questions relevant for this paper were translated into English and are presented in the Appendix. The questionnaire was divided into four sections. The first section comprised questions regarding housing and satisfaction with the living environment, including questions on the degree of annoyance experienced outdoors and indoors from several sources of annoyance, wind turbines included. The respondent was also asked to rate his/her sensitivity to environmental factors, one being noise.

The second section of the questionnaire comprised questions on wind turbines, related to the respondent by the recent development of wind turbines in the community. The response to different visual and auditory aspects of wind turbines as noise and shadows were asked for, followed by questions on frequency of disturbances and experiences during certain activities and weather conditions. Respondents were also asked to describe their level of perception and annoyance related to the wind turbine sounds they could hear, using verbal descriptors of sound and perceptual characteristics. These descriptors were obtained from previous experimental studies were subjects initially verbally described their perception of annoying sound properties for five recorded wind turbine sounds (Persson Waye and Öhrström, 2002). This, together with some given adjectives, resulted in a total of 14 adjectives that were rated on unipolar scales with regard to annoyance. In this field study, the original descriptors were complemented with regionally used phrases. Several questions on attitude to wind turbines were also included.

The third section of the questionnaire concerned health aspects such as chronic illnesses (diabetes, tinnitus, cardiovascular diseases, hearing impairment) and general well-being (headache, undue tiredness, pain and stiffness in the back, neck or shoulders, feeling tensed/stressed, irritable). Respondents were asked questions about their normal sleep habits: quality of sleep, whether sleep was disturbed by any noise source, and whether they normally slept with the window open. The last section comprised questions on employment and working hours.

D. Calculations and measurements of noise exposure

For each respondent, A-weighted SPLs (dB) were calculated as the sum of contributions from the wind power plants in the specific area. The calculations were made with calculation points every fifth meter. The calculations followed the sound propagation model for wind power plants adopted by the Swedish Environmental Protection Agency (2001) and used as a basis for granting of building permission. The model assumes downward wind of 8 m/s at 10-m height. The calculation model is slightly different depending on the distance between the source and the receiver. For the cases in this study the following equation was used:

$$L_A = L_{WA,corr} - 8 - 20\lg(r) - 0.005r, \quad (1)$$

where r is the distance from the source to the receiver in meters. The atmospheric absorption coefficient is estimated to be 0.005 dB/m. $L_{WA,corr}$ is a modified sound power level of the wind power:

$$L_{WA,corr} = L_{WA} + k \cdot \Delta v_h. \quad (2)$$

TABLE II. Study sample, study population, and response rate related to sound category (dBA).

Sound category	<30.0	30.0–32.5	32.5–35.0	35.0–37.5	37.5–40.0	>40.0	Total
Study sample	25	103	200	100	53	32	513
Study population	15	71	137	63	40	25	351
Response rate	60.0%	68.9%	68.5%	63.0%	75.5%	78.1%	68.4%

L_{W_A} is the A-weighted sound power level of the wind power plant, which in this study was given by the manufacturer; k describes how the sound power level varies with the wind speed at 10 m height and

$$\Delta v_h = v_h \left(\frac{\ln(H/z_0)}{\ln(h/z_0)} \frac{\ln(h/0.05)}{\ln(H/0.05)} - 1 \right), \tag{3}$$

where v_h is the wind speed at 10-m height, H the height of the hub, h is 10 m, and z_0 the surface roughness length. In these calculations, $z_0 = 0.05\,\mathrm{m}$ (fields with few buildings) was used and therefore no value of k was needed. The SPL calculated this way is an estimate for the equivalent level for a hypothetical time period with continuous performance at downwind conditions 8 m/s at 10-m height.

To verify the calculations, to record frequency spectra, and to study background sound, a mobile caravan equipped with a sound level meter (Larson & Davis type 820), digital audio tape recorder (Sony TCD-D8 DAT), and meteorological instruments (Davis Weather Monitor type II) was used. The mobile station was placed on different sites of the study area. Both the meteorological instruments and the noise recording instruments were computer controlled and directed remotely via a cellular phone. The microphone was attached on a vertical hardboard facing the noise source. The equipment and procedures are thoroughly described by Björkman (2004). The sound pressure levels measured on the reflecting plane were corrected by -6 dB to present the free field value. The ambient sound pressure level varied from 33 dB $L_{\mathrm{Aeq,5\,min}}$ to 44 dB $L_{\mathrm{Aeq,5\,min}}$. The variations were mainly due to the amount of traffic within a 24-h time period. The lower background levels typically occurred during evening and nights.

The respondents were classified into six sound categories according to the calculated wind turbine A-weighted SPL at their dwelling. Table II shows the number of respondents living within each sound category and also the study sample and response rate for each sound category.

Data for the distance between the dwelling of the respondent and the nearest wind turbine were obtained from property maps, scale 1:10 000. The distance differed within each sound category, depending on the number of wind turbines in the area—the larger number of wind turbines, the shorter distance at the same A-weighted SPL. Table III shows the relationship between distance and A-weighted SPL. Two values are given for each category: the range and the median interval.

E. Statistical treatment of data

Due to the fact that most of the data were categorical (ordered or nonordered) and not continuos data, and therefore no assumptions on probability distribution could be made, nonparametric statistical methods were used, all described by Altman (1991). Data from verbal rating scales were calculated as proportions with 95% confidence intervals. When relevant, the two highest ratings of annoyance (rather annoyed and very annoyed) were classified as annoyed and the three lower ones as not annoyed (do not notice, notice but not annoyed, and slightly annoyed). In the analysis of attitude, negative and very negative were classified as negative; in the analysis of sensitivity, rather sensitive and very sensitive were classified as sensitive. More advanced statistical analyses were carried out using SPSS version 11.0. Relationships between variables were evaluated using Spearman's nonparametric rank correlation (r_s). Pearson's chi-square (chi2) was used to test that all sound categories contained the same proportion of observations. To evaluate differences between two unmatched samples of observations on an ordinal scale (e.g., comparing men and women's answers on a 5-graded verbal rating scale), the Mann–Whitney test was used (z_{MW}); a nonparametric test equivalent to the t test, but based on ranks (Altman, 1991). All significance tests were two-sided and p-values below 0.05 were considered statistically significant. When exploring several relationships at the same time, 1 out of 20 calculations would be classified as statistically significant by chance. This risk of mass significance was avoided using Bonferroni's method when appropriate, reducing the p-value considered statistically significant by dividing it with the number of correlations calculated at the same time (Altman, 1991).

Binary logistic multiple regression was used to study the impact of different variables on annoyance of wind turbine noise (annoyed–not annoyed). Sound category was used as the dose variable. Logistic regression is a method used to make a nonlinear function into a linear equation, using odds rather than straightforward probability. The equation is

TABLE III. Distance between dwelling and nearest wind turbine related to sound category (dBA).

Sound category	<30.0	30.0–32.5	32.5–35.0	35.0–37.5	37.5–40.0	>40.0
Range (m)	650–1049	550–1199	450–1099	300–799	300–749	150–549
Median interval (m)	850–899	750–799	550–599	450–499	350–399	300–349

TABLE IV. Characteristics of the respondents given as proportions of respondents in each sound category (dBA) and in total.

Sound category	<30.0	30.0–32.5	32.5–35.0	35.0–37.5	37.5–40.0	>40.0	Total
n	15	71	137	63	40	25	351
Gender: Male (%)	27	35	39	50	50	48	42
Residence: Detached houses/farms (%)	100	83	61	100	97	96	81
Occupation: Employed (%)	67	59	58	53	69	67	60
Sensitive[a] to noise (%)	62	44	49	53	58	50	50
Negative[b] to wind turbines (%)	8	10	11	18	20	8	13
Negative[b] to visual impact (%)	43	33	38	41	40	58	40
Long-term illness (%)	20	29	28	16	30	24	26
Age: Mean	46	47	47	50	48	48	48
(SD)	(13.3)	(13.7)	(14.3)	(14.6)	(13.1)	(14.3)	(14.0)

[a]Sensitive consists of the two ratings: rather sensitive and very sensitive.
[b]Negative consists of the two ratings: rather negative and very negative.

$$\ln\left(\frac{p}{1-p}\right)=b_0+b_1x_1+b_2x_2+\cdots, \tag{4}$$

where, in this case, p is the probability of being annoyed by noise from wind turbines, x_1-x_n are the variables put into the model, and b_1-b_n are the logarithmic value of the odds ratio for one unit change in the respective variable (Altman, 1991). A relevant measurement of explained variance using nonparametric statistics is Nagelkerke pseudo-R^2 (Nagelkerke, 1991).

To estimate how consistently the respondents answered to questions measuring similar response, Cronbach's alpha (Miller, 1995) was calculated as a testing of the internal consistency reliability of the questionnaire. Five of the questions regarding wind turbine noise were compared: annoyance outdoors, annoyance indoors, annoyance of rotor blades, annoyance of machinery, annoyance as a describing adjective. Demographic data on age and gender of the population in the four parishes in the study area were collected from local authorities. The study population was compared to these demographical data, parish-by-parish, and divided into 10-year categories for age and gender, as well as in total.

III. RESULTS

A. Study population

The overall response rate was 68.4%, ranging from 60.0% to 78.1% in the six sound categories (Table II). No statistically significant differences in variables related to age, gender, or employment were found among sound categories (Table IV). A statistically significant difference was found between sound categories as to whether respondents lived in apartments or detached houses (chi2=62.99, df=5, $p<0.001$). Overall, most of the respondents (80%) lived in privately owned detached houses or on farms. The remaining lived in tenant-owned or rented apartments. The latter were more frequent in sound category 32.5–35.0 dBA (Table IV). However, there was no statistically significant difference between the respondents living in privately owned detached houses or on farms, on one hand, and those living in tenant-owned or rented apartments, on the other hand, regarding subjective factors, when correcting for requirements to avoid mass significance. Most of the respondents did not own a wind turbine or share of a wind turbine (95%, $n=335$). No statistically significant differences in variables related to noise sensitivity, attitude, or health were found between the different sound categories.

The mean age in the study population was 48 years (SD =14.0) (Table IV) which did not differ statistically significantly from the demographic data (45 years, SD=15.2). The proportion of women in the study population was slightly higher than in the demographic data; in the study population, 58% women and 42% men (Table IV), compared to 49% women and 51% men in the demographic data. However, no statistically significant differences were found between men and women regarding perception and annoyance due to wind turbine noise, noise sensitivity, or attitude to wind turbines. Differences between genders were found regarding well-being. Women suffered more often from headache ($z_{MW}=-3.243$, $n=328$, $p<0.001$), undue tiredness ($z_{MW}=-3.549$, $n=327$, $p<0.05$), pain and stiffness in back, neck or shoulders ($z_{MW}=-3.312$, $n=331$, $p<0.001$), and tension/stress ($z_{MW}=-3.446$, $n=328$, $p<0.001$).

B. Main results

The proportion of respondents who noticed noise from wind turbines outdoors increased sharply from 39% ($n=27$, 95%CI: 27%–50%) at sound category 30.0–32.5 dBA to 85% ($n=53$, 95%CI: 77%–94%) at sound category 35.0–37.5 dBA (Table V). The proportion of those annoyed by wind turbine noise outdoors also increased with higher sound category, at sound categories exceeding 35.0 dBA. The correlation between sound category and outdoor annoyance due to wind turbine noise (scale 1–5) was statistically significant ($r_s=0.421$, $n=341$, $p<0.001$). No respondent self-reported as annoyed at sound categories below 32.5 dBA, but at sound category 37.5–40.0 dBA, 20% of the 40 respondents living within this exposure were very annoyed and above 40 dBA, 36% of the 25 respondents (Table V).

To explore the influence of the subjective factors on noise annoyance, binary multiple logistic regression was used (Table VI). Eight models were created, all containing sound category as the prime variable assumed to predict noise annoyance. The three subjective factors of attitude to visual impact, attitude to wind turbines in general, and sensitivity to noise were forced into the model one-by-one, two-by-two, and finally all together. In the first model only noise

TABLE V. Perception and annoyance outdoors from wind turbine noise related to sound exposure.

	<30.0 $n=12$ %(95%CI)	30.0–32.5 $n=70$ %(95%CI)	32.5–35.0 $n=132$ %(95%CI)	35.0–37.5 $n=62$ %(95%CI)	37.5–40.0 $n=40$ %(95%CI)	>40.0 $n=25$ %(95%CI)
Do not notice	75 (51–100)	61(50–73)	38(30–46)	15(3–23)	15(4–26)	4(19–57)
Notice, but not annoyed	25(1–50)	24(14–34)	28(20–36)	47(34–59)	35(20–50)	40(19–57)
Slightly annoyed	0	14(6–22)	17(10–23)	26(15–37)	23(10–35)	12(19–57)
Rather annoyed	0	0	10(5–15)	6(0–13)	8(−1–16)	8(19–57)
Very annoyed	0	0	8(3–12)	6(0–13)	20(8–32)	36(17–55)

exposure was used as the independent variable. The Exp(b) was 1.87, i.e., the odds for being annoyed by noise from wind turbines would increase 1.87 times from one sound category to the next. When adding the subjective factor of attitude to visual impact as an independent variable, the influence of the noise exposure decreased, but was still statistically significant. The pseudo-R^2 increased from 0.13 to 0.46, indicating that the new model explained 46% of the variance in annoyance. Adding the two remaining subjective factors did not improve the model as the coefficients did not reach statistical significance.

Noise from rotor blades was reported as the most annoying aspect of wind turbines. Of the respondents, 16% ($n=54$, 95%CI: 12%–20%) were annoyed by noise from rotor blades. Changed view (14%, $n=48$, 95%CI: 10%–18%), noise from machinery (9%, $n=33$, 95%CI: 6%–12%), shadows from rotor blades (9%, $n=29$, 95%CI: 6%–11%), and reflections from rotor blades (7%, $n=22$, 95%CI: 4%–9%) were also reported.

C. Attitude and sensitivity

Almost all respondents (93%, $n=327$, 95%CI: 91%–96%) could see one or more wind turbines from their dwelling or garden. When asked for judgments on wind turbines, the adjectives that were agreed on by most respondents were "environmentally friendly" (79%), "necessary" (37%), "ugly" (36%), and "effective" (30%). Only the word "annoying" (25%) was judged higher among those in higher sound categories than among those in lower sound categories ($z_{MW}=-3.613$, $n=351$, $p<0.001$).

The high judgment of the word "ugly" corresponds to the outcome of the attitude questions. Of the respondents, only 13% ($n=44$, 95%CI: 9%–16%) reported that they were negative or very negative to wind turbines in general, but 40% ($n=137$, 95%CI: 34%–44%) that they were negative or very negative to the visual impact of wind turbines on the landscape scenery (Table IV).

All correlations between sound category, noise annoyance, and subjective factors are shown in Table VII. Noise annoyance was correlated to both sound category and the three subjective factors, strongest to attitude to the wind turbines' visual impact on the landscape. The subjective factors were also correlated to each other, except for general attitude and sensitivity to noise. Of all the respondents, 50% ($n=169$, 95%CI: 45%–55%) regarded themselves as rather sensitive or very sensitive to noise (Table IV).

When comparing those annoyed by wind turbine noise and those not, no differences were found regarding the judgments of the local authorities, with the exception of perceived opportunity to influence local government ($z_{MW}=-2.753$, $n=300$, $p<0.005$). Those annoyed reported negative changes to a higher degree ($z_{MW}=-5.993$, $n=307$, p

TABLE VI. Results of multiple logistic regression analyses with 95% confidence intervals.

	Variables	b	p-value	Exp(b) (95%CI)	Pseudo-R^{2a}
1	Noise exposure	0.63	<0.001	1.87(1.47–2.38)	0.13
2	Noise exposure	0.55	<0.001	1.74(1.29–2.34)	0.46
	Attitude to visual impact	1.62	<0.001	5.05(3.22–7.92)	
3	Noise exposure	0.62	<0.001	1.86(1.45–2.40)	0.20
	Attitude to wind turbines	0.56	<0.001	1.74(1.30–2.33)	
4	Noise exposure	0.63	<0.001	1.88(1.46–2.42)	0.18
	Sensitivity to noise	0.56	<0.005	1.75(1.19–2.57)	
5	Noise exposure	0.55	<0.001	1.73(1.28–2.33)	0.46
	Attitude to visual impact	1.66	<0.001	5.28(3.26–8.56)	
	Attitude to wind turbines	−0.10	0.319	0.91(0.64–1.28)	
6	Noise exposure	0.57	<0.001	1.77(1.30–2.40)	0.47
	Attitude to visual impact	1.59	<0.001	4.88(3.08–7.72)	
	Sensitivity to noise	0.22	0.344	1.25(0.79–1.96)	
7	Noise exposure	0.63	<0.001	1.88(1.45–2.45)	0.24
	Attitude to wind turbines	0.58	<0.001	1.78(1.32–2.41)	
	Sensitivity to noise	0.59	<0.005	1.80(1.22–2.67)	
8	Noise exposure	0.56	<0.001	1.76(1.29–2.39)	0.47
	Attitude to visual impact	1.63	<0.001	5.11(3.10–8.41)	
	Attitude to wind turbines	−0.10	0.597	0.91(0.64–1.29)	
	Sensitivity to noise	0.21	0.373	1.23(0.78–1.94)	

[a]Nagelkerke (1991).

TABLE VII. Correlation between noise annoyance, sound category (dBA) and the subjective variables. Statistically significant correlations in boldface. To avoid the risk of mass significance $p<0.008$ were required for statistical significance.

	Sound category	Attitude to visual impact	Attitude to wind turbines	Sensitivity to noise
Noise annoyance	**0.421**	**0.512**	**0.334**	**0.197**
Sound category	⋯	**0.145**	0.074	0.069
Attitude to visual impact		⋯	**0.568**	**0.194**
Attitude to wind turbines			⋯	0.023
Sensitivity to noise				⋯

<0.001); 83% compared to 37% among those not annoyed. Of the 138 respondents who reported negative changes overall, 41% ($n=57$, 95%CI: 33%–50%) specified wind turbines in the response to an open question.

D. The occurrence of noise annoyance

Among those who noticed wind turbine noise ($n=223$), 25% ($n=47$, 95%CI: 18%–31%) reported that they were disturbed every day or almost every day and 17% ($n=33$, 95%CI: 12%–23%) once or twice a week. Annoyance was most frequently reported when relaxing outdoors and at barbecue nights.

Perception of wind turbine noise was influenced by weather conditions. Of the respondents who noticed wind turbine noise, 54% stated that they could hear the noise more clearly than usual when the wind was blowing from the turbines towards their dwelling. Only 9% reported that the noise was heard more clearly when the wind was from the opposite direction. The noise was also more clearly noticed when a rather strong wind was blowing (39%), but 18% reported that the noise was more clearly noticed in low wind. For warm summer nights, 26% noticed the noise more clearly than usual.

E. Sound characteristics

There was a statistically significant correlation between sound category and annoyance due to noise from rotor blades ($r_s=0.431$, $n=339$, $p<0.001$) and from the machinery ($r_s=0.294$, $n=333$, $p<0.001$). In all sound categories, a higher proportion of respondents noticed noise from rotor blades than from the machinery (Fig. 2). The proportion who noticed noise from rotor blades was similar to the proportion of respondents who noticed wind turbine noise in general. Noise from rotor blades was noticed in lower sound categories than noise from the machinery, i.e., it could be heard at a greater distance. However, comparing the numbers of annoyed with the numbers of those who could hear noise from the two sources, respectively, both noises were almost equally annoying. Of the 215 respondents who noticed noise from rotor blades, 25% ($n=54$, 95%CI: 19%–31%) were annoyed. Of the 101 respondents who noticed noise from the machinery, 30% ($n=30$, 95%CI: 21%–39%) were annoyed.

Among those who noticed noise from wind turbines, swishing, whistling, pulsating/throbbing, and resounding were the most common sources of annoyance according to verbal descriptors of sound characteristics (Table VIII). These descriptors were all highly correlated to noise annoyance. All other verbal descriptors of sound characteristics were also statistically significantly correlated to noise annoyance, but to a lower degree. When analyzing annoyance due to noise from rotor blades, the strongest correlated verbal descriptor of sound characteristics was swishing ($r_s=0.807$, $n=185$, $p<0.001$), which can be compared to noise annoyance due to noise from the machinery—which had the highest correlation with scratching/squeaking ($r_s=0.571$, $n=133$, $p<0.001$).

F. Indoor noise annoyance and sleep disturbance

A total of 7% of respondents ($n=25$, 95%CI: 5%–10%) were annoyed by noise from wind turbines indoors. Forty-five percent ($n=24$, 95%CI: 32%–59%) of those who were annoyed by noise from wind turbines outdoors were also

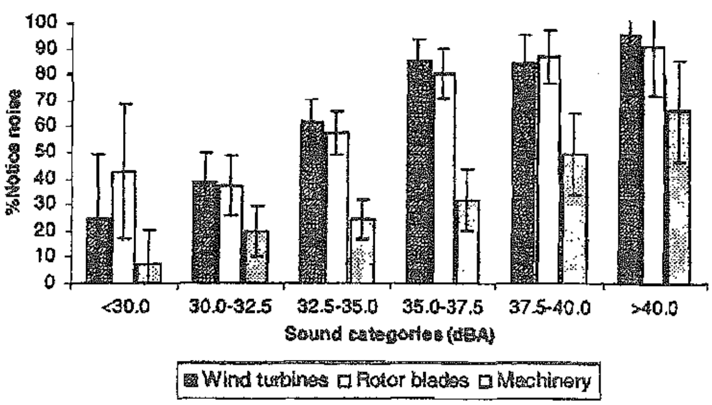

FIG. 2. Proportions with 95% confidence intervals of perception outdoors due to noise (notice but not annoyed, slightly annoyed, rather annoyed, very annoyed) from wind turbines, from rotor blades, and from machinery, related to sound categories.

TABLE VIII. Verbal descriptors of sound characteristics of wind turbine noise, based on those who noticed wind turbine sound ($n=223$). Statistically significant correlations in boldface. To avoid the risk of mass significance $p<0.0062$ were required for statistical significance.

	Annoyed by the specified sound character	Correlation to noise annoyance
Swishing	33%(27%–40%)	**0.718**
Whistling	26%(18%–33%)	**0.642**
Pulsating/throbbing	20%(14%–27%)	**0.450**
Resounding	16%(10%–23%)	**0.485**
Low frequency	13% (7%–18%)	**0.292**
Scratching/squeaking	12% (6%–17%)	**0.398**
Tonal	7% (3%–12%)	**0.335**
Lapping	5% (1%–8%)	**0.262**

annoyed indoors. There was a statistically significant correlation between indoor annoyance and sound category ($r_s = 0.348$, $n=340$, $p<0.001$).

Regarding sleep disturbance, 23% ($n=80$, 95%CI: 18%–27%) of respondents stated that they were disturbed in their sleep by noise. Several sources of sleep disturbance, such as road traffic, rail traffic, neighbors, and wind turbines, were reported in an open question. At lower sound categories, no respondents were disturbed in their sleep by wind turbine noise, but 16% ($n=20$, 95%CI: 11%–20%) of the 128 respondents living at sound exposure above 35.0 dBA stated that they were disturbed in their sleep by wind turbine noise. Of those, all except two slept with an open window in the summer. No statistically significant correlations were found between sleep quality in general and outdoor noise annoyance, indoor noise annoyance, attitude to visual impact, attitude to wind turbines in general, or sensitivity to noise.

IV. DISCUSSION

A. Method

The results were based on the questionnaire survey and calculated A-weighted SPL. The purpose of the study was masked in order to avoid other factors such as attitude and ownership influencing the answers. The survey method is well established and has been used in several previous studies exploring annoyance due to community noise (e.g., Öhrström, 2004).

The results indicate a high validity for the questionnaire. The questions detected annoyance by odor from industrial plants in the area where the biogas plant is located [of those annoyed by odor from industrial plants, 83% ($n=19$) lived close to the biogas plant]; it also detected annoyance by noise from trains in the areas where the train passes [all of the respondents who reported that they were annoyed by noise from railway traffic ($n=12$) lived in areas where the railway passed]. There was a high correspondence between the responses to the general question of noise from wind turbines at the beginning of the questionnaire and the more specific questions later (alpha: 0.8850, $n=326$), also indicating high reliability of results.

The response rate at the different sound categories ranged from 60.0% to 78.1%, with the overall mean 68.4% and the dropout fairly equally distributed over sound categories. The distribution of age in the study population was similar to that of the demographic data for the area, but the proportions of women were somewhat higher than expected, especially in the lower sound categories. It has previously been shown that annoyance is not related to gender (Miedema and Vos, 1999) and as this study found no differences between men and women regarding noise annoyance and attitude to wind turbines, the higher proportion of women in the study population presumably had no impact on the results. A rather high proportion, 50%, of respondents self-reported as rather or very sensitive to noise. Other field studies in Sweden on annoyance due to road traffic noise in urban areas have found a lower proportion of noise-sensitive persons; for example, Matsumura and Rylander (1991) reported 25% of the respondents as noise sensitive in a road traffic survey ($n=805$). The difference might reflect preference of living environment, indicating that noise sensitive individuals prefer a more rural surrounding or that people living in areas with low background noise levels might develop a higher sensitivity to noise.

The calculated A-weighted SPL reflected downwind conditions assuming a wind speed of 8 m/s. Over a larger period of time, the direction and speed of the wind will vary and hence affect the actual SPL at the respondent's dwelling. It is likely that these variations, seen as an average over a longer period of time, in most cases will result in lower levels than the calculated SPL. Several unreliabilities related to the calculations might have led to an over- or underestimation of the dose levels. However, this error would not invalidate the comparison between respondents living at different SPL. Another source of error is that no account was taken of the physical environment around the respondent's house (e.g., location of patio or veranda, presence of bushes and trees in the garden). The actual SPL that the respondent experienced in daily life might therefore differ from the calculated, leading in most cases to an overestimation of the calculated dose.

B. Results

The results suggest that the proportions of respondents annoyed by wind turbine noise are higher than for other community noise sources at the same A-weighted SPL and that the proportion annoyed increases more rapidly. A comparison between established estimations of dose–response relationships for annoyance of transportation noise (Schultz, 1978; Fidell *et al.*, 1991; Miedema and Voss, 1998; Miedema and Oudshoorn, 2001; Fidell, 2003) and an estimation of a dose–response relationship for wind turbine noise, based on the findings in this study, are shown in Fig. 3. All curves are third order polynomials. The established curves describing annoyance from transportation noise are based on a large amount of data, and the wind turbine curve on only one study, so interpretations should be done with care. An important difference between studies of transportation noises and wind turbine noise is however where the main annoyance reaction is formed. For most studies of transportation noises

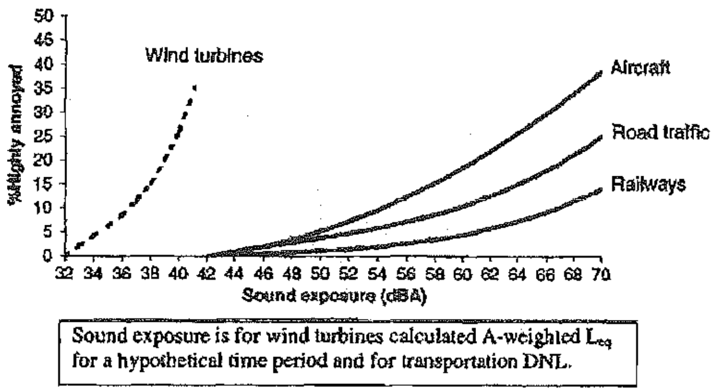

FIG. 3. A comparison between the dose–response relationship for transportation noise estimated by third order polynomials suggested by Miedema and Oudshoorn (2001) and wind turbine noise (dotted line). The latter ($\%HA = 4.38 * 10^{-2}(LEQ-32)^3 - 2.413 * 10^{-1}(LEQ-32)^2 + 2.4073(LEQ-32)$) were derived using regression based on five points interpolated from sound categories used in this study and the assumption that "very annoyed" in this study equals "highly annoyed" (Miedema and Voss, 1998).

it can be assumed that annoyance is formed mainly as a reaction to the sound pressure levels perceived indoors, and hence the actual noise dose should be reduced by the attenuation of the façade. For wind turbine noise the main annoyance reaction is formed when spending time outdoors. The actual difference in noise dose could therefore, at least partly, explain the comparatively higher prevalence of noise annoyance due to wind turbines. However, this factor does not explain the steep gradient.

Another factor that could be of importance for explaining the seemingly different dose–response relationships is that the wind turbine study was performed in a rural environment, where a low background level allows perception of noise sources even if the A-weighted SPL are low. Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0–37.5 dB. This could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise. This is also confirmed by the fact that the aerodynamic sounds were perceived at a longer distance than machinery noise.

Data obtained in this study also suggest that visual and/or aesthetic interference influenced noise annoyance. Support for this hypothesis can be found in studies evaluating auditory-visual interactions (Viollon *et al.*, 2002). In one field-laboratory study, subjects evaluating annoyance due to traffic noise were less annoyed if a slide of a visually attractive street was presented together with the noise, as compared to the same noise level presented together with a visually unattractive street. The difference in noise annoyance amounted to as much as 5 dBA (Kastka and Hangartner, 1986). The hypothesis was also supported by the logistic multiple regression analyses in the present study, where the visual variable attitude to visual impact had a significant impact on the model. However, although the inclusion of the variable increased the pseudo-R^2, the influence of noise exposure was still a significant factor for noise annoyance. A general prediction of the visual influence on noise annoyance, however, can not yet be made with any certainty as both attenuating (Kastka and Hangartner, 1986) and amplifying effects (e.g., Watts *et al.*, 1999) have been detected.

The high prevalence of noise annoyance could also be due to the intrusive characteristics of the aerodynamic sound. The verbal descriptors of sound characteristics related to the aerodynamic sounds of swishing, whistling, pulsating/throbbing, and resounding were—in agreement with this hypothesis—also reported to be most annoying. The results for the sounds of swishing and whistling agree well with results from previous experimental studies (Persson Waye *et al.*, 2000; Persson Waye and Agge, 2000; Persson Waye and Öhrström, 2002), while pulsating/throbbing in those studies was not significantly related to annoyance.

Most respondents who were annoyed by wind turbine noise stated that they were annoyed often, i.e., every day or almost every day. The high occurrence of noise annoyance indicates that the noise intrudes on people's daily life. The survey was performed during May and June when people could be expected to spend time outdoors, and the results therefore reflect the period that is expected to be most sensitive for annoyance due to wind turbine noise.

A low number of respondents were annoyed indoors by wind turbine noise. Some of the respondents also stated that they were disturbed in their sleep by wind turbine noise, and the proportions seemed to increase with higher SPL. The number of respondents disturbed in their sleep, however, was too small for meaningful statistical analysis, but the probability of sleep disturbances due to wind turbine noise can not be neglected at this stage.

Noise annoyance was also related to other subjective factors such as attitude and sensitivity. These results correspond well with the results from other studies regarding community noise (e.g., noise from aircraft, railways, road traffic, and rifle ranges). In a summary of 39 surveys performed in ten different countries, the correlation was 0.42 between dose and response, 0.15 between exposure and attitude, 0.41 between annoyance and attitude, −0.01 between exposure and sensitivity, and 0.30 between annoyance and sensitivity (Job, 1988). Corresponding numbers from this study are presented in Table VII and show a noteworthy similarity.

Two aspects of attitude were explored in the present study. Attitude to the visual impact of wind turbines on the landscape scenery was more strongly correlated to annoyance than the general attitude to wind turbines. The four most supported adjectives queried in the survey were environmentally friendly, necessary, ugly, and effective, thus giving the picture of a phenomenon that is accepted, but not regarded as a positive contribution to the landscape.

Previous studies of community noise have found that people who tend to be consistently negative could be predicted to be more annoyed by a new source of noise (Weinsten, 1980). More recent studies on community noise have included additional aspects and suggest conceptual models describing individual differences in the terms of stress, appraisal, and coping (Lercher, 1996). In the case of annoyance due to wind turbine noise, the findings suggest that individual differences others than attitude and sensitivity could influence the variation of noise annoyance. Respondents annoyed by wind turbine reported negative changes in their neighborhood to a higher degree than those not annoyed and stated that they had little perceived opportunity to influence local government. The importance of these parameters for noise annoyance due to wind turbines should be further studied.

C. Conclusions

A significant dose–response relationship between calculated A-weighted SPL from wind turbines and noise annoyance was found. The prevalence of noise annoyance was higher than what was expected from the calculated dose. It is possible that the presence of intrusive sound characteristics and/or attitudinal visual impacts have an influence on noise annoyance. Further studies are needed, including a larger number of respondents especially at the upper end of the dose curve, before firm conclusions could be drawn. To explore attitude with regard to visual impact, some of these studies should be performed in areas of different topography where the turbines are less visible. There is also a need to further explore the influence of individual and contextual parameters.

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APPENDIX: QUESTIONNAIRE

Key questions from the questionnaire used in the study. Questions with the main purpose to mask the intention of the questionnaire and standard questions on socio-economic status and health are not shown here. Translated from Swedish.

Section I

—How satisfied are you with your living environment? (very satisfied, satisfied, not so satisfied, not satisfied, not at all satisfied)

—Have there been any changes to the *better* in your living environment/municipality during the last years? (no, yes) State which changes.

—Have there been any changes to the *worse* in your living environment/municipality during the last years? (no, yes) State which changes.

—State for each nuisance below if you notice or are annoyed when you spend time *outdoors* at your dwelling: odor from industries, odor from manure, flies, noise from hay fans, noise from wind turbines, railway noise, road traffic noise, lawn mowers. (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed)

—State for each nuisance below if you notice or are annoyed when you spend time *indoors* in your dwelling: odor from industries, odor from manure, flies, noise from hay fans, noise from wind turbines, railway noise, road traffic noise, lawn mowers. (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed)

—How would you describe your sensitivity to the following environmental factors: air pollution, odors, noise, littering? (not sensitive at all, slightly sensitive, rather sensitive, very sensitive)

Section II

—Can you see any wind turbine from your dwelling or your garden? (yes, no)

—What is your opinion on the wind turbines' impact on the landscape scenery? (very positive, positive, neither positive nor negative, negative, very negative)

—Are you affected by wind turbines in your living environment with regard to: shadows from rotor blades, reflections from rotor blades, sound from rotor blades, sound from machinery, changed view? (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed)

—If you are annoyed by noise, shadows and/or reflections from wind turbines, how often does this happen? (never/almost never, some/a few times per year, some/a few times per month, some/a few times per week, daily/almost daily)

—If you hear sound from wind turbines, how would you describe the sound: tonal, pulsating/throbbing, swishing, whistling, lapping, scratching/squeaking, low frequency, resounding? (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed)

—Have you noticed if sounds from wind turbines sound different at special occasions: when the wind blows from the turbine towards my dwelling, when the wind blows from my dwelling towards the turbine, when the wind is low, when the wind is rather strong, warm summer nights? (less clearly heard, more clearly heard, no differences, do not know)

—Are you annoyed by sound from wind turbines during any of the following activities: relaxing outdoors, barbecue nights, taking a walk, gardening, other outdoor activity? (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed)

—Do you own any wind turbines? (no, yes I own one or more turbines, yes I own shares of wind turbines)

—What is your general opinion on wind turbines? (very positive, positive, neither positive nor negative, negative, very negative)

—Please mark the adjectives that you think are adequate for wind turbines: efficient, inefficient, environmentally friendly, harmful to the environment, unnecessary, necessary, ugly, beautiful, inviting, threatening, natural, unnatural, annoying, blends in.[1]

[1]Developed by Karin Hammarlund, Department of Human and Economic Geography, Göteborg University, Sweden, and used with her permission.

Ackermann, T., and Söder, L. (2000). "Wind energy technology and current status—a review," Renew. Sustain. Energy Rev. 4, 315–374.

Altman, D. G. (1991). *Practical Statistics for Medical Research* (Chapman & Hall, London).

American Wind Energy Association (2004). *Global wind energy market report 2004*, http://www.awea.org/pubs/documents/globalmarket2004.pdf (last viewed online 15 June, 2004).

Arlinger, S., and Gustafsson, H.-Å. (1988). "Hur ett ljudband med konstant ljudnivå maskerar ett brusband med periodiskt varierande ljudnivå" ("How a broadband noise with constant sound pressure level masks a broadband with periodically varying sound pressure levels"), Department of Technical Audiology, Linköping University, Sweden.

Björkman, M. (2004). "Long time measurements of noise from wind turbines," J. Sound Vib. 277, 567–572

Fidell, S. (2003). "The Schultz curve 25 years later: A research perspective," J. Acoust. Soc. Am. 144, 3007–3015.

Fidell, S., 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.

Hubbard, H. H., Grosveld, F. W., and Shepherd, K. P. (1983). "Noise characteristics of large wind turbine generators," Noise Control Eng. J. 21, 21–29.

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.

Kastka, J., and Hangartner, M. (1986). "Machen hässlichen Strassen den Verkehrlärm lästiger" ("Do ugly streets make traffic noise more annoying?"), Arcus 1, 23–29.

Lercher, P. (1996). "Environmental noise and health: an integrated research perspective," Environ. Int. 22, 117–128.

Lowson, M. V. (1996). "Aerodynamic noise of wind turbines," in *Proceedings of Internoise*, 30 July–2 August, Liverpool, England, pp. 479–484.

Matsumura, Y., and Rylander, R. (1991). "Noise sensitivity and road traffic annoyance in a population sample," J. Sound Vib. 151, 415–419.

Miedema, H. M. E., and Oudshoorn, C. G. M. (2001). "Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals," Environ. Health Perspect. 109, 409–416.

Miedema, H. M. E., and Vos, H. (1998). "Exposure–response relationships for transportation noise," J. Acoust. Soc. Am. 104, 3432–3445.

Miedema, H. M. E., and Vos, H. (1999). "Demographic and attitudinal factors that modify annoyance from transportation noise," J. Acoust. Soc. Am. 105, 3336–3344.

Miller, M. B. (1995). "Coefficient alpha: a basic introduction from the perspectives of classical test theory and structural equation modeling," Struct. Eq. Model. 2, 255–273.

Nagelkerke, N. J. D. (1991). "A note on the general definition of the coefficient of determination," Biometrika 78, 691–692.

Öhrström, E. (2004). "Longitudinal surveys on effects of changes in road traffic noise-annoyance, activity disturbances, and psycho-social well-being," J. Acoust. Soc. Am. 145, 719–729.

Pedersen, E. (2000). "Störningsupplevelser från vindkraft, förstudie" ("Experience of annoyance from wind turbines, a pilot study"), Halmstad University, Sweden.

Pedersen, T. H., and Nielsen, K. S. (1994). "Genvirkning af støj fra vindmøller" ("Annoyance by noise from wind turbines"), Report 150, DELTA Acoustic & Vibration, Lydtekniske Institut, Copenhagen, Denmark.

Persson Waye, K., and Agge, A. (2000). "Experimental quantification of annoyance to unpleasant and pleasant wind turbine sounds," in *Proceedings of Internoise*, 27–30 August, Nice, France, pp. 3994–3997.

Persson Waye, K., and Öhrström, E. (2002). "Psycho-acoustic characters of relevance for annoyance of wind turbine noise," J. Sound Vib. 250, 65–73.

Persson Waye, K., Öhrström, E., and Björkman, M. (1998). "Sounds from wind turbines–can they be made more pleasant?" in *Proceedings of 7th International Congress on Noise as a Public Health Problem*, 22–26 November, Sydney, Australia, pp. 531–534.

Persson Waye K., Agge, A., and Björkman M. (2000). "Pleasant and unpleasant characteristics in wind turbine sounds," in *Proceedings of Internoise*, 27–30 August, Nice, France, pp. 2327–2330.

Rand, M., and Clarke, A. (1990). "The environmental and community impacts of wind energy in the UK," Wind Eng. 14, 319–330.

Schultz, T. J. (1978). "Synthesis of social surveys on noise annoyance," J. Acoust. Soc. Am. 64, 377–405.

Swedish Environmental Protection Agency (2001). "Ljud från vindkraftverk" ("Noise from wind turbines"), Report 6241, Stockholm, Sweden.

Viollon, S., Lavandier, C., and Drake, C. (2002). "Influence of visual setting on sound ratings in an urban environment," Appl. Acoust. 63, 493–511.

Wagner, S., Bareiss, R., and Guidati, G. (1996). "Wind turbine noise," EUR 16823 (Springer).

Watts, G., Chinn, L., and Godfrey, N. (1999). "The effects of vegetation on the perception of traffic noise," Appl. Acoust. 56, 39–56.

Weinstein, N. D. (1980). "Individual differences in critical tendencies and noise annoyance," J. Sound Vib. 68, 241–248.

Wolsink, M., Sprengers, M., Keuper, A., Pedersen, T. H., and Westra, C. A. (1993). "Annoyance from wind turbine noise on sixteen sites in three countries," *European Community Wind Energy Conference*, 8–12 March, Lübeck, Travemünde, Germany, pp. 273–276.

NOISE RADIATION FROM WIND TURBINES INSTALLED NEAR HOMES: EFFECTS ON HEALTH

With an annotated review of the research and related issues

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Contents

Note: This paper limits its discussion to wind turbines taller than 50m or from 0.75MW up to 2MW installed capacity.

Section 1.0 ABSTRACT

Wind turbines are large industrial structures that create obtrusive environmental noise pollution when built too close to dwellings. This annotated review of evidence and research by experts considers the impact of industrial-scale wind turbines suffered by those living nearby. First, the paper includes the comments by some of the families affected by wind turbines, as well as coverage in news media internationally. The experiences described put a human face to the science of acoustics.

Second, the paper reviews research articles within the field of acoustics concerning the acoustic properties of wind turbines and noise. The acoustic characteristics of wind turbines are complex and in combination produce acoustic radiation. Next, the paper reviews the health effects that may result from the acoustic radiation caused by wind turbines, as well as the health effects from noise, because the symptoms parallel one another. Primarily, the consequent health response includes sleep deprivation and the problems that ensue as a result. In addition, this paper reviews articles that report research about the body's response not only to the audible noise, but also to the inaudible components of noise that can adversely affect the body's physiology. Research points to a causal link between unwanted sound and sleep deprivation and stress, i.e., whole body physiologic responses.

These injuries are considered in the context of Human Rights, where it is contended that the environmental noise pollution destroys a person's effective enjoyment of right to respect for home and private life, a violation of Article 8 of the European Court of Human Rights Act. Furthermore, the paper considers the consequent devaluation of a dwelling as a measure of part of the damage that arises when wind turbines are sited too close to a dwelling, causing acoustic radiation and consequent adverse health responses.

The review concludes that a safe buffer zone of at least 2km should exist between family dwellings and industrial wind turbines of up to 2MW installed capacity, with greater separation for a wind turbine greater than 2MW installed capacity.

Section 2.0 INTRODUCTION

1 Industrial wind turbines produce an intermittent flow of electricity but in the process also produce undesirable noise emissions when installed too close to people's homes, causing environmental noise pollution. (See Section 6.5 of this paper.)

2 Wind turbines located at a sensible distance from dwellings are unlikely to cause environmental noise pollution and health problems. When the State allows priority to commercial interests, the reasonable needs of families and their human rights are extinguished. There are questions of human rights and of industrial and governmental ethics when developers construct wind turbines too close to dwellings, especially when Government decision makers are fully aware that there is a high probability that families may lose the right of respect for their home and private life. In such instances, both the commercial groups and the State are party to the violation.

3 This Review seeks to bring together research evidence in the professional literature that addresses the substantive nature of the problem, both from the acoustical and biomedical perspectives. However, the Review would be incomplete without Section 3, Overview of the Problems – Personal Perspectives, which includes the observations and reflections by those living near wind turbines, as well as reports in the media. The Review also considers the possible infringement of human rights when developers build wind turbines in close proximity to dwellings.

4 Precision in predicting noise levels in homes neighbouring wind turbines has so far eluded the wind industry. As early as 1987, Glegg, Baxter, and Glendinning reported on the problems with predicting noise accurately:

> *'This paper describes a broadband noise prediction scheme for wind turbines. The source mechanisms included in the method are unsteady lift noise, unsteady thickness noise, trailing edge noise and the noise from separated flow ... [In] spite of these detailed predictions of the atmospheric boundary layer the noise predictions are 10dB below the measured levels ... [The upwind] support tower cannot be ignored, since significant acoustic scattering occurs when the rotor blade is close to the tower. This can be very important subjectively and so a theoretical model has been developed which allows for the increase in radiation due to this effect.'* [Glegg SAL, Baxter SM, and Glendinning AG. The prediction of broadband noise from wind turbines. Journal of sound and vibration 1987; 118(2): 217-39, pp 217-218]

5 In a recent (2006) Report the Dti found further studies of wind turbine noise were necessary:

> *'However, the presence of aerodynamic modulation which is greater than that originally foreseen by the authors of ETSU-R-97, particularly during the night hours, can result in internal wind farm noise levels which are audible and which may provoke an adverse reaction from a listener ... To take account of periods when aerodynamic modulation is a clearly audible feature within the incident noise, it is recommended that a means to assess and apply a correction the incident noise is developed.'* [Dti Executive

Summary of the Measurement of Low Frequency Noise at Three UK Wind Farms, contract number W/45/00656/00/00, URN number 06/1412, Contractor: Hayes McKenzie Partnership Ltd, 2006.]

The report states that '... *it may be appropriate to re-visit the issue of aerodynamic modulation and a means by which it should be assessed.*' [p 65]

6 The wind energy industry and its consultants – acoustical engineers – claim that the audible and inaudible noise effects have minimal consequence on humans and that infrasound (0Hz – 20Hz, part of the low frequency noise spectrum), is inaudible and weak and therefore not a human health risk. This review has not found any epidemiological evidence to support these suppositions.

7 As more wind turbines are installed near homes, more communities are affected by these complex sounds. Noise is the human face of the science of sound, and physicians are seeing the results. More people living close to wind turbines – within 1.5km – complain of sleep deprivation, headaches, dizziness, unsteadiness, nausea, exhaustion, mood problems, and inability to concentrate.

Physicians and researchers in the UK, Portugal, Germany, the USA, Australia, and New Zealand, among others, have observed a similar constellation of symptoms.

8 Although acousticians and engineers working for the wind energy industry conclude that audible noise and low frequency noise from wind turbines are unlikely to cause health effects, experts in biomedical research have drawn different conclusions.

9 Indeed, in 2006, the French National Academy of Medicine issued a report that concludes:

'The harmful effects of sound related wind turbines are insufficiently assessed ... 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 ... The sounds emitted by the blades being low frequency, which therefore travel easily and vary according to the wind, ... constitute a permanent risk for the people exposed to them ... An investigation conducted by the Ddass [Direction Departementale des Affaires Sanitaires et Sociales] in Saint-Crepin (Charent-Maritime) revealed that sound levels 1 km from an installation occasionally exceeded allowable limits.'

The report continues:

'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.'
[Chouard C-H. Le retentissement du fonctionnement des eoliennes sur la sante de l'homme (Repercussions of wind turbine operations on human health). Panorama du Medecin, 20 March 2006]

10 Warning signs of future problems with new technologies have been overlooked or ignored in the past, much to the detriment of the public's health. One has only to look at the history of asbestos and mesothelioma; tobacco and lung cancer and chronic pulmonary diseases; thalidomide and birth defects; mercury and neurotoxicity; x-rays and fluoroscopes and cancer; lead-based paint and childhood poisoning; and coal miners and black lung, to name but a few. The pattern of medical problems took time to emerge before a pattern of health complaints were observed, followed by epidemiologic studies and public health policy.

11 Human health effects may take years to emerge as a pattern, when the detrimental effects are past correction. As the numbers of wind turbine installations close to people's homes increase, reports of health effects have escalated, from sites across the globe. These problems do not appear to be present where wind turbines are located at a safe distance from homes.

12 This paper brings together research evidence on the characteristics of noise radiated by wind turbines and how that noise affects human health. As this is a public health issue, this paper also presents the advice and policy recommendations of medical and epidemiological experts.

This paper also considers whether as a result of reported health problems, the noise emission components of wind turbines should be regarded as an environmental noise pollution, which is a violation of basic Human Rights.

Section 3.0 OVERVIEW OF THE PROBLEMS: Personal Perspectives

***'Britain should be considerably quieter than it is ... unless something is done the situation will soon become intolerable.'* [The *Times*, London, 3 July 1963]**

1 This section of the paper, perhaps more than any other, illustrates that noise is the human face of the science of acoustics. This section presents that essential – but often ignored – side of the equation: the voices of those directly affected by the construction of wind turbines near their homes.

2 In 1966, Dr Alan Bell observed that noise is much more than an occupational hazard:

> *'Noise is a sensory input, devoid of information, that nevertheless demands attention ... it is a public nuisance and a danger to mental and physical health ... The degree of annoyance is not necessarily directly related to the intensity of the sound ... The factors influencing community responses included lack of sleep ... The results of past lack of forethought are aggravated by situations still developing that will certainly create noise problems in years to come ... Even rural peace is often shattered.'* [Bell, A. Noise: an occupational hazard and public nuisance. Geneva: World Health Organization, 1966.]

3 Both the European and British Wind Energy Associations, in their Best Practice Guidelines, state that:

> ***'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.'***

4 But these are only industry guidelines. Planning Policy Statement 22, section 22, says that:

> *'Renewable technologies may generate small increases in noise levels (whether from machinery such as aerodynamic noise from wind turbines, or from associated sources – for example, traffic).*
>
> ***Local planning authorities should ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels.***
>
> *Plans may include criteria that set out the minimum separation distances between different types of renewable energy projects and existing developments. The 1997 report by ETSU* [ETSU-R-97, The assessment and rating of noise from wind farms] *for the Dti should be used to assess and rate noise from wind energy development.'*

5 This guidance is scrupulously followed by wind turbine developers and Planning decision makers. Section 4.0 of this paper, Acoustics, addresses the limitations of ETSU-R-97; yet it is interesting to note here that the standards in ETSU-R-97 appear to provide less protection to people than the standards of the World Health Organisation *Guidelines for Community Noise 1999.*

6 ETSU-R-97 and subsequent policies based on that document fail to protect families living near wind turbines, as the following illustrates:

For a fortnight beginning 12 January 2004, complainants and witnesses gave evidence about their experiences living near the Askam, Cumbria, UK, wind turbines. These wind turbines are rather modest compared to the larger turbines of today: seven wind turbines, each 62.5m high.

Prior to the construction, the developers had assured the community that wind turbines near their homes would not create noise or visual disturbances. Background noise prior to the wind farm was as low as 16.5 dB, with a nighttime average of about 19 dB. The readings are now regularly in the middle to high 40's dB.

> *'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.'* [Brierley D., *Public Presentation,* Askam, Cumbria, 2006]

7 On seeking assistance from the local Council, the Askam residents were then informed that *'because of the court case of **Gillingham v Medway Council**, the classification of the area had changed with the passing of the planning permission'.* That is, the area where the wind turbines were built had been reclassified as a mixed rural/industrial area; local residents were unaware of this reclassification.

Consequently, their expectations of noise levels were considered *'unrealistically high'* for an industrialised area, according to the local authority. [Brierley, 2006]

8 Indeed, when the Askam residents brought a case against the developer PowerGen (E.oN), the judge eventually ruled against the residents, saying that ***"audibility and annoyance are not to be equated with nuisance."*** [Brierley D., *Public Presentation,* Askam, Cumbria, 2006]

9 The following are excerpts of statements of only a few who have lived near wind turbine installations. Some of these families have consequently moved home because they felt it impossible to enjoy a normal family life by remaining.

It is important to remember that some of these statements were written or presented several years after living with the daily, or nearly daily, intrusions of noise and/or shadow flicker / strobing caused by wind turbines.

Please note: In respect for the residents' confidentiality, the authors are identifying the families by number rather than by name.

10 *'Everything changed ... when the wind turbines arrived ... approximately 700 metres away from our property ... At this point we had no idea how this development (windfarm) was to effect [sic] our quality of life and cause so much pain and suffering. Within days of the windfarm coming into operation we began to hear a terrible noise, but didn't know, at first, where it was coming from. As it continued we eventually realised the noise originated from the windfarm. We were horrified. Were we the only ones suffering this noise?*

Would this continue for the proposed length of time the windfarm would be there i.e. for the next 20 years? The noise drove us mad. Gave us headaches. Kept us awake at night. Prevented us from having windows and doors open in hot weather, and was extremely disturbing.'
Member of Family 01

Some time after the wind turbines began operation, this resident learned that other people were experiencing the same problems; they attempted to voice their concerns and their distress:

'From that day, until the present, despite telephone calls, letters to, (and liaison meetings with), the owner, the operators, representatives of the Parish Council, the District Council, the local Planning Committee, the Environmental Health Department and our member of Parliament ... nothing has been resolved.'

11 On one occasion, several of the wind turbines were switched off on the morning of one bank holiday, to give this family some relief (this is 4 years on ...), but by evening, the turbines were operational, and the noise returned. This resident's statement continues with an anecdote: one of the wind turbine operators who lived several kilometres from the site said

'... quite openly, that he walked his dog on the foreshore ... and had identified noise from the wind turbines ... over 4 kilometres away from the site.'

Occasionally the family would request that one or more turbines could be switched off so that they could spend time in their garden, but:

'I found it beyond belief that after almost 4 years we still had to ask for time to work in our own garden and even then to be restricted to 4-5 hours.'
Member of Family 01

12 Other witnesses said that even without a view of the turbines, there is an audible impact:

'I cannot come to terms with the thought of this situation continuing for another 15 years. From our property we cannot see any of the turbines, but we can certainly hear them.' **Member of Family 02**

'They were noisy immediately, blades "whooshing" around ... if the wind is from the East, or the South, the noise is horrendous. You can't get away from the noise, where can you go? It's all around outside and you get it inside the house as well. It's worst during the night, I have to "bed hop" to get any sleep ... but it doesn't work ... This noise is like a washing machine that's gone wrong. It's whooshing, drumming, constant drumming, noise. It is agitating. It is frustrating. It is annoying. It wears you down. You can't sleep at night and you can't concentrate during the day ... It just goes on and on ... It's torture ... [4 years later] *You just don't get a full night's sleep and when you drop off it is always disturbed and only like "cat napping". You then get up, tired, agitated and depressed and it makes you short-tempered ... Our lives are hell.'* **Member of Family 03**

13 One resident near the wind farm, a mechanical engineer and his family, accepted the developer's assurance that the turbines would not be a noise nuisance. However, when the wind turbines became operational, they began to experience problems with noise. Following this, they then discovered that other families had similar problems. The developer denied that any problem existed:

> *'The wind farm was described as "inaudible", which clearly wasn't true. They also denied the existence of upwind noise, a fact they later retracted and admitted did exist ... at one of these meetings Mr ---, of ---, said ... that his company was not prepared to take any action to reduce or eliminate'* the phenomenon of shadow flicker. *'Throughout the negotiations with the developer's side, it has been disappointing to encounter the amount of "stonewalling" and intimidation, which culminated in the threat of legal action against us, when our sole intention was to remedy the problems inflicted on us by the presence of the wind farm, which caused the various nuisances.'* **Member of Family 04**

14 Another family living near the wind turbines, who had also been reassured by the developer prior to the installation that noise would not be a nuisance, did indeed experience a 'noise nuisance' when the turbines became operational. At a meeting, a representative of the developer, when asked about the problems with noise, especially after assurances that noise would not be a problem at this site, responded:

> *'... no wind farm was "inaudible". I suggested that any further correspondence publicising wind farms in general should, in future, be correctly worded and not mislead the general public in this way ... everything we were complaining about was being aggressively fought against by the developers ... My personal feeling is that the residents have been let down by all the parties involved, but specifically by the Environmental Health Department's apparent inability to resolve what is a genuine and distressing sequence of noise nuisances that have gone on now for over 4 years.'* **Member of Family 05**

15 Yet another resident living near the wind turbines, although not visible from his home, found the noise from the turbines disturbing, especially when the wind prevails from the East, which is frequent:

> *'It was like the Chinese water torture, it was constant pulsating noise. I also had to move bedrooms on occasions in an attempt to escape the noise. It's a feeling as much as a noise ... It's an irritating and tiring noise, especially when you have not had any sleep because of it.'* **Member of Family 06**

16 The litany continues: One resident, with many years work experience of oil and gas exploration, development, and production, including work as a consultant internationally, questioned the wisdom of installing wind turbines near homes. It was not the technology to which he objected. However, he felt reassured by the developer that the wind turbines would not create a nuisance, and that the developer would safeguard their 'continuing quality of life':

> *'It is not necessarily the noise level per se, but the nature of this noise. It may not be constant. It has lasted some 10 – 12 days without respite, with varying intensity such that even when not present you are waiting for it to re-occur.*

The most apt description is that it is an audio version of the Chinese Water Torture. The noise is such that the noise is felt as much as heard ... Developers have been informed ... that this noise is making people ill, although I have no experience of this. This, I believe, may be attributable to the low frequency element of noise created by the wind farm. This phenomenon is documented in a report published by DEFRA, where wind farms are confirmed as a source of low frequency noise.'
Member of Family 07

This particular resident was 'appalled' when the signatory of the developer's letter assuring the community that the wind turbines, when operational, would not create a noise nuisance, later admitted to him privately, that:

'There is noise with all wind farms. It is to be expected and you have to live with it.'

'This confirmed my worst fears that the residents had been misled ...'

17 Apparently, the developer eventually provided attempts at noise mitigation:

'This, I believe, is an admission that noise problems exist ... the developers want to dictate the times of day, duration and location of the residencies [sic] that will and will not be affected by noise emanating from their wind farm. This is entirely contrary to the [developer's] letter and the BWEA and EWEA guidelines ... It is also contrary to the EHO's mission statement as publicly depicted on their web site.' **Member of Family 07**

18 And from a farming family:

'The noise is a big "Whooshing" noise ... I hear it inside my home ... If I sit in the garden it's there, not always as it depends really on the wind direction and if the wind is from the west side of my property it is worse ... I am not against wind energy, but these are definitely in the wrong place. If only someone had come and looked at it or even if they came today, they would realise what I am trying to say.' **Member of Family 08**

19 One family has since moved away; their home was 680m from the nearest wind turbine.

Another family that has since moved away lived 700m from the nearest wind turbine.

Another family is moving away; they live 800m from the nearest turbine.

Of the other witnesses, distances from the nearest turbines range from 600m to 1000m. One resident, who lives 390 m away, sleeps with the radio on, but this person declined to testify.

20 In a paper known as "The Darmstadt Manifesto", published in September 1998 by the German Academic Initiative Group, and endorsed by more than 100 university professors in Germany, the German experience with wind turbines is described in graphic terms:

'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 frequencies below the normal audible limit].'

21 In Bradworthy, North Devon, UK, noise complaints lodged to the local environmental health officer after three wind turbines – each 85m high – became operational in 2005, are still unresolved. One resident, who lives as near as 533m to these three turbines, endures

'strobe or shadow flicker entering my Kitchen, Conservatory and Sitting room, all on the East side, when the sun rises in the east, in Autumn and Winter behind the wind turbines. This will last for three months and is NOT ACCEPTABLE ... The prolonged flicker causes a headache, affects my eyes and causes disorientation.'

This resident has observed and described the noise at various times of day, in all weather conditions, and rarely is there a lull in the noise, which is characterised, depending upon the strength and direction of the wind, as swooshing, swishing, whining, a constant aeroplane drone, a police siren, and like a spin dryer.

'That shadow flicker would cause problems was denied 3 times in the planning appeal book.' [MH, Bradworthy]

Yet, the developer's Planning Appeal stated:

'Shadow Flicker. As previously stated, this is not considered an issue due to the distance and orientation of the turbines to the nearest dwelling.'

Instead, this property owner explains that the shadow flicker *'actually reaches past my property and over a public highway ... 500 metres away is too close.'* [MH, Bradworthy]

22 In a letter to the *Western Morning News*, 16 October 2001, Patrick and Phoebe Lockett, of Wadebridge, Cornwall, UK, wrote:

'We live near the Bears Down windfarm in North Cornwall, where there are 16 turbines between 750 and 1400 metres from our home, and we are subjected to intrusive noise. When the wind direction is south to south-westerly, there is a rhythmic thumping sound which disturbs us and our neighbours, in our homes and gardens, day and night.

We are writing to residents in the areas of North Devon where there are proposed wind farm developments, advising them not to take reassurances from developers at face value.

I quote from a letter we received in October 1998 from National Wind Power's head of operations and technology, John Warren:

"We are 100 per cent confident that there will be no noise problem at any nearby residence."

NWP say that they do not know why the turbines are making this noise. They are monitoring it and tell us they will try some experimental adjustments to the turbine blades. Our only hope is that NWP's investigations will provide a solution to the distressing situation in which we and our neighbours find ourselves.'

23 Two years later, in a letter to the Western Morning News on 15 November 2003, Phoebe Lockett wrote:

> *'We are still experiencing noise problems with the turbines on Bears Down.'*

24 *The Courier-Mail* (Queensland, Australia) reported on 4 October 2005, that a Queensland government-owned wind farm, which began operating in 2000, was creating sleep disturbances and noise problems at nearby properties. Jim and Dot Newman said:

> *'... the throbbing, thumping noise from the generators could be heard at all hours of the day. It was very frustrating in the beginning and makes us extremely upset, but there is nothing we can do about it.'*

After a year, the couple decided to move, but could not find a buyer for their property. The newspaper reported that:

> *'A number of Victorian residents know exactly how the Newmans feel and are equally angry at Stanwell Corporation.'*

Stanwell had assured residents that they would not be disturbed by the turbines.

With two 60m towers standing 750m and 810m from their homes, Keith and Terry Hurst said:

> *'It was terrible, we had real trouble sleeping and the worst part was we decided to move and it took 18 months to sell the place.' In a 'booming' property market, they lost money selling their house. One real estate agent said that 'it was nearly impossible to sell a property within one kilometre of a wind turbine or a proposed wind turbine.'*

25 Stanwell's spokesperson said that:

> ***'... independent experts and noise level monitoring had verified the Toora Wind Farm [as] fully compliant with its operating permit conditions.'*** (Gregg N. Wind energy not resident-friendly. The Courier-Mail, Queensland, Australia, 4 October 2005.)

26 A common thread runs through these observations by those who live near wind turbines: It is not necessarily only the loudness of the noise; it is also the character of the noise that is disturbing. The wind turbine noise is periodic; intermittent; 'whooshing' or 'swishing'; it interferes with outdoor activities at one's home and with sleep or studying, i.e., it severely disrupts normal family life.

As one of those living near the wind farm in Askam observed:

'You think "Oh it's stopped" – then it starts up again.'
(Member of Family 09)

27 In New Zealand, a man may be forced from his home because noise from wind turbines will make his house 'uninhabitable'. After 20 years, it is understandable he is reluctant to leave. However, the nearest of the planned twelve turbines is only 500m from his boundary, and the decibel levels will exceed those allowable, according to the state-owned power company's representatives.

28 In 2005, a family living near the Te Apiti wind farm in New Zealand, had to move house because noise and vibration *'made it impossible for them to stay'*. [http://stuff.co.nz : *Turitea man fears he'll have to go.* 10 November 2006]

Indeed, those living near the Te Apiti wind turbines have first-hand experience with those problems:

'... 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.'

At another time,

"... 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," said Wendy Brock.

29 According to Meridian, the developer:

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

And another Meridian spokesperson, Alan Seay, said that:

'... the monitoring has shown quite clearly they were well within the guidelines.'
[Flurry of complaints after wind change. TV1 News, New Zealand, 25 July 2005, http://tvnz.co.nz/view/page/411749/599657]

30 In Nova Scotia, Canada, one family and one wind farm developer have drawn different conclusions from similar noise readings at the family's home. Although the family insists that the noise from the 17 wind turbines – the closest is 400m from their home – has affected their well-being, the developer does not acknowledge any deleterious effects on the family. [Keller J. Nova Scotians flee home, blame vibrations from 17 turbines for loss of sleep, headaches. Canadian Press, 13 November 2006, http://thestar.com]

The d'Entremont family complained of noise and low frequency vibrations in their house after the wind turbines began operation in May 2005. The inaudible noise deprived his family of sleep, gave his children and wife headaches, and *'made it impossible for them to concentrate'*. They now live nearby; if they return to their home, the symptoms return.

31 *'But a study released this month by the federal natural resources department, which oversees funding for wind farm projects, found no problems with low-frequency noise, also known as infrasound.'*

The government report concludes that the measurements:

'indicate sound at infrasonic frequencies below typical thresholds of perception; infrasound is not an issue'.

The developer says he was not surprised by the report's findings:

'It essentially says that there's no issue whatsoever with infrasound.'

32 D'Etremont hired his own consultant to record the noise levels at his home:

'Gordon Whitehead, a retired audiologist with twenty years of experience at Dalhousie University in Halifax conducted tests.'

Whitehead's data was similar to that of the government's report. However, as a health professional, Whitehead reaches a different conclusion:

'They're viewing it from the standpoint of an engineer; I'm viewing it from the standpoint of an audiologist who works with ears ... The report should read that (the sound) is well below the auditory threshold for perception. ***In other words, it's quiet enough that people would not be able to hear it. But that doesn't mean that people would not be able to perceive it.'***

Whitehead explains that

'... low-frequency noise can affect the balance system of the ear, leading to a range of symptoms including nausea, dizziness and vision problems. It's not perceptible to the ear but it is perceptible. It's perceptible to people with very sensitive balance mechanisms and that's generally people who get very easily seasick.'

33 The developer has acknowledged that some questions remain:

'From our perspective, I think it's really up to the scientific community to really address and research such issues (as low-frequency noise) ... I know there is research that points to different directions.' [Keller J. Nova Scotians flee home, blame vibrations from 17 turbines for loss of sleep, headaches. Canadian Press, 13 November 2006, http://thestar.com]

34 In a newspaper article describing the d'Etremonts' situation and the wind power company's position, Michael Sharpe, a Dalhousie University audiologist, said that:

'Even if someone isn't affected directly by low-frequency noise, the constant swoosh of the blades, even at allowable levels, can have psychological effects.

"If the sound is audible and it annoys you, then it can seem louder," says Sharpe who compares it to a dripping tap that can keep someone awake at night.

"As your stress level increases, your awareness of the annoying sound increases as well. As we know, elevated stress levels for a prolonged period of time can have a negative health effect."' [Keller J. Turbines stir up debate. *The Chronicle Herald*, Halifax, Nova Scotia 21 May 2006.]

35 The d'Etremonts are unable to sell their home because of the wind farm. [Keller J. Nova Scotians flee home, blame vibrations from 17 turbines for loss of sleep, headaches. *Canadian Press*, 13 November 2006 http://thestar.com]

36 Dr Robert Larivee, a Professor of Chemistry who lives 3000m east of twenty wind turbines – commissioned in 2003 – in Meyersdale, Somerset County, Pennsylvania, USA, wrote to his County Commissioners (2005) after an acoustician measured noise at his property that rose to 75 dB.

> *'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 ...'*

Dr Larivee quotes the US Environmental Protection Agency, which says that

> *'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.'* [Letter from Dr Robert Larivee, Meyersdale, Pennsylvania, USA, to the County Commissioners http://www.pbase.com/wp/image/39285457]

37 Another resident of Meyersdale, who lives less than one mile from the twenty wind turbines, wrote a lengthy letter on 7 March 2006 to 'Interested Parties'. Karen Ervin felt she had to *'share the realities and impacts'* of living near a wind turbine facility. She calls her situation the "**Human Experimental Factor**", as the community deals with *'the multiple nuisances and issues'* affecting her family, her neighbours, and local adjacent property owners during the two years the wind turbines have been operating:

> *'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 ...'*

> *'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. During the summer months, we cannot have our windows open ...'*

> *'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.'

Noise is not the only problem: flicker and 'strobing' are also nuisances. Ms Ervin concludes her letter with this observation:

> *'This industry without stringent regulations can be truly labelled 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.'* [Letter, Karen Ervin, Meyersdale, Pennsylvania, USA, 7 March 2006, www.pbase.com/wp/image/39285457]

38 Yet another resident living near the Meyersdale wind turbine facility, Mr Rodger Hutzell, Jr, and his family 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 [sic] to get back to sleep due to the threshing sounds produced by the wind turbines.'* [Letter, Rodger A Hutzell, Jr, Meyersdale, Pennsylvania USA, 13 February 2005, www.pbase.com/wp/image/39285457]

39 In Mackinaw City, Michigan, USA, wind turbines rise 325 feet high, visible from nearby homes. Kelly Alexander's home is ¼ mile away from the nearest turbine. Initially Mr Alexander was in favour of the turbines, especially after the developer's assurances that the wind turbines would not be noisy. Flicker is also a problem, but this was never mentioned by the developer to Mr Alexander or the community.

Once the turbines became operational, Alexander heard

> *'a constant humming sound inside his home when the turbines are running, whether the windows are open or not. He said the situation was unliveable and all he wants is for things to be the way they were ...'*

40 **The wind energy company representative said that it *'has lived up to ordinance requirements.'***

Alexander's response was:

> *'Stop lying about these turbines. Tell people the truth.'* [Holland *Sentinel*, 31 December 2002]

41 In September 2002, the Mackinaw *Journal* reported on these turbines. Danny Dann and Kelly Alexander said that the turbines *'were exceeding a 60-decibel noise limit'*, and that ten other immediate neighbours were also concerned about the noise. The Mackinaw City Community Development Director said that they had sought legal advice because they did not have *'anything in our lease agreement to terminate the contract.'*

42 The owner, Bay Windpower, planned to erect at least two more wind turbines in the same area. [McManus S. Turbines still causing a problem, neighbors say. Mackinaw *Journal*, August 29 – September 26, 2002, p 3]

43 In 2004, Dr James LeFanu wrote that *'there have been some interesting comments on the substantial health problems – headaches, anxiety, sleep disturbances'* experienced by those living near wind farms:

> *'The cause seems to be the low-frequency noise generated by the incessant throb of their turbines ("like a concrete mixer in the sky"). "I like to think I know a bit about sound," writes Basil Tate, a recording engineer from Cornwall, "but it always amazes me how my wife can feel low-frequency sounds that are a long way away and be extremely distressed by them." Little wonder that some of those living close to wind farms have been forced to flee their homes.'* [LeFanu J, Dr. In sickness and in health. *Daily Telegraph* 14 March 2004]

44 Unhappily, this is not an exaggeration. Gwen Burkhardt was surprised when Dewi Jones, director of Winjen, which runs Blaen Bowi wind farm in Wales, UK, said:

> ***'There are a lot of wind farms operating in the UK and we haven't come across the complaint before.'*** ['Did turbines make you sick? Journal 18 May 2005, www.thisissouthwales.co.uk]

In her letter to the Journal [1 June 2005], Ms Burkhardt wrote that:

> *'I spoke to you and two of your employees on March 10 this year ... I explained to you in great detail about my own illness which was also brought on by the low frequency sound emitting from the very same turbines.*
>
> *It has caused me and my family a great deal of distress and has resulted in us having to move away from the area where I was born and where we have farmed for the last 27 years. Have you just forgotten our conversation? Do you simply not care? ... I do remember you sympathising with me and also telling me that you would not like to live near the turbines yourself.'* [Burkhardt G. Complaints are not new. *Journal*, 1 June 2005, www.thisissouthwales.co.uk]

45 In July 2005, Mr Murray Barber wrote to inform Energiekontor AG about the noise problems at the Forestmoor wind farm near Bradworthy, Devon, UK. His family's home, located 650m from the nearest of three turbines, is affected especially during calm days when the noise is very audible.

> *'The noise nuisance caused is irritating, distracting, stressful ... We do not understand why it is necessary for all three turbines to be driven at a high speed of rotation in absolute still air.'* [Letter from M Barber to Energiekontor AG, 12 July 2005]

In response, Energiekontor AG informed Mr Barber that:

> ***'The threshold of hearing is considerably lower than these levels, so noise from the turbines will be audible, however, at a level which is considered by the guidelines not to unduly affect amenity.'*** [Letter to M Barber from Energiekontor AG 19 July 2005]

46 In Fenner, New York, USA, when the trees are bare, Wayne Danley's wife 'flees' the living room of their house because of the flicker created by the turbine's rotating blades. Mr Danley lives 900 feet from the nearest wind turbine:

> *'It sounds like a train going through, except the train never comes through ... It's too close.'* [Neighbors complain of wind farm nuisances, The Albuquerque *Tribune*, 28 April 2006]

In response, Marion Trieste, publicist for the Alliance for Clean Energy New York, said:

> ***'There's a lot of misinformation, and a lot of inflamed discussion about negative encroachment.'*** (Neighbors complain of wind farm nuisances, The Albuquerque *Tribune* 28 April 2006)

And according to Laurie Jodziewicz, a policy specialist for the Alliance, **there are 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.'*** (Neighbors complain of wind farm nuisances, The Albuquerque *Tribune* 28 April 2006)

47 Given the sophistication of engineering design computer modelling, one might presume that these effects could be calculated prior to the construction of the wind turbines. However, Mr Danley had it right: the wind turbine was too close. With appropriate planning and distances between homes and wind turbines, these problems would not only be attenuated, they would cease to exist.

> *"It's not there all the time, but you're always waiting for it ... [It's] totally infuriating.'*

The thump-thump-thump 'reverberates up to 22 times a minute,' said Les Nichols, who lives beside a wind farm in Furness, UK. When seeking permission for the seven turbines, the developers *'guaranteed there would be no noise nuisance.'* (Garrett A. Ugly side of wind power. The Observer, Sunday, March 2, 2003)

48 Yet Bruce Allen, a director of Wind Prospect, the management company for the owner, PowerGen Renewables, said that:

> ***'The wind farm "had not breached its planning requirements. It's a subjective thing – like living beside a busy road."'*** (Garrett A. Ugly side of wind power. The Observer, Sunday, March 2, 2003)

Garrett's article continues:

> Giant wind turbines *'planted on your doorstep ... can transform a tranquil neighbourhood overnight into a menacing industrial site ... there are no rules about how close they can be to homes.'*
>
> *'The Welsh Affairs Select Committee recommended they shouldn't be less than 1.5 kilometres (0.93 miles) from any house, but developers generally go as close as between 500 metres (1,640 ft) and 600 metres (1,968 ft) ...'* (Garrett A. Ugly side of wind power. *The Observer*, Sunday, March 2, 2003)

49 As Phoebe Lockett, who lives near the Bears' Down wind farm in Cornwall, UK, wrote in a personal communication:

> *'There seems to be little known of what noise there may be from wind turbines and very few people who have genuine expertise in this area. The planning guidelines and studies carried out beforehand are, in my opinion, of little use.'*
>
> *'Please let me know if I can be of further assistance, as I do not like to think of others having to go through the same distress.'* [Letter, personal communication, 15 November 2003]

50 Eleven wind turbines, 121m high, have been operating in Taurbeg, Cork, Ireland, since February 2006, where residents *'are anything but happy ...'* The noise from the turbines are causing sleepless nights; one resident said the noise was like a *'plane which consistently hovers but never lands.'*

Another resident told the newspaper that *'The thought of another six going up within 500 metres of my front door is just a nightmare ... The noise from the windmills kept everybody in the area awake.'*

There were a number of complaints about the inaccuracies of the photomontages produced by the developer during the application process. Residents also suffer flicker, and one person labelled the result *'visual chaos'*.
[Herlihy M. Windmills 'are a nightmare'. The Corkman, 6 April 2006]

51 In the summer of 2006, eight wind turbines with an installed capacity of 16MW became operational at Deeping St Nicholas, Lincolnshire, UK. The noise from these turbines transformed the lives and the livelihood of the Davis family, living in a farmhouse only 907m from the nearest turbine. Jane and Julian Davis, who farm at Deeping St Nicholas and who learned of the development while reading their local newspaper, did not object to the development. They support wind energy and believe that renewable energy sources are essential to preserving the environment.

Although the Davis family cannot see the wind turbines from their home, the noise – both inside and outside their home, and which also caused vibrations within the structure of their home – has had a deleterious impact on their health and sense of well-being. Prior to the wind farm, they had no problems sleeping through the night. Now, when the wind blows from the southeast or the southwest, the noise from the acoustic radiation seriously disturbs their sleep.

> *'They have spent more than 60 nights in the last six months sleeping at friends' houses', and when home, they 'are existing on less than four hours sleep a night and sometimes a lot less.'* [Couple driven out of home by wind farm. Spalding Today (UK) 21 December 2006]

After taking its own acoustic readings, the local Council confirmed the noise problem, and it is investigating the matter further. [Davis J. Personal communication, 19 January 2007]

Local land agents have told them that their property is 'unsaleable'. Although consultants for the developer are evaluating the issue, and the Dti are investigating wind farm noise, that does not alleviate the impact on the family. [Tasker J. 'Wind farm noise is driving us out of our house.' Farmers Weekly 12 January 2007]

As the noise established itself as an ongoing problem, the Davis family learned that developers had used only predicted levels for their home without taking actual baseline measurements. Indeed, background noise most often measured below 20 dB at night (and usually in the range of 14 dB); now noise in the range of 40 dB occurs when the wind shifts to the southeast or the southwest, and on occasion, the noise has measured over 60 dB. [Personal Communication, 19 January 2007]

Quite generously under these circumstances, the Davis family continue to support wind energy but believe that wind turbines must be sited further from homes because the noise level and the impact of the noise cannot be accurately predicted. Jane Davis says that:

> *'More needs to be done if wind power is to become a viable alternative source of energy. It is a national issue and the Government ought to be doing more about this if we need lots more wind power.'* [Spalding Today (UK) 21 December 2006]

The Environmental Statement that accompanied the developer's application said that there would be no noise. [Davis J. Personal communication, 19 January 2007]

Meanwhile, Jane Davis says that she and her family are literally ***'fighting for our lives.'*** [Personal communication, 19 January 2007]

52 These are the voices and concerns of people who are despairing. However, with civic spirit, they speak out to alert others to the realities of living near wind turbines. As Bell noted in his 1966 report on noise for the World Health Organization:

> *'Anti-noise campaigns serve a useful purpose in focusing public attention on the matter; they provoke discussion and are often a stimulus to positive control measures.'*

53 According to Dr Dilys Davies, consultant clinical psychologist:

> *'Noise problems can lead to ill health'*, leaving the person *'more easily disturbed by noise in the future ... There is pressure on the heart, your breathing and whole arousal system. Your muscles tense as you wait for the noise, and if you are not careful you get used to being in that state constantly ...'* [Aitch, I. Keep It Down. Telegraph, 2 December 2006]

54 Many of those affected by wind turbine noise believe that the developers and decision-makers of the State have misled them. One explanation might be that the methodology for calculating the disturbance levels created by wind turbines at nearby homes is woefully inadequate, concentrating almost entirely on audible sound levels while dismissing other noise characters with a 'penalty in the

condition' [Planning Approval], which has produced unreliable information. The consequent release of noise pollution on people's homes produces sleep deprivation and other health injury, and the adverse effects are entirely avoidable.

There appears to be a total 'disconnect' between the experiences of those living near wind turbines and those who have a commercial interest.

55 The natural commercial instinct of developers is to maximise development potential from land, thereby leaving the minimum distance between turbines and homes. This presumes reliability and certainty in determining the physical impacts on families. However, such reliability and precision in calculating the effects does not exist, as the wind energy industry itself notes in its professional literature. (See Section 4.0, Acoustics, of this paper.)

56 It is too easy to dismiss the reports of noise disturbances and flicker effects by people living near turbines. Yet these problems emanate from many people in many countries, living in varied topographies, with one thing in common: they all live in close proximity to wind turbines.

57 It is somewhat hypocritical of public officials to decry the despoiling of the environment on a global basis, while ignoring the despoiling of the environment – including noise pollution – on a local level. At what point will officials and government agencies respond to these issues that involve the genuine – and avoidable – suffering of those living near wind farms? **At the least, further investigation into the health effects is warranted, with a minimum buffer zone of 2km between the nearest wind turbine and any dwelling.**

Section 4.0 ACOUSTICS

Acoustic Radiation experienced by people living near commercial wind turbines

1 In 2004, a small group met to consider the likely cause of adverse health effects reported by families where developers built wind turbines too close to their homes. Prof James Lovelock, retired NASA scientist and Harvard Medical School; Prof Ralph Katz, Chair, Department of Epidemiology and Health Promotion, New York University; Dr Amanda Harry, physician; and Dr David Coley, acoustician, Exeter University, decided the relationship was most likely to be an acoustic radiation of sound characters, which in combination unbalanced the natural function of the human body.

2 The reason for this is that the human ear responds not only to 'loudness', that is, sound pressure, measured in decibels – dB – with which many people are familiar, but also to sound frequency, measured in Hertz (Hz). [WHO Fact Sheet No 258, 2001]. In addition, sound affects the human body itself; even when a sound is 'inaudible' to the ear, the character of the sound may affect the body.

3 While the wind energy industry seeks to dismiss the adverse health effects reported by families living near wind turbines, there is ample evidence from medical research that noise in diverse circumstances can indeed have a negative impact on health. Noise can induce adverse physical and/or psychological symptoms. The qualities of the symptoms are similar to the complaints of those living near wind turbines. The phenomena may be produced intentionally, e.g., in a laboratory or in a specific instance, or unintentionally by the interaction of technical events, as with wind turbines.

4 Military weaponry exists that relies on low-frequency sound to disperse crowds or control crowd behaviour. [The Cutting Edge: Military Use of Sound, The Toronto Star (Canada), 6 June 2005] The effect of low-frequency noise at high intensities creates discrepancies in the brain, producing disorientation in the body:

> *'The knees buckle, the brain aches, the stomach turns. And suddenly, nobody feels like protesting anymore. The latest weapon in the Israeli army's high-tech tool kit.'*
>
> *'The intention is to disperse crowds with sound pulses that create nausea and dizziness. It has no adverse effects, unless someone is exposed to the sound for hours and hours.'* [The Toronto *Star*, 6 June 2005]

5 Hillel Pratt, a professor of neurobiology specializing in human auditory response at Israel's Technion Institute, said,

> *'It doesn't necessarily have to be a loud sound. The combination of low frequencies at high intensities, for example, can create discrepancies in the inputs to the brain.' Such technologies produce 'simulated sickness'.* [Pratt H. Personal communication, 14 March 2006]

In a subsequent communication, Prof Pratt explained that:

> *'... by stimulating the inner ear, which houses the auditory and vestibular (equilibrium) sensory organs with high intensity acoustic signals* *<u>that are</u>*

BELOW the audible frequencies (less than 20Hz), the vestibular organ can be stimulated and create a discrepancy between inputs from the visual system and somatosensory system (that report stability of the body relative to the surroundings) and the vestibular organ that will erroneously report acceleration (because of the low-frequency, inaudible sound). This will create a sensation similar to sea or motion sickness. Such cases have been reported, and a famous example is workers in a basement with a new air-conditioning system that all got sick because of inaudible low frequency noise from the new system.'
[Pratt H. Personal communication, 15 March 2006]

6 Wind turbines create these unintentional acoustic effects via the confluence of their design and operation. Noise, including low frequency noise, are long-standing issues with wind turbine design and operation. The wind turbine interacts with the topography, meteorology, spatial structure of the site, and with other wind turbines on the site. As an example of this unintentional confluence: Wind turbines produce visual flicker and strobe effects at certain times of the day, an effect similar to driving by a stand of trees when the sun is behind them. Acoustic characters and visual characters can combine and induce body 'disharmony'. Dr Bucha first identified this effect in the 1950s, after he was asked to investigate a series of unexplained helicopter crashes.

7 The pilots surviving the crashes reported feeling fine until the sudden onset of nausea and dizziness. During the episode, pilots lost control of their aircraft. Bucha found that when the blades maintained a rotational rate for sufficient time, the resulting strobe effect of sunlight closely matched human brainwave frequencies. The 'Bucha effect' is a seizure-inducing effect of light flashing in high frequency, similar to epilepsy but without being restricted to a small fraction of the population.

8 In "Present Status of Aeroelasticity of Wind Turbines", a report by Flemming Rasmussen and his colleagues at the Riso National Laboratory, Denmark, the authors observed:

> *"The term aeroelasticity is inherited from aeronautical engineering, and applying this with respect to wind turbines also makes an association to the high level of technology. From this perception the wind turbine is a helicopter. The operation of the flexible rotor in the turbulent atmospheric boundary layer is influenced by the control actions involves many of the same phenomena."* [Rasmussen F; Hartvig Hansen M; Thomsen K; Larsen TJ; Bertagnolio F; Johansen J; Aagaard Madsen H; Bak C; Melchior Hansen A. Present status of aeroelasticity of wind turbines. *Wind Energy* 2003; 6(3):213-228]

9 The military has made use of the combination of visual and acoustic characters to control behaviour. A report of the United States Air Force Institute for National Security Studies identifies and describes numerous non-lethal techniques. Among those that pertain to acoustic and/or optical effects on human physiology, several share characteristics with wind turbine noise and visual effects. [Bunker RJ, ed. Nonlethal Weapons. USAF Institute for National Security Studies, INSS Occasional Paper 15, July 1997].

'Acoustic infrasound: very low frequency sound which can travel long distances and easily penetrate most buildings and vehicles. Transmission of long wavelength sound creates biophysical effects, nausea, loss of bowels, disorientation, vomiting, potential organ damage or death may occur. Superior to ultrasound because it is 'inband', meaning it does not lose its properties when it changes mediums such as air to tissue. By 1972 an infrasound generator had been built in France, which generated waves at 7Hz. When activated it made the people in range sick for hours.'

Techniques include:

a. <u>Bucha effect</u>: high intensity strobe lights that flash at near human brain wave frequency causing vertigo, disorientation and vomiting.

b. <u>Stroboscopic device</u>: devices employed against demonstrators that use stroboscopic flashing; same principle as a discotheque strobe. In the 5 – 15Hz range, these devices can cause various physical symptoms and in a small portion of the population may trigger epileptic seizures.

c. <u>Lag time</u>: The physiological time lag that occurs between the time a stimulus is perceived until the body responds. In a healthy, well-rested human, this takes about three-quarters of a second.

d. <u>Sensory overload</u>: A temporary inability of an organism to correctly interpret and appropriately respond to stimuli because of the volume of the input.

10. Although the military examples use acoustic and visual devices that intensify physiological reactions, the noise and visual effects of wind turbines produce similar physiological reactions. Indeed, the physical complaints of those living near wind turbines share symptoms, though fortunately, not at the levels induced by the military devices. Unfortunately, those individuals living near wind turbines experience the adverse effects without remission. Additionally, military use relies upon high dosage over a short time span. Unintentional occurrence, as with wind turbines, produces a small dose over a long time-span with apparent compounding similar effects.

11. Another example of military use of LFN is called SONAR (SO(und) NA(vigation and R(anging). In *"Navy adapts sonar to protect whales"*, The Sunday Times reported on 26 March 2006, that amid evidence that navy sonar was causing whale and dolphin deaths by confusing them so that they would surface too quickly *'that they suffer fatal attacks of the 'bends'*:

'Navy warships are to be equipped with a £2.5m scanning system to spot marine mammals after post-mortem tests linked the death of beached whales to military sonar.

The use of military sonar appears to interfere with the echo-location system the animals use to navigate, leaving them so disorientated they misjudge depths and swim to the surface too quickly.

The low frequency system will operate at long range and the MOD admits it has the potential to be harmful to marine life. Liz Sandeman, co-founder of

Marine Connection, a conservation group, said, "Low frequency sonar can travel for hundreds of miles, yet the marine animal detection system will only work for two miles".'

12. Following the publication 'Noise annoyance from wind turbines – a review' [Pedersen E, August 2003], Pedersen et al published an article in August 2004, 'Living close to wind turbines – a qualitative approach to a deeper understanding'. [Pedersen E; Persson Waye K; Hallberg LRM. Proceedings of InterNoise2004, Prague, 2004]

    The authors state that:

    a. *'Informants annoyed by wind turbine noise perceived the impact of turbines as a serious intrusion of their privacy. The force of the violation experienced was partly determined by the informants' conception of the living environment as a place where audible and visual impact from wind turbines did not belong. Categories increasing or decreasing the intrusion were experiences of not being believed, being subjected to injustice, lacking influence, and being out of control.'*

    b. *'Surprisingly many respondents reported themselves as annoyed by wind turbine noise at rather low A-weighted sound pressure levels (dB), compared to other sources of community noise such as traffic noise ... One hypothesis is that wind turbine sound has special characteristics such as amplitude modulations that are easily perceived and that could lead to annoyance even at low sound pressure levels (dB). Furthermore, in earlier laboratory studies where noise from different wind turbines were compared, the most annoying noises were predominantly described by the subjects as "swishing", "lapping", and "whistling".'* [Persson Waye K and Ohrstrom E. Psycho-acoustic characters of relevance for annoyance of wind turbine noise. Journal of sound and vibration 2002; 250(1): 65-73]

    c. *'An interesting observation was that other responses due to wind turbines, such as annoyance of shadows from rotor blades, seemed to interact with the noise dose-response relationship indicating that exposure to noise from wind turbines should be studied within its context'.* [Pedersen E and Persson Waye K. Audio-visual reactions to wind turbines. Proceedings of Euronoise 2003; 5th European Conference on Noise Control, May 19-21, 2003, Naples, Italy, 2003]

    d. In describing the results of interviews with the study group living close to wind turbines, the report says that:

       'For some informants, the exposure reached further, not only intruding their home environment but also into themselves, creating a feeling of violation of them as a person. They expressed anger, uneasiness, and tiredness, disclosing being under strain, using a tense voice and sometimes crying when talking about the impact of the wind turbines.'

       To be affected by the turbines to such a high degree, not being able to protect oneself from the intrusion that constantly raised negative emotions was experienced as a serious decline in well-being and life quality.'

13. In their article, 'Aeroacoustics of large wind turbines', Hubbard and Shepherd observe that buildings are affected by noise transmitted by wind turbines:

> *'The transmitted noise is affected by the mass and stiffness characteristics of the structure and its dynamic responses and the dimensions and layouts of the rooms. Minimum noise reductions occur at frequencies near 10Hz, probably because of associated major house structural resonances. This frequency range of low noise reductions unfortunately coincides generally with the frequency range of the intense rotational harmonics.* ***Noises in this low-frequency range will probably not be heard by human observers but may be observed indirectly as a result of noise induced vibrations of the building structure or furnishings.'***
> [Hubbard HH; Shepherd KP. Aeroacoustics of large wind turbines. JASA Journal of the acoustical society of America 1991 June; 89(6): 2496 – 2508, p 2505]

14. In 'Noise induced house vibrations and human perception', Hubbard's research indicates that:

    a. ***'A person inside the house can sense the impingement of noise on the external surfaces of the house by means of the following phenomena: noise transmitted through the structure*** *... vibrations of the primary components of the building such as the floors, walls and windows; the rattling of objects ...'*

    b. Addressing the issue of 'whole body perception', Hubbard refers to the ISO Guidelines and says that a noise level outside a building between 55 – 60 dB (around 0.001 rms) in a frequency range of 0.1 HZ – 80 Hz, is the *'Most sensitive threshold of perception of vibratory motion by humans'*.
    [Hubbard HH. Noise induced house vibrations and human perception. Noise control engineering 1982; 19(2): 49 – 55]

15. In 'Do wind turbines produce significant low frequency sound levels?' [2004], GP van den Berg, observes that:

> *'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 Hz to 10 Hz when the incoming 1/3 octave band sound pressure level is at least approaching 52 dB; 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 750 m distance and further.****'* [van den Berg GP. Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, The Netherlands, 30 August – 1 September 2004. See also Stephens DG; Shepherd KP; Hubbard HH; Grosveld F. Guide to the evaluation of human exposure to noise from large wind turbines. NASA National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia (USA), NASA-TM-83288, March 1, 1982.] [emphasis added]

16. In 2003, the new International Standard for 'Equal Loudness Level Contours' was agreed (ISO 226:2003). In a comparative study with previous curves, Advanced Industrial Science and Technology (AIST) observed:

> *'Between the new and the previous standards, very large differences are recognised up to about 15dB (decibels) for a wide area of frequency region lower than 1KHz (1,000Hz).*
>
> ***A difference of 10dB means a 10 fold difference in sound energy and that of 15dB corresponds to a 30 fold difference (fig 1).'***

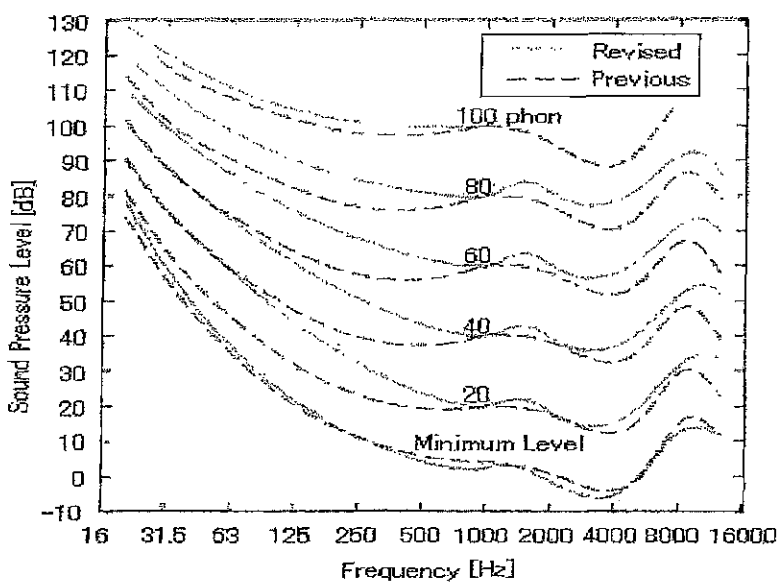


Fig. 1. Comparison between the new and the previous characteristics of equal-loudness-level contours. Remarkable differences are observed in the low frequency range.

Source: AIST. Full revision of International Standards for Equal-Loudness Level Contours (ISO 226), 2003 http://www.aist.go.jp

[Note: The threshold of hearing at about 20 Hz is circa 75dB.]

17. In a report by Dr D Manley and Dr P Styles, "Infrasound Generated by Large Sources", the authors discussed a test conducted near a wind farm in October 1994, using only vibration analysis equipment. Measurements were taken between 0.75 miles and 2 miles downwind of the wind farm at the same elevation:

> *'Wind speed was about 20 knots, and it was possible to hear turbines with a characteristic 'beat' (at about 0.8Hz) ...*
>
> *The blade rotation was usually timed at 43 rpm and therefore the main seismic wave is related to the rotational period of the three bladed machine.*
>
> *All three transducers show (from a typical frequency spectra) that there are odd numbered harmonics of the fundamental blade rotation frequency (0.8Hz, 2.4Hz and 4.0Hz being examples).*

In March 1995 experiments were repeated in eight places, in a location 0.75 miles UPWIND of the wind farm, with a 20 knot wind. The speed of turbine blades was visually measured at 43 rpm. The results clearly show a second harmonic (a higher harmonic) spaced 2.15 Hz ...
[Manley DMJP; Styles P. Infrasound generated by large sources. Proceedings of the Institute of Acoustics 1995; 17:239 – 246]

18. Wind turbines radiate noise not only above ground; they also radiate noise below ground. Following his investigations of ground vibration at the Eskdalemuir seismic monitoring facility in Scotland, Professor Peter Styles, in a summary report to the Defence Estate, made these recommendations:

    a. *To 'define an exclusion zone of 10 km within which no windfarm / turbine development is acceptable.'*

    b. *'Between 10 and 50 km the TOTAL permitted windfarm / turbine generated seismic rms amplitude should not exceed 0.25 rms measured at Eskdalemuir' [the recipient].*

    c. *'This is best illustrated with two hypothetical examples:*

        i. *'A single windfarm of 3 (no.) x 1.8 MW turbines located at 15 km from Eskdalemuir will produce a predicted rms amplitude of 0.20 nm.'*

        ii *'A single windfarm of 17 (no.) x 2.5 MW turbines located at 26 km from Eskdalemuir will produce a predicted rms amplitude of 0.11 nm.'*

    d. In the final report, Prof. Styles shows that while at a distance of 17 km from the wind farm, the amplitude might only be 3 nm/sec, **at a distance of only 1.2 km, the amplitude could be 1,800 nm/sec.** The figure indicates that the law of decay of surface seismic signals diminishes in impact with distance. [Styles (Keele University). Summary Report to Defence Estates. 3 March 2004]

19. The July 2005 Report by Prof P Styles, et al, "Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations from Windfarms" commented:

    "When the windfarm starts to generate at low wind speeds, considerable infrasound signals can be detected at all stations out to c 10km. Clear harmonic components which are the second multiple and up of 1.4Hz (the blade passing frequency) can be seen although interestingly and somewhat enigmatically the blade passing frequency itself is not so strongly detected". [p 66]

    "We have clearly shown that both fixed speed and variable speed wind turbines generate low frequency vibrations which are multiples of blade passing frequencies and which can be detected on seismometers buried in the ground at significant distances away from the wind farms even in the presence of significant levels of background seismic noise (many kilometres)." [p 76]

In answer to the question: *"If we have a wind farm of N turbines, how does the seismic amplitude increase as compared to 1 turbine?"*
Answer: *"We have shown it varies as the square root of N and this is to be expected because the turbines are not all in phase and neither are they operating at exactly the same frequency because of the slight possible variations in rotation speed and also wind conditions across the farm. There is also a possible 10% variation in speed (Optislip) which will cause broadening of the spectral peaks. They are quasi-random sources and therefore add as square root of N. Therefore 100 turbines are 10 times as noisy as one, not 100 times."* [p 77]
[Styles P; Stimpson I; Toon S; England R; Wright M. Microseismic and infrasound monitoring of low frequency noise and vibrations from windfarms: recommendations on the siting of windfarms in the vicinity of Eskdalemuir, Scotland. Keele University (UK), Report for the Ministry of Defence, 18 July 2005]

'*The Effect of Windmill Farms on Military Readiness*', a 2006 report by the US Department of Defense for the US Congressional Committees, supports Styles et al for the seismographic methods and devices used to measure low frequency noise and vibration at Eskdalemuir.

However, the Department of Defense report recommends that the United States modify the approach:

'Measurements of seismic noise generated by wind turbines that Styles made must be updated to reflect the increased size of SOA wind turbines.'
(SOA = State Of the Art) [United States Department of Defense. The effect of windmill farms on military readiness. Report to the Congressional Defense Committees. Office of the Director of Defense Research and Engineering, US Department of Defense, 2006, p 62]

20. Moreover, Hubbard and Shepherd ('Aeroacoustics of large wind turbines', 1991) observe in their discussion on Atmospheric Propagation,

'Acoustic refraction that arises from sound-speed gradients associated with atmospheric wind and temperature gradients, can cause non-uniform propagation around a sound source.'

In an *'illustration of the effects of atmospheric refraction, or bending of sound rays, caused by vertical wind sheer gradient over flat homogeneous ground for an elevated point source'*, the rays are bent toward the ground in a downwind direction. That is, the ground can act as a large and effective microphone at low frequencies.

21. The WHO *Guidelines for Community Noise 1999* (S.4.2.1) say that:

"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."
[Authors' note: See also Section 3.51 of this Review]

22. Research by GP van den Berg, of the University of Groningen in the Netherlands, examines how wind turbine sound acts in the environment. In '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], van den Berg writes:

   a. *'Our experience* ***at distances of approximately 700 m 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 changes to clapping, thumping or beating when night falls, like a washing machine.'* (p.14)

   b. *'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 fluctuations 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 approximately 5 dB are common but may reach values up to 9 dB.'* (p.14)

   c. *'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.'* (p.15).

   d. *'The hypothesis that these fluctuations are important, is supported by descriptions of the character of wind turbine sounds as 'lapping', 'swishing', 'clapping', 'beating', or 'like the surf'.'*

   e. *'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'.* [See also Persson Waye et al, "Living close to wind turbines – a qualitative approach to a deeper understanding"] (p.15)

   f. *'Fluctuations with peak levels of 3 – 9 dB above a constant level may have effects on sleep quality.* ***The Dutch Health Council ['Effects of Noise on Sleep and Health', pub. No. 2004/14] 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'.*** [emphasis added]

   g. *'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 [Dutch Health Council]. 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 indoors SEL-values may exceed the threshold level.'* (p15)

23. GP van den Berg concludes:

    a. *'Atmospheric stability has a significant effect on wind turbine sound, especially for modern tall turbines.'* (p 15)

    b. *'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.* [van den Berg GP. Effects of the wind profile at night on wind turbine sound. Journal of sound and vibration 2004; 277 (4-5): 955 – 970]

    c. *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.*

       '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.' (p 15 – 16)

    d. Third, van den Berg notes that *'atmospheric stability involves a decrease in large scale turbulence ... 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.*

       Sound level differences ($L_{A\,max} - L_{Amin}$) (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 the time and may less often be as high as 8 to 9 dB. This level difference did not decrease with distance, but even increased 1dB when distance to the wind farm rose from 400 m to 1,500 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.' (p.16)

24. In 2001, Casella Stanger produced "Low frequency Noise", a report for DEFRA (Technical Research Support for Defra Noise programme). Section 4 addresses the 'Possible Effects of LFN':

    'As with any noise, reported effects include annoyance, stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep.

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 frequencies. For example the chest wall can resonate at frequencies of about 50 to 100Hz and the head at 20 to 30Hz.' [S.4.1]

25. In the U.K., decision-makers are guided by the State according to Planning Policy Statement 22 (2004).

    PPS 22 'Noise' states:

    *"The 1997 report by ETSU-R-97 for the Dti **should** be used to assess and rate noise from wind energy developments."* [emphasis added]

    (Note: "should" is not a command statement.)

26. There were 14 Members of the ETSU-R-97 Noise Working Group (NWG), including the Chairman from the Dti. Nearly 60% were either from Power companies involved in wind farm schemes, wind energy trade associations, or specialist advisors to wind farm developers. [Preface, p. i]

    Indeed, the following statement appears in the introduction to ETSU-R-97:
    "While the Dti facilitated the establishment of this Noise Working Group this report is not a report of Government and should not be thought of in any way as replacing the advice contained with relevant Government guidance." [Preface p.i]

27. ETSU-R-97 states in its Executive Summary that:
    a. *"This document describes a framework for the measurement of wind farm noise and gives indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, **without placing unreasonable restrictions on wind farm development** or adding unduly to the costs and administration burdens on wind farm developers or local authorities."* [emphasis added] [Summary S. 1]

    b. *"The NWG ... wind farms are usually sited in the more rural areas of the UK where enjoyment of the external environment can be as important as the environment within the home."* (Summary S. 3)

    c. *" The NWG considers that absolute noise limits applied at all wind speeds are not suited to wind farms in typical UK locations and that limits set relative to the background noise are more appropriate in the majority of cases."* [Summary, S.8]

    d. *"The **recommendation** of the NWG is that, generally the noise limits should be set relative to the existing background noise at nearest noise-sensitive properties ... We have considered whether the low noise limits which this could imply in particularly quiet areas are appropriate and have concluded that it is not necessary to use a margin above background approach in such low-noise environments. **This would be unduly restrictive on developments** ..."* (emphasis added) [Summary S.11]

    e. *Separate noise limits should apply for day-time and for night-time. The reason for this is that during the night the protection of external amenity* *becomes less important **and emphasis should be on preventing sleep disturbance.** Day-time noise limits will be derived from background noise data taken during quiet periods of the day and similarly the night-time limits will be derived from background noise data during the night"* (night-time is defined as 11pm-7pm)

f. *"The NWG recommends that the fixed limit for night-time is 43 dB(A). This is derived from the 35 dB(A) sleep disturbance criteria referred to in PPG24. An allowance of 10 dB(A) has been made for attenuation through an open window (free-field to internal) and 2dB subtracted to account for the use of LA90.10min rather than LAeq.10min."* [Summary S.23]

g. *"Lower limit"*
*Applying the margin above background approach to some of the very quiet areas in the UK would imply setting noise limits down to say 25 – 30 dB(A) based upon background levels perhaps as low as 20 – 25 dB(A). **Limits of this level would prove very restrictive on the development of wind energy.** As demonstrated below, it is not necessary to restrict wind turbine noise below certain lower fixed limits in order to provide reasonable degree of protection of the amenity."* (emphasis added)

28. In contrast, two years after ETSU-R-97, the WHO *Guidelines for Community Noise 1999* set tighter maximum permitted levels for community noise, yet ETSU-R-97, page 20 refers to *"the WHO document Environmental Health Criteria 12 – WHO 1980(14).* Clearly, ETSU-R-97 does not reflect the latest World Health Organisation *Guidelines for Community Noise.*

29. Independent experts researched and wrote the WHO Guidelines for Community Noise 1999. In brief, the Guidelines state:

"In these Guidelines for Community noise only guideline values are presented. These are essentially values for the onset of health effects from noise exposure." (5th paragraph S. 4.1)

"For each environment and situation, the guideline values take into consideration the identified health effects and are set, based on the lower levels of noise that effect health (critical health effects). (6th paragraph S. 4.1)

"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 45dB LAmax for single sound events. Lower levels may be annoying, depending on the nature of the noise source,..." (S 4.3.1 & see also S 3.3 sleep disturbance)

"Thus when assessing the effects of environmental noise on its people it is relevant to consider the importance of the background noise level, the number of events, and noise exposure level independently." (3rd paragraph S 4.1)

"Most problems occur at lower frequencies, where most environmental noise sources produce relatively high sound pressure levels." (S 2.6)

"If 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." (S 4.3)

"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 pulsating sensation can be more disturbing than continuous noise. (Bradley 1994b). Research suggests that variations at about 4 per second are more disturbing (Zwicker 1989)." (3rd paragraph S 2.3.2)

"At night sound pressure levels at the outside facade 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."*

30. It may seem that 15dB is a high level of attenuation through the external envelope especially for timber-framed buildings and high glazed areas. However, the guideline for the onset of sleep deprivation is 30dB, reduced if low frequency noise characters are present and further reduced if throbbing/pulsating characters are present – both of which are present for wind turbine noise. This lower figure represents a new base level to which is added the noise attenuation factor for the external envelope, with a window partially open, to give the outside façade level.

    [Note: the 30dB max for a bedroom is a continuous maximum noise level, which is substantially different to the ETSU-R-97 guideline that allows 5dB above background noise.]

31. The importance of an 'in the bedroom at night maximum level' is emphasised by the findings of GP van den Berg. Van den Berg's research reveals that [van den Berg GP. *Effects of the wind profile at night on wind turbine sound.* Journal of sound and vibration 2004; 277(4-5): 955-970]:

    '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 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.'*

32. During stormy weather, the background wind noise sometimes disturbs sleep, but to suffer wind turbine noise in addition (as per ETSU-R-97) is likely to make sleep intermittent if not impossible.

'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.)"* [WHO Guidelines for Community Noise 1999, S.3.8, The effects of combined noise sources]

33. In assessing how a level of below 30 dB is achieved (WHO S. 4.3.1 & S. 3.3), allowance must be made for a window to be open in order to provide ventilation, especially in warm weather. In addition, the sound reduction index of the external wall is only part of the consideration. The construction of the ceiling might only be a 15mm sheet of plaster, some thermal insulation (not sound insulation), a paper-thin vapour barrier, and thin roofing slate. The transmission loss through the ceiling or roof is slight.

'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.' [WHO Guidelines for Community Noise 1999, S.3.9, 'The effects of combined noise sources'.]

'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 LA_{eq} 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 LA_{eq}. These values are based on annoyance studies, ***but most countries in Europe have adopted 40dB LA_{eq} as the maximum allowable level for new developments (Gottlob 1995). Indeed the lower level should be considered the maximum allowable sound pressure level for all new developments whenever feasible.'*** (WHO S.4.3.1.)

34. It should be noted that:

   a The 30 dB LAeq is not variable with external weather conditions – it is a fixed level regardless of external weather conditions and external background noise.

   b The nature of the pulsating beat of the wind turbine, together with probable ground vibration, and the low frequency noise character, are clear reasons to support a lower level than 30 dB LAeq, especially at night.

   c WHO *Guidelines for Community Noise 1999* does not provide for measurements limited to background noise plus 5 dB as per ETSU-R-97, but clearly states that noise in a bedroom above 30 dB causes sleep disturbance.

d It is possible to conceive of a position where a lightly constructed dwelling with minimal sound transmission loss between bedroom ceiling and the external wall is subjected to an external wall sound of 45 dBA at night. If the WHO 30dBA maximum bedroom level is applied but reduced to reflect the pulsating character and the low frequency character, the actual measurement inside the bedroom, with the window open for ventilation, will be only marginally less than 45 d BA, potentially creating a 15 dBA excess of sound **which is a staggering 30 fold difference in sound energy.** (See S. 4.18 & S. 4.40 of this review.)

35. The WHO Guidelines for Community Noise 1999 are shown on the following chart:

Table 1: Guideline values for community noise in specific environments:
WHO *Guidelines for Community Noise 1999*

Specific Environment	Critical Health Effects	LAeq [dB(A)]	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 Inside bedrooms	Speech intelligibility & moderate annoyance, daytime & evening Sleep disturbance, night-time	35 30	16 8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School classrooms & 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	as low as possible		

The WHO *Guidelines for Community Noise 1999* also examine the acoustic measurement of sound:

'The A – weighting (dBA) is most commonly used and is intended to approximate the frequency response to our hearing system ... C – weighting (dBC) is also quite common and is nearly a 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 measured noise.' (WHO S.2.1.2)

'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 (of 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.'* (WHO S.4.3)

36. In August 2006, the Dti (UK) published 'The Measurement of Low Frequency Noise at Three UK Wind Farms' [Report for Dti by Hayes McKenzie Partnership Ltd].The report measured LFN at three wind farm sites in the UK, and although unidentified in the report, these sites are believed to be:

    Site 1: Askam, Cumbria 7 x 0.66 MW wind turbines of 4.62 MW installed capacity, built 1999.

    Site 2: Bears Down, Cornwall 16 x 0.6 MW of 9.62 MW installed capacity, built September 2001.

    Site 3: Blaen Bowi, Carmarthenshire 3 x 1.3 MW of 3.9 MW installed capacity, built July 2002.

37. For the purpose of its Report, the Dti defined low frequency noise sources as between 20 – 250 Hz [S.1.3]. The Dti stated: *'Infrasound is noise at frequencies below the normal range of human hearing, i.e., less than 20 Hz.'* [S.1.2] The report stated that *'noise sources associated with these frequencies are generated by unsteady loading of the wind turbine blade.'*

Hubbard and Shepherd also make this observation. Their paper, 'Wind turbine acoustics' [NASA Technical Paper 3057, 1990, p 2496], considered three upwind and four downwind turbines. The upwind MODS.B and WWG-0600 machines measured between 60 dB – 70 dB below 20 Hz [p 2499; p 2502].

38. The Dti Report supports the Hubbard and Shepherd measurement of upwind machines:

'Measurements of infrasound [below 20 Hz] in the vicinity of wind farms, and confirmed within this study, indicate typical sound pressure levels between 1 – 10 Hz of 60 – 80 dB, which falls well below the normal environmental infrasound levels experienced by all humans.' [p 12]

39. The Dti Report observes:

'The common cause of complaints associated with wind turbine noise at all three wind farms is not associated with low frequency noise, but is the audible modulation of the aerodynamic noise, especially at night.' [p 3]

In the Report, the Dti does not provide evidence to support this statement as the sole cause of complaints. There is little doubt that audible modulation is a contributory cause, but as Professor James Lovelock, Professor Ralph Katz, Dr Amanda Harry, and Dr David Coley suggested, the "common cause" will be the acoustic radiation of sound characters of which a cocktail strikes the human body, the responses mainly being of a physiological (biologic/medical) nature, producing both short-term and long-term effects.

40. Section 2.10 of this Review noted several examples of public health concerns that emerged only after time, when a pattern of human exposure and adverse response could be observed, e.g., as reflected by the public health history with tobacco, mercury, asbestos, and thalidomide. It is therefore unsafe for the Dti to conclude that there is no environmental noise pollution from wind turbines without first conducting an independent acoustic and epidemiologic assessment.

41. The Dti Report uses the word *"perception"* and as this does not appear to be defined, one has to presume the authors are referring to *"perception of the auditory system"*, i.e., whether a sound is audible. The WHO *Guidelines for Community Noise 1999* states in S.2.1.6:

"Sound is a sensory perception evoked by physiological process in the auditory brain." [That is, the process of 'perceiving' sound is a biologic/ physiologic process.]

42. The Dti Report Conclusions [August 2006] state, on page 66:

"Community Noise, WHO 'there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects."

The Dti report repeats this quotation on pages 2, 10, 46 and 66. However, this quotation is taken from the ***WHO Community Noise Paper 1995*** **and does not appear in the final document of 1999.**

In fact, the WHO *Guidelines for Community Noise 1999* clearly states in Section 3.8:

"The evidence on low frequency noise is sufficiently strong to warrant immediate concern."

"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)."

43. Other conclusions of the Dti Report on page 66 include:

> *"Infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range."* (Below 20Hz)

There is significant medical evidence that infrasound is perceived by other organs in the human torso with negative health responses. (See Section 5, Health Effects, in this Review). The Dti Report measured at Site 2, Appendix 6C, levels of 40 – 50 dB between 10Hz-20Hz. The UKNA survey (S.4.52) measured 70dB below 20Hz on three wind farms. Both measurements are inaudible to the auditory brain (the ear), yet may medically have an impact on body organs.

44. Another conclusion from the Dti Report on page 66 states:

> *"It may therefore be concluded that infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to health of a wind farm neighbour."*

There is no substantive epidemiological or physiological evidence in the Dti Report to support this conclusion.

The Dti Report does not address the physiological or biological responses of the human body. Acousticians – with experience working as consultants to the wind industry – produced the Dti report, and as acousticians, they focus on acoustic analysis, identifying the sound power levels [dB] down to around the threshold of audibility.

45. The Dti Report considered the 'individual thresholds of hearing', observing that:

> *'Measurements of the equal-loudness contours at frequencies below 20 Hz have been investigated by Moller and Andresen, and Whittle et al.'* (p. 26)

In a comparison of the results of these studies, the '*measurements indicate good agreement between the two papers and indicate a continuing tendency for the contours to become closer as the frequency reduces. Therefore,* ***in the infrasonic range, an increase of the sound pressure level by 10 dB may be perceived as an 8 – 16 fold increase in loudness as compared to a doubling, 2 fold increase at 1 kHz [1,000 Hz]. The result of this change in perceived loudness with change in sound pressure level in the low frequency region is that small changes in the pressure level may be experienced as a large change in perceived loudness."*** [emphasis added] [Moller H; Andresen J. Loudness of pure tones at low and infrasonic frequencies. Journal of low frequency noise and vibration 1984; 3(2): 78 – 87; and Whittle LS; Collins SJ; Robinson DW. The audibility of low frequency sounds. Journal of sound and vibration 1972; 21: 431 – 448]

*'**Therefore, when infrasound and low frequency are of sufficient level to be detected, then a small change in pressure level above this threshold will quickly become perceived as a large change in loudness which may be considered unacceptable.** The experience of the low frequency sufferers within the Salford Study* [Proposed criteria for the assessment of low frequency noise disturbance. Report for Defra by Dr Andy Moorhouse et al, February 2005] *indicated that once the subject has been 'sensitised' to low frequency noise, then only a small increase in pressure level above the hearing threshold is required to be considered unacceptable.'* [Dti S.3.3, p. 27]

46. The Dti Report compares the difference in sound power level (dB) at infrasound frequency, between downwind and upwind wind turbines:

> *'Infrasound noise emissions were identified within a paper by Shepherd and Hubbard* [Physical characteristics and perception of low frequency noise from wind turbines. Noise control engineering journal 1991 Jan/Feb; 36(1): 5 – 15] *which provided field data from a number of upwind and downwind rotor configuration wind turbines. The generation of blade passage frequency (BPF) energy and associated harmonics were found to be more dominant for downwind rotor configurations. This was due to the effect of the supporting tower wake interaction as the blade passed behind the tower and would experience a sudden and significant change to the airflow.'* [Dti S.5, p 32]

However, if one refers to Hubbard and Shepherd's '*Aeroacoustics of Large Wind Turbines*' [JASA Journal of the Acoustical Society of America 1991, figure 8, p 2499], the upwind wind turbines show a similar noise spectra, indicating sound pressure levels (dB) between 60 – 70 dB in the 1Hz – 20 Hz range. This compares with the Dti Report on upwind machines of between 50 – 60 dB in the 6 – 20 Hz range.

47. The Dti Report refers to infrasound noise immissions:

> *'The measured data indicates that wind turbines do increase the level of infrasound acoustic energy within the environment but that this energy is below the perception threshold.'* [Dti p 36]

While the Dti Report provides evidence to support the view that the sound pressure level (dB) when below 20 Hz is below the threshold of audibility, the report provides no evidence to support the view that the noise is below the threshold of human perception. Indeed, a purely acoustics report cannot provide evidence in that regard, because humans are physiologically affected by inaudible sound. Inaudible sound affects not only humans, but also animals; e.g., animals retreated from the coastal areas of the tsunami that devastated parts of Asia in 2004, and sonar can affect whales and dolphins. [Mott M. Did animals sense tsunami was coming? National Geographic News, 4 January 2005. See also Section 4.11 of this paper.]

48. In identifying complaints from the three wind turbine sites where measurements were taken, the Dti Report noted: (pages 56-57)

> *'In general, the occupants of Site 1: Location 1 and Site 3: Locations 1 & 2, have described wind farm noise as being most intrusive within the dwellings during the night-time or early morning periods. The occupants have also indicated that the amplitude modulation of the aerodynamic noise is a character that draws their attention to the noise and which makes it readily identifiable when heard within an internal living space. The levels of external noise when the wind farms were considered to give rise to audible noise within the dwellings and specifically identified by the occupants ranged as follows:*

Site 1 Location 1: 38.5 – 41.0 dB LAeq 10 min : 36.3 – 38.7 LA90, 10 min

Site 2 Location 1: 37.5 – 40.2 dB LAeq 10 min : 36.2 – 38.1 LA90, 10 min

Site 3 Location 1: 40.4 – 45.5 dB LAeq 10 min : 39.0 – 39.8 LA90, 10 min

> *'Irrespective of the existing background noise level at the time of the measurements, the external noise levels associated with the operation of the wind turbines meet the requirements of ETSU-R-97 for night-time operations'* – the greater of 43 dB L_{A90} (or background + 5 dB) – *'i.e., noise levels are lower than 43 dB L_{A90}. This level provides protection against the awakening of an occupant, based upon the recordings, where no occupant was noted to awaken due to noise associated with the operation of the wind turbine.'*

> *'Measured internal noise levels for the same measurement periods detailed above are as follows:* (page 60)

Site 1 Location 1: 22.7 – 24.6 L_{Aeq} 10 min : 21.8 – 22.5 dB L_{A90}, 10 min

Site 2 Location 1: 27.6 – 36.7 L_{Aeq} 10 min : 25.9 – 30.1 dB L_{A90}, 10 min

Site 3 Location 1: 42.5 – 53.1 L_{Aeq} 10 min : 41.6 – 42.0 dB L_{A90}, 10 min

Site 1, location 1 is within a double glazed conservatory with no windows open.

Site 2, location 1, is within a room with windows open.

Site 3, location 1, is within a room with windows open with the internal measurement location having a direct line of sight down to the stream in the valley below and the microphone placed within 0.3 m of the open window.'

[Authors' note: Compliance with the noise limits based on ETSU-R-97 does not imply that there will be no significant noise impact on local residents.]

49. The following are further examples of measurements forming part of the Dti report Appendix:

For example, Site 1, measurements taken on 16 May 2005, are within the frequency range of 10 Hz – 20 Hz, an L_{eq} dB of between 40 dB – 45 dB 'Low frequency noise audibility external façade', location 1:00:00 – 1:02:35 (figures 1 and 32).

For example, Site 2 measurements taken on 14 June 2006, '*Low frequency noise audibility internal before windows open*', an L_{eq} dB within the frequency range of 10 Hz – 20 Hz of between 40 – 45 dB was measured, Location 1:21:00 – 1:21:15 (figures 1 and 4).

50. This, however, portrays just a small part of the picture. To be useful, all wind turbine acoustic measurements should include the following information. This is because the rotation speed of the blades can be controlled remotely, especially when a noise management scheme is in place. The rotation speed (rpm) has a direct bearing on the noise emission from the wind turbine.

   i. Distance of the measured point from nearest wind turbine;
   ii. Measured point relative to the wind turbines (array impact);
   iii. Wind speed and direction at the hub height;
   iv. Actual revolutions per minute of the blades at the time of measurement – as this does not necessarily correlate to wind speed;
   v. Difference in altitude between the measured point and the wind turbine;
   vi. A definitive description of the terrain; and
   vii. A dB(A) and dB(C) measurement of frequency down to 1 Hz.

51. Referring to Site 1, the Dti report [p 81] comments:

'It should be noted that the description of the noise by the awoken occupant was that the noise was "intolerable". The range in levels in the 400 – 500 Hz third octave bands was measured to lie between 9 – 10 dB and to be 17 dB above the B.S. ISO 226:2003 Threshold Criterion Curve. In this event, ***the perceived change in level in this frequency range would be a doubling of the perceived loudness, with levels potentially rising in and out of the Threshold of Audibility.*** [emphasis added] *This would give rise to a sound of a muffled swish that could be described as a heart beat type sound as the sound may only be audible for part of the time, i.e., as the noise associated with the wind farm is aerodynamic in origin and is associated with the rotation of the blades, then this will appear at 3 times the rotational speed also known as the blade passage frequency (bpf). The turbines operate with a rotational speed of 26 rpm, which equates to a blade passage frequency = 78 bpf. This is in the normal range of a heart beat.'* [p 81]

According to 'Measuring Sound', a publication from Bruel and Kjaer, a company that manufactures acoustical measuring and calibrating equipment used by many researchers and industries, when noise levels are too high and no other means of attenuation has worked or is feasible, then:

'Shut down the offending machinery. In severe cases, this step must be considered. It is also possible to limit the hours of operation.'
[Bruel and Kjaer. Measuring Sound, September 1984 (rev)]

52. In August 2006, the United Kingdom Noise Association (UKNA) published a report by John Stewart, ***'Location, Location, Location'***. This report, believed to be the first produced with input and evidence from both acoustic and medical resources and experts, addresses the cause of the suffering of families when wind turbines have been built too close to their homes:

'Our own conclusion, after reviewing the evidence ... So much depends on the location of the wind farm relative to where people live.'

The UK Noise Association measured noise levels around three wind farms: Bears Down (October 2005) in Cornwall; Bradworthy (December 2005) in Devon; and Blaen Bowi (October 2005) in Wales. (As previously mentioned it is believed that the Dti took its measurements at Bears Down-- its Site 2; and Blaen Bowi – its Site 3.)

53. UKNA summarised its findings of wind turbine noise measured outdoors:

'At 10 Hz, the noise from the wind farms ranged from negligible (upwind from the turbines) to 75 dB (C) (downwind). Because 'Watanabe and Moller' figures are 'G' weighted and the UK Noise Association used 'C' weighting, only approximate comparisons are possible. But these findings are well within the 97 decibels where it would become a noise problem at 10 Hz, whatever the weighting.'

'At 20 Hz, the noise from the wind farms ranged from a low of 10 dB (C) (upwind of the turbines) to a high 82 dB (C) (downwind), with the great majority of the results falling in the 40 – 70 dB (C) range.' [p 14]

54. UKNA also tested for low frequency noise indoors. A house close to the Blaen Bowi wind farm was used (p 15):

"The results we obtained were these:

'At 10 Hz, the noise levels ranged from 44 to 48 decibels, well below the levels at which the noise could be heard. At 20 Hz, the noise levels ranged from 40 to 48 decibels, again well below audible levels. At 60 Hz, the noise levels ranged from 44 to 63 decibels, which suggests that low-frequency noise is being heard at times. At 100 Hz, the decibel levels ranged from 42 to 52 decibels, which indicates that the 'swish' sound is being heard, containing low frequency content.' "

55. The UKNA Report also stated:

<u>On page 19</u>: *'Conclusions on Noise and Health.*

Pedersen's arguments are persuasive that the dancing shadows and the rotating blades can significantly add to the annoyance and stress caused by noise from the turbines. The questions being asked by some in the medical profession as to whether this cocktail of effects – the noise, low frequency, rotating blades, the shadows and the strobing – is leading to ill health out of proportion to the noise turbines make, needs serious examination.'

On page 20 - first conclusion: *'Overall Conclusions.*

> *1. Wind farm noise, in common with noise generally, affects different people in different ways, but the evidence suggests there is rarely a problem for people living more than 1 – 1.5 miles from a turbine.'*

On page 21- first recommendation. *'Overall Recommendations.*

> ***It would be prudent that no wind turbine should be sited closer than 1 mile away from the nearest dwelling.*** *This is the distance the Academy of Medicine in Paris is recommending, certainly for the larger turbines and until further studies are carried out.* ***There may even be occasions where a mile is insufficient depending on the scale and nature of the proposed development.'***

56. The following charts from the UKNA survey confirm the presence of LFN. Using the WHO alternative measure (*Guidelines for Community Noise 1999*, S 2.1.2), *"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."* The difference in two sample readings at Bradworthy (005 & 007), between A and C weighting was 29 and 30 decibels; at Bears Down (05 & 06), the difference was between 25 and 30 decibels; and at Blaen Bowi (005 & 006), the difference was between 26 and 27 decibels.

BRADWORTHY 05 Wind Direction SW speed 9 – 19 MPH Shielded from Wind

Location Hillside Farm SS 294 135

Microphone – 1Hz

Shielded from Direct Wind

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 19:53:13
End Time:	07/12/2005 19:56:20
Elapsed Time:	00:03:07
Bandwidth:	1/3-octave
Max Input Level:	140.50

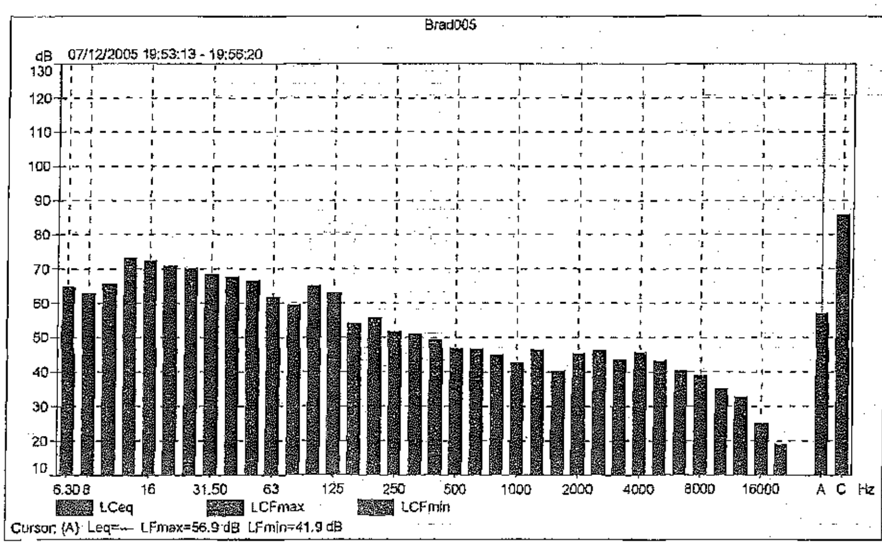
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Brad005 Text

		Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value					0.00	47.7	56.9	41.9
Time		19:53:13	19:56:20	0:03:07				
Date	07/12/2005		07/12/2005					



BRADWORTHY 07 Wind Direction NW speed 9 – 23 MPH Shielded from Wind

Location SS 304 135

Microphone – Normal

Audio File – Track Brad02

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	08/12/2005 11:19:27
End Time:	08/12/2005 11:24:07
Elapsed Time:	00:04:40
Bandwidth:	1/3-octave
Max Input Level:	141.24

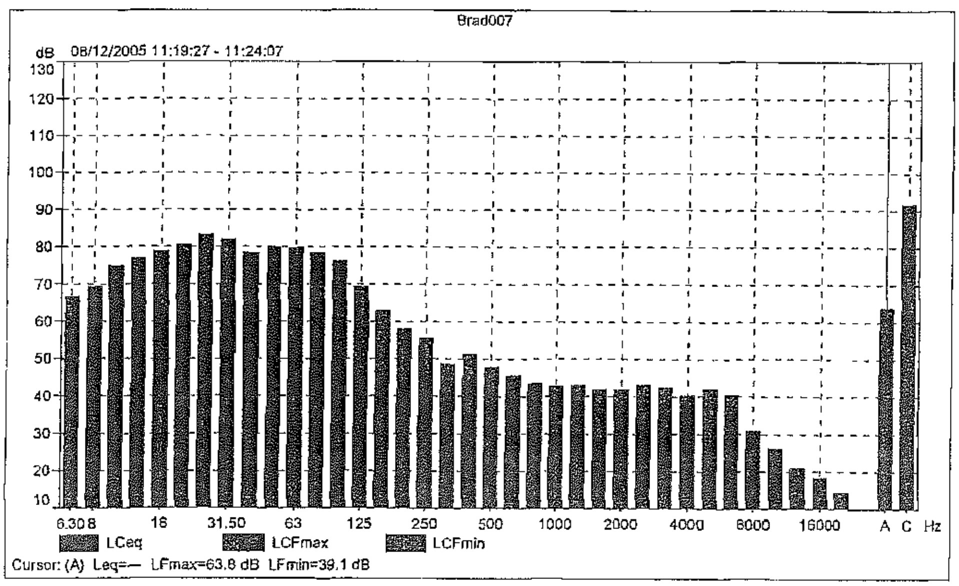
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	08/12/2005 09:45:31
Calibration Type:	External reference
Sensitivity:	48.41 mV/Pa

Brad007 Text

	Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	49.5	63.8	39.1
Time	11:19:27	11:24:07	0:04:40				
Date	08/12/2005	08/12/2005					



BEARSDOWN 05 Location SH 904 685

Wind Speed	12 – 15 MPH
Wind Direction	S
Microphone	Normal

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 15:22:25
End Time:	07/12/2005 15:24:27
Elapsed Time:	00:02:02
Bandwidth:	1/3-octave
Max Input Level:	140.50

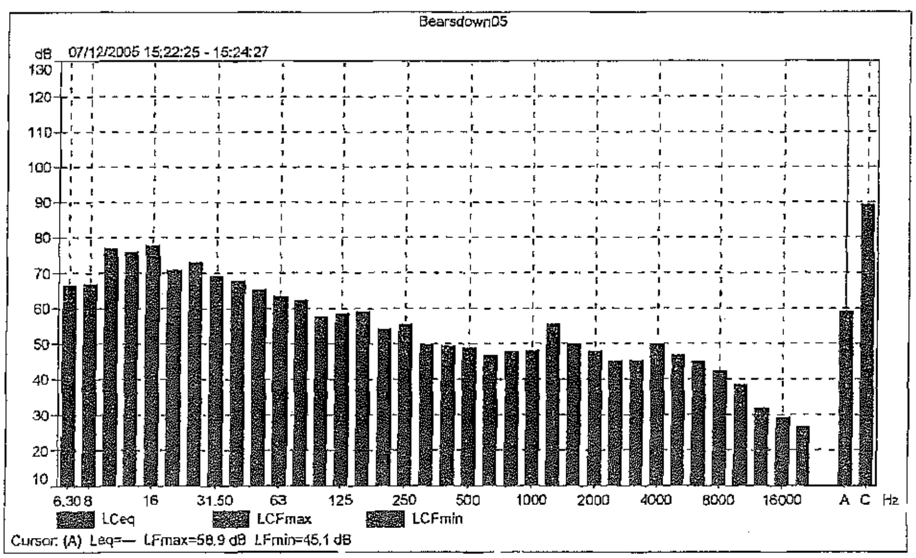
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Bearsdown05 Text

	Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	52.6	58.9	45.1
Time	15:22:25	15:24:27	0:02:02				
Date	07/12/2005	07/12/2005					



BEARSDOWN 06 Location SH 904 685

Wind Speed	10 – 18 MPH
Wind Direction	S
Microphone	1 Hz

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	07/12/2005 15:26:33
End Time:	07/12/2005 15:28:39
Elapsed Time:	00:02:06
Bandwidth:	1/3-octave
Max Input Level:	140.50

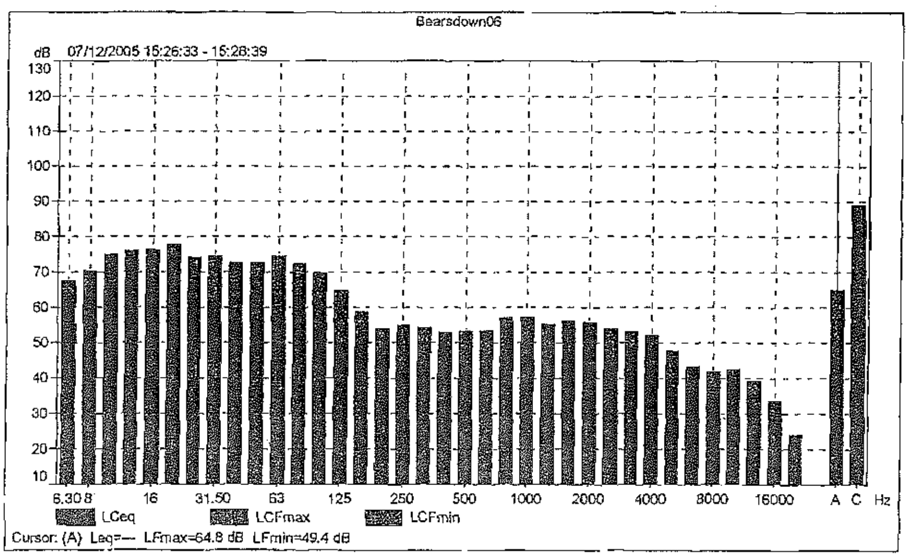
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	None
Sound Field Correction:	Free-field

Calibration Time:	07/12/2005 14:47:11
Calibration Type:	External reference
Sensitivity:	52.78 mV/Pa

Bearsdown06 Text

		Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value					0.00	57.2	64.8	49.4
Time		15:26:33	15:28:39	0:02:06				
Date	07/12/2005		07/12/2005					



BLAEN BOWI 005 No Filter Installed Location SN 32314 BNG 36829

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	01/12/2005 11:55:22
End Time:	01/12/2005 11:57:32
Elapsed Time:	00:02:10
Bandwidth:	1/3-octave
Max Input Level:	140.67

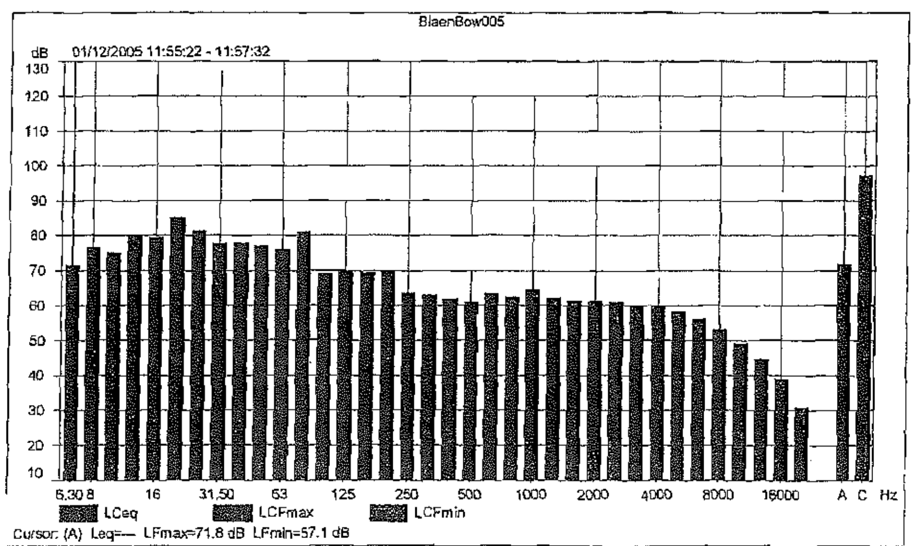
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	01/12/2005 10:12:59
Calibration Type:	External reference
Sensitivity:	51.65 mV/Pa

BlaenBow006 Text

		Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value					0.00	65.4	71.8	57.1
Time		11:55:22	11:57:32	0:02:10				
Date	01/12/2005		01/12/2005					



BLAEN BOWI 006 Location SN 33081 BNG 35867

Wind Speed 17 – 24 mph

Instrument:	2250
Application:	BZ7223 Version 1.2
Start Time:	01/12/2005 11:55:22
End Time:	01/12/2005 11:57:32
Elapsed Time:	00:02:10
Bandwidth:	1/3-octave
Max Input Level:	140.67

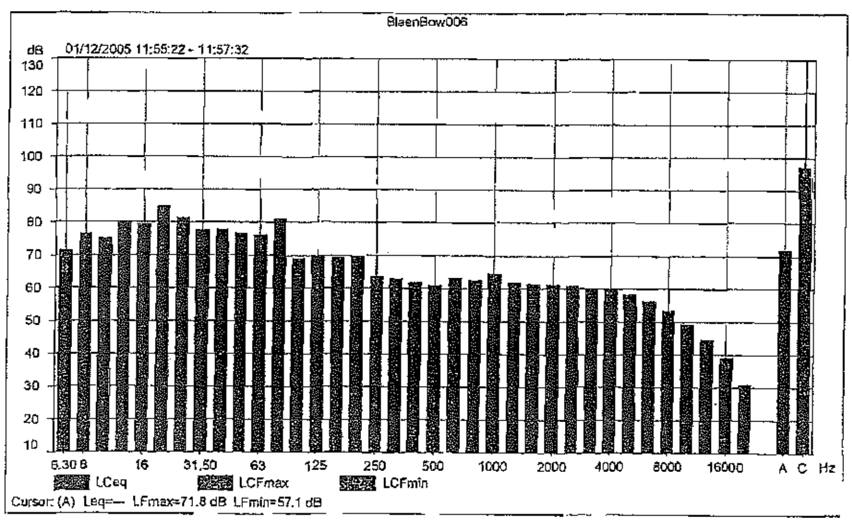
	Time	Frequency	
Broadband (excl. Peak):		FSI	AC
Broadband Peak:		C	
Spectrum:	FS	C	

Instrument Serial Number:	2505941
Microphone Serial Number:	2508682
Input:	Top Socket
Windscreen Correction:	UA 1650
Sound Field Correction:	Free-field

Calibration Time:	01/12/2005 10:12:59
Calibration Type:	External reference
Sensitivity:	51.65 mV/Pa

BlaenBow006 Text

	Start time	End time	Elapsed time	Overload [%]	LAleq [dB]	LAFmax [dB]	LAFmin [dB]
Value				0.00	65.4	71.8	57.1
Time	11:55:22	11:57:32	0:02:10				
Date	01/12/2005	01/12/2005					



57. The following chart is an analysis of low frequency noise from a DAT tape prepared by Delta, consultants for 'Bonus' of a Bonus 1.3MW wind turbine. The chart formed part of "A Report to Vale of the White Horse District Council"(UK) by Dr G Leventhall, March 2004:

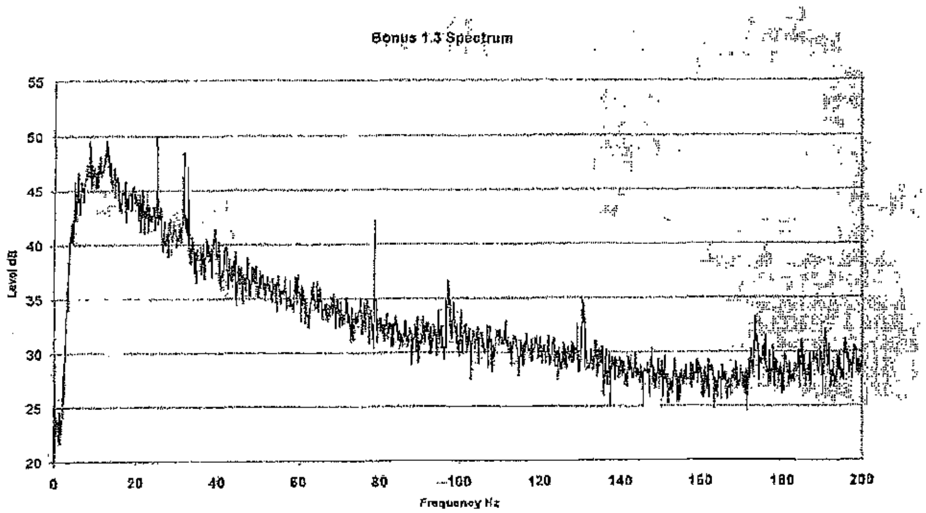


Fig 4. analysis of low frequency noise from the DAT tape of noise from the Bonus 1.3MW wind turbine

It is significant that the noise measurements taken by UKNA correlate with the noise chart in the low frequency noise range, of the Bonus 1.3 MW wind turbine. However, the fall-off at 0Hz – 6Hz is a surprise and may be due to the instrumentation.

58. In a recent publication [Leventhall G. Infrasound from wind turbines – fact, fiction and deception. Canadian acoustics 2006 Jun; 34(2): 29 – 36], Geoffrey Leventhall, acoustician and consultant to Defra and Dti, writes that:

> *'Infrasound from wind turbines is below the audible threshold and of no consequence.'*

However, Leventhall does acknowledge that wind turbine noise can be problematic:

> *'Low frequency noise is normally not a problem, except under conditions of unusually turbulent inflow air.'*
>
> *'Turbulent air inflow conditions cause enhanced levels of low frequency noise, which may be disturbing, but the overriding noise from wind turbines is the fluctuating audible swish ...'*
>
> A wind turbines' main noise source is produced by the *'repeating sound of the blades interacting with the tower. This is the noise which requires attention, both to reduce it and to develop optimum assessment methods.'* [See also section 4.19 of this paper: Report by Styles et al; report by the US Department of Defense]

59. The suitability of using ETSU-R-97 as a guide for reasonableness is challenged by Dick Bowdler in *'ETSU-R-97: Why it is Wrong'* [July 2005]. The Bowdler Report comments:

On page 61 of ETSU-R-97, the Noise Working Group stated that:

> *'During the night one can reasonably expect most people to be indoors and it will not be necessary to control noise to levels below those required to ensure that the restorative process of sleep is not disturbed. A night-time absolute lower limit is therefore appropriate based upon sleep disturbance criteria.'* [ETSU-R-97]

Bowdler counters this assumption by the Noise Working Group [NWG] with the following:

> *'What this says is that a turbine noise level inside peoples' houses of just less than the World Health Organisation say is necessary to get back to sleep if you wake up in the night is satisfactory. It seems to me this must be the very upper limit of acceptability, not one that is well balanced. Since then, the WHO has revised its guidance 5 dB lower. So the ETSU night standard is now higher than WHO say you need to get back to sleep.'* [Bowdler, 3.15]

60. On page 62 of ETSU-R-97, the NWG wrote:

> *'It is also the opinion of the Noise Working Group that there is no need to restrict noise levels below a lower absolute limit of LA90, 10min = 33db(A); if an environment is quiet enough so as not to disturb the process of falling asleep or sleep itself then it ought to be quiet enough for the peaceful enjoyment of one's patio or garden.'* [ETSU-R-97]

Again, this conclusion relies on presumption; Bowdler responds:

> *'This is a bizarre statement. It seems that the 33dBA is the 35dB sleep restoration level set out by the World Health Organisation for inside bedrooms at night. They seem to be saying that there is no need for noise levels during the day to be any lower than is necessary to allow you to go to sleep on your patio on a sunny afternoon.'* [Bowdler, 3.16]
>
> *'Having suggested that 33dB would be satisfactory because people could get to sleep on their patio – they now say that "This level would however be a damaging constraint on the development of wind power in the UK as the large separation distances required to achieve such low noise levels would rule out most potential wind farm sites" [ETSU-R-97]. There is absolutely no evidence brought forward to justify this.* ***A margin of 2km would normally easily achieve this even with the noisier modern turbines.*** *They argue that "Wind farms have global environmental benefits which have to be weighed carefully against the local environment impact" [ETSU-R-97]. So do many other things. They argue that "Wind farms do not operate on still days when the more inactive pastimes (e.g. sunbathing) are likely to take place" [ETSU-R-97]. The suggestion seems to be that the protection of*

people's amenity does not include protecting them whilst sunbathing in their gardens on a slightly windy day or sleeping on the patio.' [Bowdler, 3.17]

'*Then, on page 63 [of ETSU-R-97] there is another leap of credibility: "There is no evidence for or against the assertion that wind farm noise with no audible tones is acceptable up to and including LA90, 10min levels of 40dB(A) even when background noise levels are 30dB or less". This is just nonsense. There most certainly is evidence against this assertion. The 40dB is actually 42dB in BS4142 units. This is at least 12dB above background noise level of "30dB or less" and BS4142 says there are likely to be complaints at turbine levels of plus 10dB. Furthermore there is no argument that BS4142 is not applicable. Even BS4142:1990 (which was current when ETSU-R-97 was written) might easily be applicable here. If the wind speed is 5m/s, the background noise 30dB and the turbine noise 42dB(LAeq) then there is no reason not to use BS4142, it does not exclude itself in these circumstances.* ***This noise level is also 12dB more than (twice as loud as) the WHO considers necessary for you to be able to get to sleep.***' [Bowdler, 3.18]

61. In August 2005, the Renewable Energy Foundation (REF) released a statement that commented on the new report by 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 and Vibration 2005; 24:1-24].

Prof. Ffowcs-Williams, Emeritus Professor of Engineering, Cambridge University, one of the UK's leading acoustical experts and an advisor to REF said [REF Studies on wind turbine noise raise further concerns, 4 August 2005]:

'*Van den Berg's paper adds weight to the criticisms frequently offered of the UK regulations covering wind turbine noise, ETSU-R-97. The regulations are dated and in other ways inadequate. It is known that modern, very tall turbines, do cause problems, and many think the current guidelines fail adequately to protect the public.*"

62. "Wind Energy" (published by John Wiley & Sons), a technical bimonthly journal of wind turbine engineering papers, provides evidence that confirms just how imprecise the forecasting of wind turbine performance is:

a *"Challenges in modelling the unsteady Aerodynamics of wind turbines"* by JG Leishman, Department of Aerospace Engineering, University of Maryland (USA) [Wind Energy 2002;5;85-132]:

"Such problems include the challenges in understanding and predicting the unsteady blade airloads and rotor performance, as well as predicting the dynamic stresses and aeroelastic response of the blades. Wind turbines are also subjected to complicated environmental effects such as atmospheric turbulence, ground boundary layer effects, directional and spatial variations in wind shear, thermal stratification, and the possible effects of an upstream unsteady, bluff body-like wake from support structure (tower shadow).

Fig. 1 [in original document] *summarises the various aerodynamic sources that may affect air loads on a wind turbine, which can be decomposed into a variety of mostly periodic and mostly periodic contributions. The net effect*

is that the wind turbine operates in an adverse unsteady aerodynamic environment that is both hard to define using measurements and also to predict using mathematical models."

b "Survey of modelling methods for wind turbine wakes and wind farms" by A Crespo, J Hernandez, and S Frandsen [Wind Energy 1999;2;1-24]:

"The final report (intensified study of wake effects behind single turbines and in wind power wakes, National Power, London), indicates that the experimental and analytical studies reported (annex) point to significant energy losses in arrays spaced at less than seven turbine diameters. Similarly, turbulence may increase in arrays, sufficiently to cause measurable damage to fatigue and dynamic loads."

[Comment: In these circumstances, noise characters become more clearly pronounced.]

63. Morris et al further explain the difficulties [Morris PJ; Long LN; Brentner KS. An aeroacoustic analysis of wind turbines. American Institute of Aeronautics and Astronautics: AIAA-2004-1184; 42nd AIAA Aerospace Sciences Meeting, 5-8 January 2004, Reno, Nevada, 2004]:

'Since the wind turbine noise problem is very challenging, only some of the important noise sources and mechanisms are being considered [in this particular study]. *These are airfoil self-noise, the effects of blade rotation, and the propagation of sound over large distances.'*

Their research encompasses *'two aspects of airfoil self-noise ... The first is the relatively low frequency noise generated by deep stall and the second is trailing edge noise. The noise associated with blade rotation includes the effects of blade rotation on the blade aerodynamics, incoming gusts, incoming atmospheric turbulence and wind shear.'*

The authors add that:

'Wind turbines have aerodynamic and aeroacoustic behaviors with unique characteristics that make their prediction more challenging in many ways than already complicated aeroacoustic problems such as rotorcraft or propeller noise.'

Some of the challenges are due to the unpredictable and sudden changes in *'blade / inflow / tower wake interactions.'* Moreover, wind turbine flows are complex, moving through *'a varying atmosphere over an irregular terrain'*, with *'the blade speed varies linearly from root to tip'*:

'It would be unrealistic to suggest that all aspects of the wind turbine noise problem could be simulated within the framework of a single aerodynamics/ aeroacoustics code. The computational resources required to perform such a simulation will remain beyond the capabilities of available computers for many years.'

(Note: Interestingly, Morris et al use the permeable surface Ffowcs Williams-Hawkings formulation to couple unsteady flow simulations to the radiated noise field; see item 61 of this section, Acoustics, for Professor Ffowcs Williams's comments on ETSU-R-97.)

The authors further note that:

'While discrete frequency noise is certainly an important component of wind turbine noise (especially at low frequencies), broadband noise sources are also very important (especially at the higher frequencies).'

Additionally:

'However, the sound generated by wind turbines, particularly the low frequency components, may propagate large distances through an unsteady, non-uniform atmosphere over an irregular terrain. Atmospheric absorption can also be significant for the high frequency noise components. Thus, for wind turbine applications, sound propagation is an important component of the complete aeroacoustic problem.'

64. Sezer-Uzol and Long concur with Morris et al and observe that:

'... the acceptance of wind turbines by the public depends strongly on achieving low noise levels in application ... Furthermore, the acoustic propagation is of interest at relatively large distances from the wind turbine.' [Sezer-Uzol N; Long LN. 3-D time-accurate CFD simulations of wind turbine rotor flow fields. American Institute of Aeronautics and Astronautics: AIAA Paper No. 2006-0394, 2006; CFD = Computational Fluid Dynamics]

65. If the measure for setting a noise standard lacks credibility to many professionals, it is understandable why it lacks credibility to those suffering adverse health consequences. If the methodology is inadequate, then an impartial team of experts should redesign the measure. Moreover, until there are newly defined measures that conclusively work beyond reasonable doubt, the old measure should be withdrawn from use immediately and **an immediate minimum 2km zone placed between people's homes and wind turbines.** Greater separation may be necessary in specific circumstances or with a wind turbine of greater than 2MW installed capacity.

66. Moreover, as Paul Schomer noted in 2002 [Schomer PD. For purposes of environmental noise assessment, A-weighting needs to be retired. JASA Journal of the acoustical society of America 2002 Nov; 112(5, pt 2): 2412]:

'... for the purposes of environmental noise assessment, A-weighting needs to be retired ... A-weighting fails to properly assess multiple noise sources ... and it fails to properly assess sound with strong low-frequency content. It performs better outdoors than indoors even though the receivers are indoors. It certainly cannot be used for room noise criteria. A-weighted Leq cannot assess the audibility of sound, and in fact, Leq in fractional octave bands cannot be used to assess the audibility of sounds at low frequencies.'

[See also WHO *Guidelines for Community Noise 1999*, s.1.2 & s.3.9]

Schomer continues:

> *'There are better measures for all of these functions such as loudness-level rating using ISO 226. At low frequencies, data show some people (about one-third) are "C-weighted" listeners. For all noise, it may be that one model just does not fit all. Experiments show that a majority of listeners make categorical judgments and merely count events based on level with the minority of subjects fitting three other models. There are many ways to clearly move forward but we must give up our A-weighting, it has now reached old age.'*

67. According to Berglund et al [Berglund B; Hassmen P; Soames Job RF. Sources and effects of low-frequency noise. JASA Journal of the acoustical society of America 1996 May; 99(5): 2985 – 3002]:

> *'Low frequency noise is common ... 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 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 ... 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 ...* [p 2985]

> *... 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. Definitive solutions to these problems would require unethical exposures to low-frequency noise ... 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 ... The evidence provided ... warrants concerned action without the potentially extremely lengthy delay that may be occasioned by waiting for definitive proof which may never arise.* [p 2998]

68 Noise from wind turbines combines with visual phenomena such as shadow flicker, which compounds the adverse impact on those living nearby. R Bolton, who is president of a company that develops engineering software, observes in his report on shadow flicker:
[Bolton R. Evaluation of Environmental Shadow Flicker Analysis for "Dutch Hill Wind Power Project". Environmental Compliance Alliance, New York, USA, 30 January 2007]

> *'Large scale shadow flicker is a new phenomenon, not experienced by people on an "industrial scale", with football field sized shadows moving across their home or through their local views. As a new source of environmental pollution extra care is needed when evaluating the long term consequences.'*

For example, on elevated ridges with wind turbines that are 400 feet high, the turbines *'will cast shadows for thousands of feet, well above any vegetative screening'*.

Shadow flicker is not only a day-time phenomenon; night-time flicker is also problematic. Conditions for shadow flicker include moon-lit nights, with the rising and setting of the moon. Moreover, ridgeline wind turbines can cast shadows that *'easily extend 2 to 4 miles'*:

> *'Residents and passers-by (highway traffic) not immediately within the shadow will nevertheless readily observe the shadow flicker ...'*

> *'Often numerous wind turbines are sited linearly if placed on a ridgeline and nearby residents will be exposed to numerous shadow flickers simultaneously.'*

That is, all three blades of each wind turbine will create flicker, and the flicker from all the wind turbines will not be synchronised.

According to the UK's Planning Guide for Renewable Energy: a companion guide to PPS22 (2004), *'flicker effects have been proven to occur only within ten rotor diameters of a turbine'*. Meridian Energy, a wind farm developer, recommends that *the 'nearest affected receptors'* to a wind turbine producing shadow flicker, *'should be no closer than 10 turbine rotor diameters'*.

For a wind turbine with a 300-foot rotor diameter, the nearest receptor to shadow flicker should be no closer than 3000 feet.

In New York State (USA), the Department of Environmental Conservation Program Policy provides guidance for the phenomenon of shadow flicker:

> *'A properly sited and designed project is the best way to mitigate potential impacts.'*

The guidance specifies that:

> *'It is the burden of the applicant to provide clear and convincing evidence that the proposed design does not diminish the public enjoyment and appreciation of the qualities of the listed aesthetic resource.'*

Recognising the impact of shadow flicker, the Swedish building authority introduced a rule that the calculation of shadow flicker should be made for the building lot (garden), instead of only the window of a façade.

Bolton concludes that:

> *'... shadow flicker is a serious environmental pollutant that can have significant harmful effects on the welfare of persons subjected to it.*

When coupled with the noise pollution and visual degradation that many residents will be subjected to, it is clear that wind farm turbine setbacks should be increased to a minimum of 3,000 feet from any residence.'
[Bolton R. Evaluation of Environmental Shadow Flicker Analysis for "Dutch Hill Wind Power Project". Environmental Compliance Alliance, New York, USA, 30 January 2007]

69 This Section of the Review, **Acoustics**, provides evidence that the noise radiation from wind turbines is made up of a number of sound characters, which include low frequency noise (0Hz – 200Hz), infrasound (0Hz – 20Hz), vibration, rhythmic pulsation, and tonal qualities. Moreover, the noise combines with visual phenomena, such as strobe effects and shadow flicker, which can act synergistically with the acoustic qualities in the effects on people nearby. A prolonged dose at an appropriate level of any of these characters individually can evoke serious physiological changes in the human body, with health consequences.

Wind turbines emit a cocktail of acoustic characters and are delivered with a rhythmic, pulsating character, all of which can combine to create serious health responses from people if the wind turbines are constructed too close to their dwellings.

The ETSU-R-97 guidelines endorsed by the Dti do not protect families from the sleep deprivation and the consequent health effects where wind turbines are built too close to their homes.

Peter Hadden

Section 5.0 HEALTH EFFECTS

1 Levels of sound, both audible and inaudible (including that in the low frequency range) can have an adverse effect on health, not only psychologically, but also physiologically, with medical consequences. As previously discussed, wind turbines emit noise radiation, both audible and inaudible (including that in the low frequency range). The industry has struggled to accurately predict and control wind turbine noise and its impact on people in nearby dwellings, with inconsistent results. When installed near homes, the noise is not merely a persistent, unremitting nuisance. Whether in the UK, the US, Canada, the Netherlands, Australia, or elsewhere, those living near wind turbines share similar health and medical complaints.

2 Measuring the audibility of noise does not take into consideration that the human body also receives sound characters without the involvement of the auditory system.

3 Merely focusing on audible sound ignores the harmful impacts on human body organs of low frequency noise, vibration, and the whole combination of characters – e.g., pulsations – that act in combination to exacerbate the impact on the body's organs.

4 Acousticians measuring noise near wind turbines do not take into account the physiologic/medical aspects of the effects of noise, as this is not their area of expertise; only those with backgrounds in medicine, the human biologic sciences, and epidemiology can properly study the effects and responses of the human body to wind turbine noise.

5 Moreover, measuring the audibility of a sound, its loudness, and its characteristics does not account for the dose received. Dosimetry is an important part of the equation when considering the effects of noise on human health. Although one may acclimatise to certain noises, wind turbine noise, with its pulsating nature, varying harmonics and low frequency components, does not have a time-limit factor, and continues day after day and year after year, unlike noise at work, e.g., which has a time-limit factor. Because the impact on body organs builds over a long period of time, wind turbine noise is difficult to replicate in laboratory experiments. Moreover, it would be unethical to subject people to extended exposure in the laboratory setting.

6 According to 'Occupational and Community Noise', World Health Organisation Fact Sheet No 258 (February 2001, drawn from the WHO *Guidelines for Community Noise 1999*):

> *'The noise problems of the past are incomparable with those plaguing modern society ... the thumps and whines of industry provide a noisy background to our lives. But such noise can be not only annoying but also damaging to the health, and is increasing with economic development.*
>
> ***Health Impact.*** *The recognition of the noise as a serious health hazard as opposed to a nuisance is a recent development and the health effects of the hazardous noise exposure are now considered to be an increasingly important public health problem.*

- *Prolonged or excessive exposure to noise whether in the community or at work, can cause permanent medical conditions, such as hypertension ... (ref WHO Guidelines p XII).*
- *Noise can adversely affect performance, for example in reading, attentiveness, problem solving and memory. Deficits in performance can lead to accidents (ref WHO Guidelines p XII).*
- *A link between community noise and mental health problems is suggested by the demand for tranquillizers and sleeping pills ...'*

7 The WHO fact sheet continues:

> Noise may *'interfere with communication, disturb sleep, cause cardiovascular and psycho-physiological effects, reduce performance, and provoke annoyance responses and changes in social behaviour ... Many countries have regulations on community noise from rail, road, construction and industrial plants based on emission standards, but few have any regulations on neighbourhood community noise, probably owing to difficulties with its definition, measurement and control. This and the insufficient knowledge of the effects of noise on people handicap attempts to prevent and control the problem.'*

Environment	**Critical Health Effect**	**Sound Level dB(A)***	**Time hours**
Outdoor living areas	Annoyance	50 – 55	16
Indoor dwellings	Speech intelligibility	35	16
Bedrooms	**Sleep disturbance**	**30**	**8**
School classroom	Disturbance of communication	35	During class

Source: Who Fact Sheet No 258, Occupational and Community Noise, February 2001.

The WHO *Guidelines for Community Noise 1999* state that:

> *"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.*

8 Indeed, the human body does emanate measurable 'sound', which can be detected by various testing equipment, as is used for excluding the presence of or for diagnosing disease. For example, in 'EEG measurement', G Blundell notes that

The brain operates	Normal activity	13 – 30 Hz
	Relaxed	8 – 13 Hz
	Drowsiness	4 – 7 Hz
	Deep sleep	0.5 – 4 Hz

[See also Hedge, A. 'Whole body vibration', Cornell University, April 2002; SafetyLine Institute, Government of Western Australia, 'Whole body vibration effects on health', 1998]

9 In the paper, "Human Body Vibration Exposure and its Measurement", G. Rasmussen looked at body vibration exposure at frequencies of 1 Hz – 20Hz. This chart details some of the findings:

Symptoms	**Frequency**
General feeling of discomfort	4Hz – 9Hz
Head symptoms	13Hz – 20Hz
Influence on speech	13 Hz – 20 Hz
Lump in throat	12 Hz – 16Hz
Chest pains	5Hz – 7Hz
Abdominal pains	4Hz – 10Hz
Urge to urinate	10Hz – 18Hz
Influence on breathing movements	4Hz – 8Hz

10 Rasmussen's 'mechanical man' illustrates these distributions:

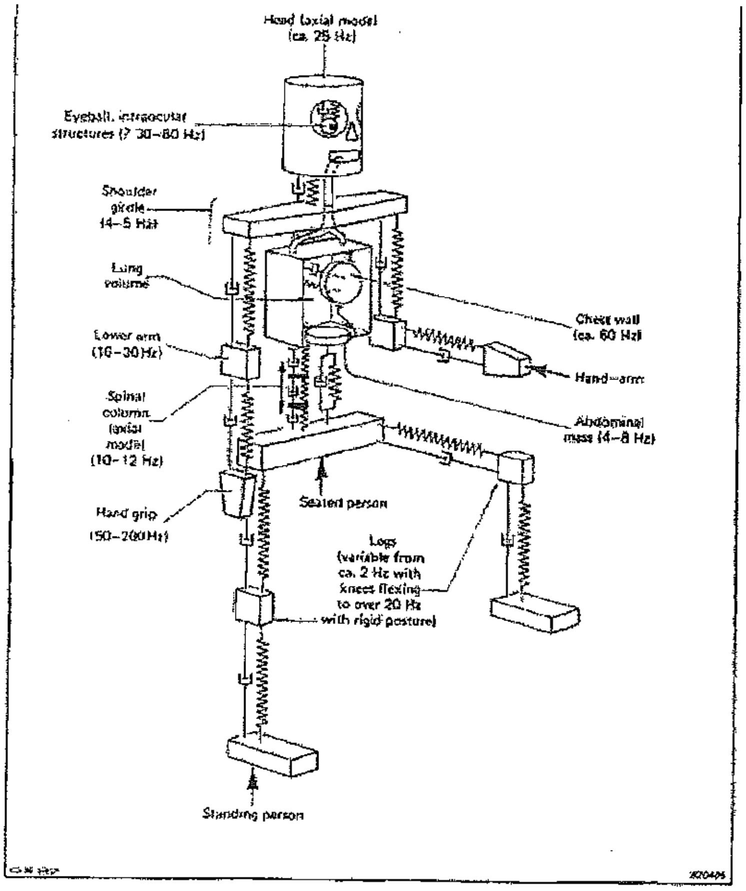


Fig. 1. Simplified mechanical system representing the human body standing on a vertically vibrating platform

Note that the head will vibrate at about 25 Hz and the chest wall at 60 Hz.

> *"Also, in the region 60 to 90 Hz disturbances are felt which suggest eyeball resonances, and a resonance effect in the lower jaw-skull system has been found between 100 and 200Hz."*

11 In "Community Noise Rating" [2d ed, Applied Science Publishers, 1982], the author, Theodore Shultz, wrote that the International Standards Organisation (ISO) had recently (1982) adopted a "Guide for the Evaluation of Human Exposure to Whole-Body Vibration".

In evaluating low frequency noise and vibration, he noted that there are:

> *"... four physical factors of primary importance in determining the human response to vibration: the* ***intensity****, the* ***frequency****, the* ***duration****, (exposure time) and the* ***direction*** *of the vibration."*

12 Shultz gives limits for longitudinal (2–axis) and for transverse (x–and y–axis) vibration respectively. Each curve, or boundary, represents a limit beyond which exposure to vibration carries a significant risk of fatigue or impaired working efficiency. Shultz comments:

> *"The 'exposure limit' boundaries are similar in general form to those for fatigue: but they lie 6 dB higher and the boundaries for reduced comfort have a similar form but lie 10dB lower than the fatigue boundaries."*
>
> *"The Standard mentions in a note that the criteria of acceptability in residential contexts, particularly at night, may lie near the threshold of detectability; for frequency bands of greatest sensitivity (4 – 8Hz for longitudinal, and 1 – 2 Hz for transverse vibration), this lies in the vicinity of* ***0.01m/s****, (though it varies greatly in individual circumstances)."*

Merely as a rough guide, the longitudinal acceleration limits for fatigue indicates that for 0.20 rms between 10Hz – 20Hz, the limits of exposure should not exceed 24hrs – 30hrs. For transverse exposure, the limit is only 10hrs. [Authors' note: See also Section 4.18 or this Review]

13 In his coursework description of "Whole Body Vibration", Prof Alan Hedge of Cornell University writes:

> *"Vibrations in the frequency range of 0.5Hz to 80Hz have significant effects on the human body.*
>
> *Individual body members and organs have their own resonant frequencies and do not vibrate as a single mass, with its own natural frequency. This causes amplification or attenuation of input vibrations by certain parts of the body due to their own resonant frequencies.*
>
> *The most effective resonant frequencies of vertical vibration lie between 4Hz and 8Hz.*
>
> *Vibrations between 2.5 and 5Hz generate strong resonance in the vertebra of the neck and lumber region with amplification of up to 240%.*
>
> *Vibrations between 4 and 6Hz set up resonances in the trunk with amplification of up to 200%.*
>
> *Vibrations between 20 and 30Hz set up the strongest resonance between the head and shoulders with amplification of up to 350%.*
>
> *Whole body vibration may create chronic stresses and sometimes even permanent damage to the affected organs or body parts."* [Hedge A. Whole body vibration. DEA350, April 2002, c January 2006]

14 The SafetyLine Institute (Government of Western Australia) notes in its documentation and coursework:

> *"Prolonged exposure to whole body vibration at frequencies below 20Hz results in hyperventilation, increased heart rate, oxygen intake, pulmonary ventilation and respiratory rate.*

Digestive system disease often observed in persons exposed to whole body vibration over a long period of time. Associated with the resonance movement of the stomach at frequencies between 4 and 5 Hz.

Spinal column disease and complaints, perhaps the most common disease associated with long term exposure to whole body vibration, where the back is especially sensitive to the 4 – 12Hz range."

15 One of the most important parts of the body with respect to vibration and shock appears to be the abdomen with the resonance occurring in the 4 – 8 Hz range. The other main resonant effect is found in the head and neck region, with a range of 20 – 30 Hz. Eyeball resonance is similar, with vibration in the range of 25 – 90 Hz. *'The skull itself has a fundamental mode of of vibration in the region of 300 – 400 Hz.'* [SafetyLine Institute of WorkSafe Western Australia, Department of Consumer and Employment Protection, Government of Western Australia. 'Identification of whole-body vibration: Effects on Health', SLI 1998]

16 Another study concurring with these results looked at human body vibration induced by low frequency noise in the range of 20 – 50 Hz:

> *"The level and rate of increase with frequency of the vibration turned out to be higher on the chest than on the abdomen."* [Takahashi Y; Yonekawa Y; Kanada K; Maeda S. A pilot study on the human body vibrations induced by low frequency noise. Industrial health 1999 Jan; 37(1): 28-35]

17 Berglund, Hassmen, and Job, in "Sources and effects of low frequency noise", [Berglund B, Hassmen P, Job RF. JASA Journal of the acoustical society of America 1996 May; 99(5): 2985 – 3002] made these observations:

> *"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. 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, Stansfield 1992.)"

"Third, determination of health and other effects of LFN must consider field data. Real occurrences of low frequency noise will often include considerable energy below 20Hz as well as energy in what is usually considered the LFN range. Thus the arbitrary setting of a cut off at 20Hz is not conducive to analysis of such data."

"The determination of precisely what constitutes LFN is also not perfectly clear in terms of its upper limit. Sound up to 250Hz are sometimes referred to as LFN although others have set the upper limit of the range to 100Hz (e.g. Backteman et al 1983a)."

18 In referring to impulsive noise, Berglund et al commented:

> *"... impulsive noise generates greater levels of subjective reactions such as annoyance and dissatisfaction than does non-impulsive noise of the same energy level."*

The authors referred to the fact LFN travels extended distances with very little energy loss:

> *"... as the frequency wave is lowered, more of the energy enters the ear, the body and other objects (von Gierke & Nixon 1976). Thus LFN 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."* [Berglund et al]

19 Although within the aircraft industry, in extensive research on vibroacoustic disease (VAD, i.e., LFN-induced pathology), Dr M Pereira found that:

> *'... when continuous LFN is present in the home it can cause VAD. When pulsating LFN is experienced in the home it can aggravate the LFN induced pathology, either by making particular signs and symptoms more severe or by accelerating the onset of other signs and symptoms.*

> *'Mainstream concepts hold that acoustical phenomena impact the human body through the auditory system. While this may be true for certain regions of the acoustical spectrum, there are other regions of the acoustical spectrum (0 – 250Hz – LFN) where acoustical phenomena impact the human body without the involvement of the auditory system.* ***So any study that tries to understand the effects of LFN, as it is perceived by the auditory system is missing the point.'***

20 For those in work environments with extended exposure to large pressure amplitude and LFN (LPALF), e.g., for aircraft technicians, vibroacoustic disease is an occupational health hazard, a disease process that was studied extensively after patterns of health problems were observed.

21 In one study by Castelo Branco et al [Castelo Branco NA, Rodriguez E, Alves-Pereira M, Jones DR. Vibroacoustic disease: some forensic aspects. Aviation, space, and environmental medicine 1999 Mar; 70(3 Pt 2): A145-51], among 236

aircraft technicians, the disabilities manifested themselves after a minimum of 16 years. Disabilities included neurological (34%), psychiatric (9.7%), cardiovascular (6.8%), and osteoarticular (5.9%). Echocardiograms (EEGs) showed 'characteristic changes in pericardial structures', with five pericardial layers instead of three.

Among the study participants, 73% were disabled after an average of 24 years.

22 An important aspect of these studies is the observation that not only can noise have adverse health effects, but also that low frequency noise can adversely impact the human body. This is because, to reiterate, although people perceive sounds and noise via the auditory system:

> ***"Acoustical phenomena impact the human body without the involvement of the auditory system"*** and ***"any study that tries to understand the effects of LFN, as it is perceived by the auditory system is missing the point".*** [M Alves-Pereira]

23 In 2002, Moller and Lydolf [Moller H and Lydolf M. A survey of complaints of infrasound and low frequency noise. Journal of low frequency noise, vibration and active control 2002; 21(2): 53-63] reported on 198 persons who had reported complaints about noise, identified as infrasound and low frequency noise:

> *"Their verbal reports often described the sound as deep and humming or rumbling, as if coming from the distant idling engine of a truck or pump. Nearly all respondents reported a sensory perception of sound. In general they reported that they perceived the sound with their ears, but many mention also the perception of vibration, either in the body or external objects."*

The authors continue:

> *"The sound disturbs and irritates during most activities, and many consider its mere presence as a torment to them. Many of the respondents reported secondary effects, such as insomnia, headache and palpitation. Typically, measurements have shown that existing limits (and hearing thresholds) are not exceeded."*

Moller and Lydolf suggest that there is ample evidence to pursue this research issue further, including the frequencies and levels involved.

24 Research published in 2003 on low frequency and broadband noises and annoyance [Pawlaczyk-Luszczynska M, Dudarewicz A, Waszkowska M, Sliwinska-Kowalska M. Assessment of annoyance from low frequency and broadband noises. International journal of occupational medicine and environmental health 2003; 16(4): 337-43] shows that:

> *"LFN was rated as significantly more annoying than BBN at the comparable A-weighted sound pressure levels. The annoyance assessment of either noise did not depend on age, length of employment or the level of exposure to noise at a current workplace. LFN presents a high risk of influencing human well-being ..."*

Indeed, additional studies, most in controlled environments and laboratories, have confirmed their findings.

25 In a 2004 study conducted at the Nofer Institute of Occupational Medicine in Lodz, Poland, the authors wrote [Pawlaczyk-Luszczynska M, Dudarewicz A, Waszkowska M, Szymczak W, Kamedula M, Sliwinska-Kowalska M. The effect of low frequency noise on human mental performance [article in Polish]. Medycyna pracy 2004; 55(1):63-74]:

> *'There is a growing body of data showing that low frequency noise (LFN) defined as broad band noise with dominant content for low frequencies (10 – 250 Hz) differs in its nature from other noises at comparable levels. The aim of this study was to assess the influence of LFN on human mental performance. Subjects were 193 male paid volunteers ... LFN at 50 dB(A) could be perceived as annoying and adversely affecting mental performance (concentration and visual perception) ...*

26 In another study by this group of 96 men and women, [Pawlaczyk-Luszczynska M, Dudarewicz A, Waszkowska M, Szymczak W, Sliwinska-Kowalska M. The impact of low frequency noise on human mental performance. International journal of occupational medicine and environmental health 2005; 18(2): 185 - 198], the authors note that:

> *"Low frequency noise differs in it nature from other environmental noise at comparable levels, which are not dominated by low frequency components."* [See also Berglund et al, Sources and effects of low frequency noise, JASA 1996]

In addition:

> *"Recent investigations show that low frequency noise at relatively low A-weighted sound pressure levels (about 40 – 45 dB) can be perceived as annoying and adversely affecting the performance, particularly when executing more demanding tasks. Moreover, persons classified as sensitive to low frequency noise may be at a higher risk."*
>
> The results of this study *"supports a hypothesis that LFN at levels normally occurring in the control rooms (at about 50 dB(A)) might adversely influence the human mental performance and lead to work impairment."*
>
> These authors also note *that "previous studies on the effects of community LFN (in dwelling rooms) showed that subjects sensitive to this type of noise were not necessarily sensitive to noise in general as measure by noise sensitivity scales ... Sensitivity to this special type of noise [LFN] was somewhat different from sensitivity in general."*
>
> *"LFN at relatively low A-weighted SPL (about 40 dB) could be perceived as annoying and adversely affecting the performance, particularly when mentally demanding tasks were executed ... "* [see also Persson Waye et al, Low frequency noise pollution interferes with work performance. Noise and health 2001 Oct-Dec; 4(13): 33 – 49]

The subjects *"reported a higher degree of annoyance and impaired working capacity during exposure to LFN ... LFN adversely affected performance in two tasks sensitive to reduced attention in a proof-reading task."* [see also Bengtsson et al. Evaluation of effects due to low frequency noise in a low demanding work situation. Journal of sound and vibration 2004; 278(1/2): 83 – 99]

The authors conclude *that "the adverse effect of LFN at 50 dB(A) (compared to reference noise without dominant content of low frequencies) on performance was found in tasks demanding perceptiveness and concentration ... Moreover, during exposure to LFN, differences in performance between higher and lower sensitive-to-noise subjects were observed in tasks requiring visual differentiation and selective or continuous attention; the persons categorized as high-sensitive to LFN achieved worse results than low-sensitive ones."* [Pawlaczyk-Luszczynska M, Dudarewicz A, et al, 2005]

27 Subsequent research reinforces the WHO *Guidelines for Community Noise 1999*. Pedersen and Persson Waye [Pedersen E, Persson Waye K. Perception and annoyance due to wind turbine noise – a dose-response relationship. JASA Journal of the acoustical society of America 2004 Dec; 116(4): 3460-70] studied the dose-response relationship of perception and annoyance caused by wind turbines. Their results conclude that:

"a significant dose-response relationship between calculated A-weighted SPL from wind turbines and noise annoyances was found. The prevalence of noise annoyance was higher than what was expected from the calculated dose."

The authors recommend further studies, to include the effect of visual impact.

In their paper, Pedersen and Persson Waye identify a factor that supports the WHO Guidelines in its discussion of sleep disturbance:

This *"wind turbine study was performed in a rural environment, where a low background level allows perception of noise sources even if the A-weighted SPL are low."*

"Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0 – 37.5 dB. This could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise. This is also confirmed by the fact that the aerodynamic sounds were perceived at a longer distance than machinery noise."

Although Pedersen and Persson Waye found that *"visual and/or aesthetic interference influenced noise annoyance"*, they also found that *"the influence of noise exposure was still a significant factor for noise annoyance."*

As the authors note:

> *"The high prevalence of noise annoyance could also be due to the intrusive characteristics of the aerodynamic sound ... The verbal descriptors of sound characteristics related to the aerodynamic sounds of swishing, whistling, pulsating/throbbing, and resounding were – in agreement with this hypothesis – also reported to be most annoying."*

The extent of the impact of noise is pervasive:

> *"Most respondents who were annoyed by wind turbine noise stated that they were annoyed often, i.e., every day or almost every day. The high occurrence of noise annoyance indicates that the noise intrudes on people's daily life."*

Although their data was not extensive enough to draw conclusions on wind turbine noise and sleep disturbance, based on their observations they recommend that:

> *"... the probability of sleep disturbances due to wind turbine noise can not be neglected at this stage."* [Pedersen and Persson Waye, 2004]

28 There are numerous studies addressing the problems of noise causing sleep disturbance. The noise may be an annoyance but may also trigger physiologic changes that are signs of physiologic (bodily) stress.

29 In an article published in 2004, Griefahn and Spreng [Griefahn B, Spreng M. Disturbed sleep patterns and limitation of noise. Noise and health 2004 Jan-Mar; 6(22): 27-33] note that because of:

> *"... the indisputable restorative function of sleep, noise-induced sleep disturbances are regarded as the most deleterious effects of noise. They comprise alterations during bedtimes such as awakenings, sleep stage changes, body movements and after-effects such as subjectively felt decrease of sleep quality, impairment of mood and performance. The extents of these reactions depend on the information content of noise, on its acoustical parameters, and are modified by individual influences and by situational conditions."*

In context with the described nature of wind turbine noise, Griefahn and Spreng note that intermittent noise *"is particularly disturbing and needs to be reduced."*

30 When the human body responds to stress, there are biological functions activated:

> These functions *"serve an important role in the organism's adaptation to the environment by protecting and restoring the body but may, under certain conditions, also have health damaging consequences."* [Lundberg U. Coping with stress: neuroendocrine reactions and implications for health. Noise and health 1999; 1(4): 67-74] Lundberg writes that *"knowledge about these psychobiological pathways is of considerable importance for the possibilities to prevent and treat environmentally induced ill health."*

31 Further research by Ising et al [Ising H, Babisch W, Kruppa B. Noise-induced endocrine effects and cardiovascular risk. Noise and health 1999: 1(4): 37-48] reiterates that:

> *"Noise has the potential to cause stress reactions. Chronic noise-induced stress accelerates the ageing of the myocardium and thus increases the risk of myocardial infarction."*

The authors note that:

> *"The involved pathomechanisms include acute increase of catecholamines or cortisol under acute noise exposure and an interaction between endocrine reactions and intracellular Ca/Mg shifts."*

Furthermore:

> *"Recent epidemiological studies support the importance of noise as a risk factor in circulatory and heart diseases, especially in myocardial infarction."*

32 As Spreng notes [Spreng M. Possible health effects of noise induced cortisol increase. Noise and health 2000; 2(7): 59-64]:

> *"The auditory system is permanently open – even during sleep ... Thus noise causes the release of different stress hormones (e.g., corticotrophin releasing hormone: CRH; adrenocorticotropic hormone: ACTH) especially in sleeping persons during vagotropic night/early morning phase. These effects occur below the waking threshold of noise and are mainly without mental control."*
>
> For example, *"Increased cortisol levels have been found in humans when exposed to aircraft noise or road traffic noise during sleep."*
>
> As a consequence, this imbalance has possible adverse health outcomes. *"The effects of longer-lasting activation of the HPA-axis, especially long-term increase of cortisol, are manifold"*, and include cardiovascular diseases.

Spreng also found that:

> *"Longer lasting activation of the HPA-axis, especially abnormally increased or periodically elevated levels of cortisol ... may lead to disturbed hormonal balance and even severe disease."* [Spreng M. Central nervous system activation by noise. Noise and health 2000; 2(7): 49-58]

33 Wust et al, in their research published in 2000 [Wust S, Wolf J, Hellhammer DH, Federenko I, Schommer N, Kirschbaum C. The cortisol awakening response – normal values and confounds. Noise and health 2000; 2(7): 79-88], state that:

"When measured with strict reference to the time of awakening the assessment of this endocrine response is able to uncover subtle changes in hypothalamus-pituitary-adrenal (HPA) axis activity, which are, for instance, related to persisting pain, burnout and chronic stress."

The HPA axis changes may serve as an indicator *"in subjects exposed to prolonged environmental noise."* The authors looked at four separate studies with a total of 509 subjects to *"provide reliable information on normal values for the free cortisol response to awakening. Corresponding with earlier findings, a mean cortisol increase of about 50% within the first 30 minutes after awakening was observed."*

This reinforces the determination of cortisol levels as a useful tool in identifying physiologic changes that may have clinical significance. *"The cortisol awakening response can be assessed under a wide variety of clinical and field settings, since it is non-invasive, inexpensive and easy-to-employ."*

34 In their review on the acute and chronic endocrine effects of noise [Ising H, Braun C. Acute and chronic endocrine effects of noise: review of the research conducted at the Institute for Water, Soil and Air Hygiene (Berlin, Germany). Noise and health 2000; 2(7): 7 – 24], Ising and Braun cover research results from the early 1980s, during which time:

"... mechanisms of acute noise-induced stress reactions as well as long-term increase of stress hormones in animals and persons under chronic noise exposure were studied."

They note that:
"... habituated noise caused a chronic increase of noradrenaline from the sympathetic synapses under longterm noise exposure at work. Environmental noise exposure (Leq >/= 60 dB(A) caused catecholamine increase if activities such as conversation, concentration, recreation etc. were disturbed through noise."

However, for a sleeping person, *"... traffic noise with only Leq >/= 30 dB(A) and Lmax >/= 55 dB(A) caused significant acute increase of cortisol, which developed into chronic increase if the noise exposure was repeated consistently."*

35 In 2002, Babisch [Babisch W. The noise/stress concept, risk assessment and research needs. Noise and health 2002; 4(16): 1-11] states that:

"In principle, the noise/stress hypothesis is well-understood: Noise activates the pituitary-adrenal-corticol axis and the sympathetic-adrenal-medullary axis. Changes in stress hormones including epinephrine, norepinephrine and cortisol are frequently found in acute and chronic noise experiments."

"Cardiovascular disorders are especially in focus for epidemiological studies on adverse noise effects ... The relative importance and significance of health outcomes to be assessed in epidemiological noise studies follow a hierarchical order, i.e., changes in physiological stress indicators, increase

in biological risk factors, increase of the prevalence or incidence of diseases, premature death."

"Magnitude of effect, dose-response relationship, biological plausibility and consistency of findings among studies are issues of epidemiological reasoning."

Babisch identifies the need for further research:

"The cardiovascular risk is a key-outcome in non-auditory noise effects' research because of the high prevalence of related diseases in our communities. Specific studies regarding critical groups, different noise-sources, day/evening/night comparisons, coping styles and other effect-modifying factors, and the role of annoyance as a mediator of effect are issues for future research in this field."

36 Babisch emphasises these points [Babisch W. Stress hormones in the research on cardiovascular effects of noise. Noise and health 2003 Jan-Mar; 5(18): 1-11]:

"Since endocrine changes manifesting in physiological disorders come first in the chain of cause-effect for perceived noise stress, noise effects in stress hormones may therefore be detected in populations after relatively short periods of noise exposure."

Therefore, *"Stress hormones can be used in noise studies to study mechanisms of physiological reactions to noise and to identify vulnerable groups."*

37 Maschke and Hecht underscore the association of changes in stress hormones and sleep disturbances [Maschke C, Hecht K. Stress hormones and sleep-disturbances – electrophysiological and hormonal aspects. Noise and health 2004 Jan-Mar; 6(22): 49-54]:

"Frequent or long awakening reactions endanger therefore the necessary recovery in sleep and, in the long run, health. Findings derived from arousal and stress hormone research make possible a new access to the noise induced nightly health risk."

The author adds that, *"Frequent occurrences of arousal triggered by nocturnal noise"* disturbs the circadian rhythm. *"Additionally, the deep sleep phases in the first part of the night are normally associated with a minimum of cortisol and a maximum of growth hormone concentrations."*

The physical well-being and *"psychic recovery of the sleeper"* rely on the circadian rhythms *"of sleep and neuroendocrine regulations."*

"Noise exposure during sleep which causes frequent arousal leads to decreased performances capacity, drowsiness and tiredness during the day. Long-term disturbances of the described circadian rhythms have a deteriorating effect on health, even when noise induced awakenings are avoided." [Maschke C and Hecht K, 2004]

38 Spreng [Spreng M. Noise induced nocturnal cortisol secretion and tolerable overhead flights. Noise and health 2004 Jan-Mar; 6(22): 35-47] notes that:

> *"repeated noise events (e.g., overflights during night times) may lead to accumulation of the cortisol level in blood."*
>
> *"This fact and the unusual large permeability of cortisol through the cell membranes opens a wide field of connections between stress-dependent cortisol production and the disturbance of a large number of other endocrine processes, especially as a result of long-term stress activation by environmental influences such as environmental noise."*

39 Initial research into low frequency noise in a workplace [Bengtsson J, Persson Waye K, Kjellberg A. Evaluations of effects due to low-frequency noise in a low demanding work situation. J Sound Vibration 2004; 278: 83-99] was tested on subjects using two ventilation noises at 45 dB(A), one with low-frequency noise character. Most of the tasks required of the subjects were routine and undemanding.

> *"The major finding was that low-frequency noise negatively influenced performance on two tasks sensitive to reduced attention and on a proof-reading task, while performance of tasks aimed at evaluating motivation were not significantly affected. The negative effects on performance were not reflected by the subjective reports."*

40 Further research has shown that noise with a low-frequency component also has an effect on cortisol levels. In a work environment experiment with *"exposure to ventilation noise, with dominant low frequencies (low-frequency noise) or a flat frequency spectrum (reference noise)"*, with both noises at 40 dB(A): [Waye KP, Bengtsson J, Rylander R, Hucklebridge F, Evans P, Clow A. Low frequency noise enhances cortisol among noise sensitive subjects during work performance. Life sciences 2002 Jan 4; 70(7): 745-58]

> *"The normal circadian decline in cortisol concentration was however significantly attenuated in subjects high-sensitive to noise in general, when they were exposed to the low frequency noise. This noise was rated as more annoying and more disruptive to working capacity than the reference noise. The study showed physiological evidence of increased stress related to noise sensitivity and noise exposure during work."*
>
> This study demonstrates the *"effect of moderate levels of noise on neuroendocrine activity."*
>
> The authors conclude that *"The impact of long-term exposure to moderate noise levels, and particularly low frequency noise, in the workplace deserves further investigation."*

41 Noise and noise with a low frequency component influence cortisol levels during sleep as well. [Waye KP, Clow A, Edwards S, Hucklebridge F, Rylander R. Effects of nighttime low frequency noise on the cortisol response to awakening and subjective sleep quality. Life sciences 2003 Jan 10; 72(8): 863 – 875]

42 Waye et al studied traffic noise or low frequency noise (LFN) and night-time effects on the cortisol awakening response and subjective sleep quality:

> *"A significant interaction between night time exposure and time was found for the cortisol response upon awakening. The awakening cortisol response following exposure to LFN was attenuated at 30 minutes after awakening. Subjects took longer to fall asleep during exposure to LFN."*
>
> *"This study thus showed that night time exposure to LFN may affect the cortisol response upon wake up and that lower cortisol levels after awakening were associated with subjective reports of lower sleep quality and mood."*

43 The WHO *Guidelines for Community Noise 1999* address sleep disturbance caused by noise:

> *'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 solution is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.' (WHO Guidelines for Community Noise, p xiii, 1999)*

44 Physicians, particularly general practitioners who are community-based, are often the first to detect patterns of symptoms described by their patients. Thus was the situation for Dr Amanda Harry, a physician in Cornwall, who in 2003 noted that patients began complaining of poor sleep, headaches, stress, and anxiety. [Harry A. Wind Turbines, Noise and Health. In process for publication, 2007] For example, further discussion with one couple revealed that their health problems coincided with the commissioning of wind turbines, approximately 400 meters from their home. Their symptoms were relieved when they were away from their home, and from the wind turbines. Their symptoms occurred

when the wind blew in certain directions: the noise was sometimes so disrupting that they would go to a nearby bed and breakfast, just far enough away to sleep undisturbed.

45 As a result of her initial clinical observations, Dr Harry investigated further, finding that physicians elsewhere had noted – as had those living near wind turbines have reported – a similar constellation of symptoms. Dr Harry's research included contact and interviews with respondents from a number of sites near wind turbines in the UK – Wales, Cornwall, and the north of England; her international contacts have included among them, France, Germany, Portugal, the Netherlands, and the USA.

Based on her research, Dr Harry concludes that *'further independent research is warranted'*, although she also notes reluctance for those affected to participate:

> *'There is much concern within communities that if one is seen to complain about the noise that if they decide to move away their properties will be difficult to sell and possibly devalued as a result. Therefore they feel that they are in a "Catch 22" situation.'*

46 As a concerned and inquisitive health professional, Dr Harry initiated her own independent pilot study, as she noted a dearth of research on the health effects of wind turbine noise.

The three key areas surveyed by Dr Harry included:

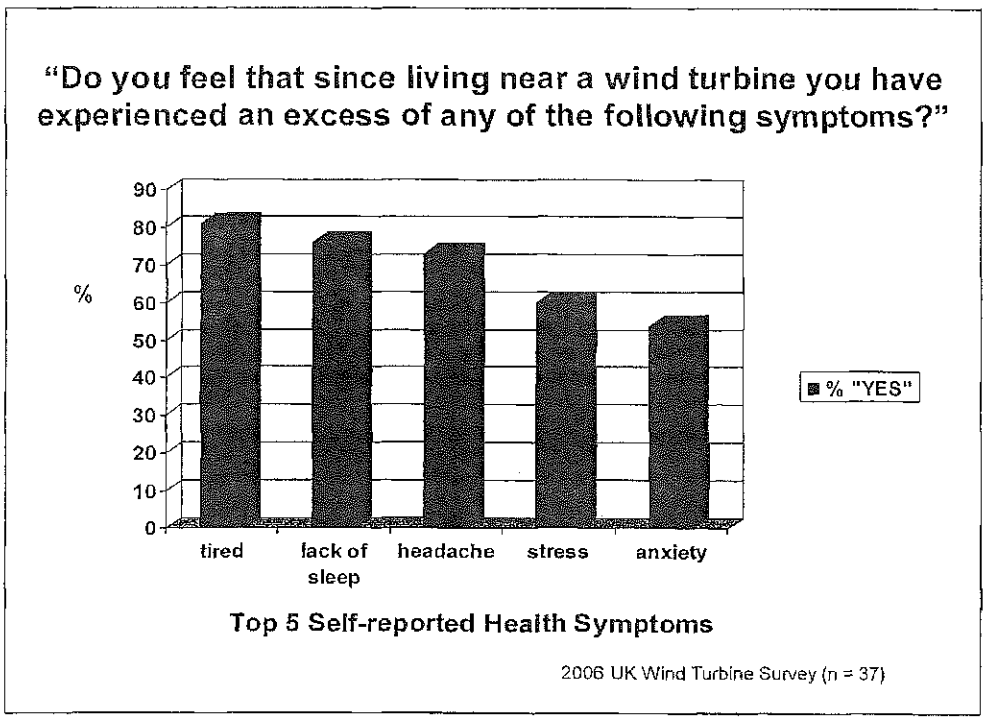
1. *Has your health in any way been affected since the erection of these turbines?*
   -- 81% of the 42 respondents reported that their health had been affected.

2. *As a result, have you gone to see your doctor?*
   -- 76% of the respondents felt that the effects had been severe enough to initiate a visit to a physician.

3. *Do you feel that your quality of life has in any way been altered since living near the wind turbines?*
   -- 73% of these respondents reported that their quality of life had been adversely impacted.

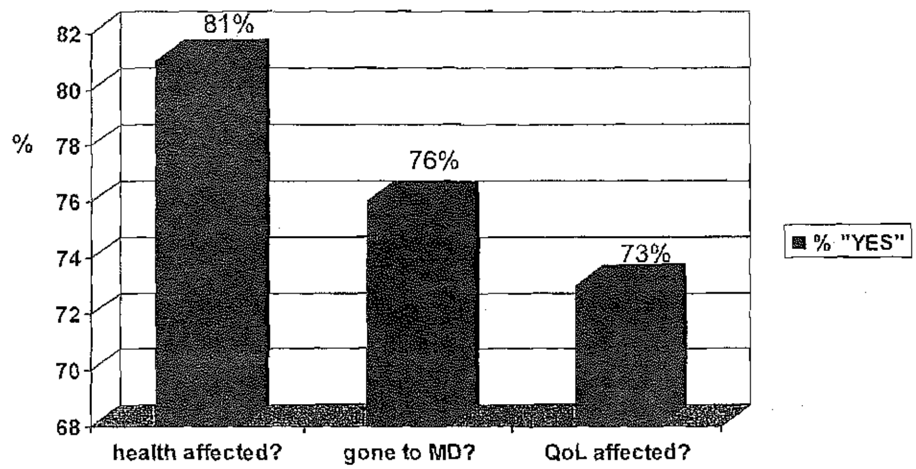
The following charts summarise the responses by those included in this pilot phase.

Note that 80% of respondents felt that the presence of wind turbines had precipitated at least one symptom that impelled them to visit their physicians.


"Do you feel that since living near a wind turbine you have experienced an excess of any of the following symptoms?"
90
80
70
%
60
50
40
30
20
10
0
tired
lack of sleep
headache
stress
anxiety
% "YES"
Top 5 Self-reported Health Symptoms
2006 UK Wind Turbine Survey (n = 37)

2006 UK Wind Turbine Health Survey: 3 Key Questions

1. *Has your health in any way been affected since the erection of these turbines?*
2. *As a result, have you gone to see your doctor?*
3. *Do you feel that your Quality of Life has in any way been altered since living near the wind turbines?*



Top 5 Self-reported Health Symptoms

2006 Devon Wind Turbine Survey (n = 42)

47 Dr Harry's inquiries led her to conclude:

> *'There are people living near turbines who are genuinely suffering from health effects from the noise produced by wind turbines. These neighbours of turbines clearly state that at times the noise from turbines is unbearable. The developers are usually heard to say that noise is not a problem. Clearly this cannot be the case.'*

> *'Some of these acoustic experts have made statements categorically saying that the low frequency noise from turbines does not have an effect on health. I feel that these comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent medical researchers.'*

48 **As a result of her observations and investigation, Dr Harry concluded that wind turbines should be sited not less than 1.5 miles (2.4 km) from the nearest home or residential facility.**

49 The impact of wind turbines on health has commanded the attention of physicians elsewhere. On the basis of patient contacts and research into existing medical evidence, Nina Pierpont, MD, PhD, a physician with a practice in New York State [USA], has suggested that the emerging pattern of complaints by those living near wind turbines is not coincidental. Dr Pierpont supports renewable energy but says that the place for wind energy *'is not near people's homes or near schools, hospitals, or other locations where people have to sleep or learn'*.

50 As Pierpont notes, wind farms are *'large industrial installations'* that produce *'large scale, industrial noise'*. [Pierpont N. Wind Turbine Syndrome: testimony before the New York State Legislature Energy Committee, March 7, 2006] Pierpont summarises the constellation of symptoms as 'Wind Turbine Syndrome'; these symptoms include:

1. Sleep problems. Noise or physical sensations of pulsation or pressure make it difficult to go to sleep and cause frequent awakening;
2. Headaches. Headaches increase in frequency or severity;
3. Dizziness, unsteadiness, nausea;
4. Exhaustion, anxiety, anger, irritability, and depression;
5. Problems with concentration and learning; and,
6. Tinnitus (ringing in the ears).

'Chronic sleep disturbance is the most common symptom. Exhaustion, mood problems, and problems with concentration and learning are natural outcomes of poor sleep.'

Pierpont also notes that *'Deciding whether people have significant symptoms is not within the expertise of engineers or specialists in acoustics ...'* Moreover, *'not everyone near turbines has these symptoms ... there are differences among people in susceptibility. These differences are known as risk factors ...'*

51 Pierpont mentions several risk factors:

1. Sensitivity to low frequency vibration, which is highly variable in people, and poorly understood [lack of research].

2. Pre-existing migraine disorder – migraines are not merely severe headaches. Migraines are a *'complex neurologic phenomenon which affects the visual, hearing, and balance systems'*, and can affect motor control and consciousness. Many people who experience migraines have heightened sensitivity to noise and to motion.

People rely on the input from three sources in order to maintain balance: the eyes; the 'stretch receptors in joints and muscles'; and 'balance organs in the inner ear'. To maintain balance, two of these systems must be working in agreement. If not, *'one feels both ill and unsteady'*, as with vertigo or seasickness.

> *'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.'*

3. Age-related changes in the inner ear – *'Disturbing the inner ear disturbs mood, not because a person is a whiner or doesn't like turbines, but because of neurology.'*

Pierpont continues:

> *'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.'*

52 As with other health professionals and those other professionals and organisations who have scrutinised the health effects of wind turbine noise, **Pierpont recommends a minimum setback of 1.5 miles (2.4 km) of wind turbines from people's homes, schools, hospitals, and similar institutions,** while also urging appropriate epidemiologic studies and analysis of clinical data by qualified, independent medical researchers.

53 Indeed, the medical research literature supports the clinical observations of Drs Harry and Pierpont, as well as those by researchers such as Pedersen, Persson Waye, Berglund, and van den Berg. Moreover, as already mentioned, the symptoms described by those living near wind turbines coincide with those symptoms described in the broader literature examining noise and its health effects. Those living near wind turbines complain not only of noise, but also of the character of that noise (impulsive, pulsating, periodic), as well as the impact and synergy of the 'visual noise' of wind turbines, i.e., the shadow flicker and strobe effect from the motion of the blades.

54 Earlier research in the area of headache and migraine showed that patients with tension headaches or migraine are more sensitive to light (photophobia) and

sound (phonophobia) than those who are not prone to headaches. Those who are prone to tension headache or migraine are more sensitive to light and noise even during the intervals between headache occurrences. (Those with cluster headaches are more sensitive during headache, but not during remission.) [Drummond PD. Sensitivity to light and noise in tension-type and cervicogenic headache. Cephalalgia 1998; 18: 303]

Drummond also states that:

'Mechanisms that normally suppress photophobia are disrupted during the headache-free interval as well as during migraine. The persistence of phonophobia in various forms of headache implies that a similar process modifies sensitivity to sound ... '

55 Many who live near wind turbines complain of headaches and migraines (new onset of problem or exacerbation), e.g., as with more than 70% of Dr Harry's respondents. (See also Section 3.0 of this paper, Overview of the Problems.) Indeed, researchers have studied phonophobia and photophobia (including flicker) and their association with headache and migraine, which may help explain some of the clinical symptoms shared by those living near wind turbines – although epidemiologic studies are clearly urged.

Moreover, researchers have also noted that learning can be affected by noise; for example, Wolach and Pratt found that:

'Processing was prolonged when the distracter items were phonological.' [Wolach I; Pratt H. The mode of short-term memory encoding as indicated by event-related potentials in a memory scanning task with distractions. Clinical neurophysiology 2001 Jan; 112(1): 186 – 197]

56 Between 70% – 83% of migraine patients are phonophobic during an attack, and 76% remain more sensitive between attacks. Headache patients – both tension-type and migraine – were hypersensitive to sound both with and without pain. [Vanagaite Vingen J, Pareja JA, Støren O, White LR, Stovner LJ. Phonophobia in Migraine. Cephalalgia 1998; 18: 243-249]

Furthermore, Vanagaite Vingen et al found that:

'... the results of the questionnaire study refute the argument that anxiety about provoking attacks is the main cause of the increased sensitivity to sound outside attacks.'

57 Researchers have also studied how trigger factors acquire the capacity to precipitate headache. In one study [Martin PR. How do Trigger Factors acquire the capacity to precipitate headaches? Behaviour Research and Therapy 2001; 39: 545-554], participants were exposed to validated trigger factors:

' "visual disturbance" (flicker, glare and eyestrain) induced by a very bright, stroboscopic light':

'The headache sufferers experienced more visual disturbance and head pain in response to the stimulus than the non-headache individuals.'

Martin concludes that *'more research is needed urgently to clarify the processes by which trigger factors acquire and lose their capacity to precipitate headaches'* – some studies recommend avoidance of triggers, while others recommend desensitisation.

58 In 2003, McKendrick and Badcock analysed flickering stimuli between migraine attacks. [McKendrick AM, Badcock DR. An analysis of the factors associated with visual field deficits measured with flickering stimuli in-between migraine. Cephalalgia 2004; 24: 389-397] In this study, the authors measured flicker perimetric performance in a broad group of migraine sufferers and found that:

> *'The migraine groups showed significantly lower general sensitivity across the visual field and higher incidence of localized visual field deficits relative to controls.'*
> (Note: The most severe migraine sufferers, those on preventative therapy, were not included in this study.)

The authors also suggest that *'there is some contribution of both migraine frequency and cumulative migraine history in determining general sensitivity to flickering stimuli across the visual field.'*

In addition, the authors found *'a weak, but statistically significant, correlation between decreased generalized sensitivity and increased migraine frequency. Abnormalities in cortical neuronal function that increase susceptibility to migraine, thereby resulting in more frequent attacks, may manifest as decreases in generalized visual sensitivity ...'* This implies *'... some cumulative effect of migraine on visual processing'*.

59 It is not only migraine sufferers whose attacks may be triggered or exacerbated by light or noise. One study looked at headaches triggered by negative affect or by noise, analysing physiologic responses,

> *'including 'headache intensity ratings, forehead electromyographic activity, heart rate, blood pressure, and temporal pulse amplitude (TPA).' ('TPA is thought to be a measure of arterial distension caused by the passage of the pressure pulse.')* [Martin PR, Todd J, Reece J. Effects of Noise and a Stressor on Head Pain. Headache 2005; 45: 1353-1364]

The authors note that physiologic changes occur during an episode of headache:

> *'... both stressor and visual disturbance could trigger headaches. The stressor was associated with increases in blood pressure, heart rate, and temporal pulse amplitude (TPA), while visual disturbance was associated with increases in blood pressure only.'*

One group of subjects, the Stressor group, was given highly difficult anagrams to solve, accompanied by failure feedback to create anxiety and mood change. Another group of subjects was exposed to a 'Noise Challenge', a white noise that resembled a loud and un-tuned television set. As the authors observe, those exposed to the Noise had an aversive response.

A third group, exposed to both Stressor and the Noise Challenge simultaneously, rated noise levels as higher than the group exposed only to the noise, even though the noise levels were identical.

The authors found that *'79% of subjects exposed to noise developed a headache.'*

Significantly: ***'Increased headache ratings occurred during the noise challenge relative to the control condition and continued through the recovery period even though the noise was no longer present.'*** [emphasis added]

Moreover, while 'Negative Affect' (those exposed only to the Stressor of the anagrams) was not associated with physiologic changes when compared to controls:
'The Noise Challenge led to elevated TPA [Temporal Pulse Amplitude].'

60 Martin, Todd, and Reece note that in a previous study, Martin and Teoh had found that visual disturbance as a trigger for headache was also associated with physiologic changes, specifically increases in blood pressure, heart rate, and TPA. [Martin PR, Teoh H-J. Effects of visual stimuli and a stressor on head pain. Headache 1999; 39: 705-715]

Martin, Todd, and Reece conclude that:

'... none of the physiological changes associated with headache induction were in terms of muscle tension – all were in terms of cardiovascular variables.' [emphasis added]

61 Martin, Reece, and Forsyth looked more closely at headaches and noise exposure and sensitivity. Headache sufferers most commonly report stress, anxiety, glare, and noise, as triggers; negative affect, visual disturbance, hunger, and noise are experimentally validated triggers. [Martin PR, Reece J, Forsyth M. Noise as a trigger for headaches: relationship between exposure and sensitivity. Headache 2006; 46: 962-972]

In this study, the authors consider whether those who suffer headaches should endure short exposure to triggers to desensitise themselves to the trigger (hypothetically), although this might lead to increased sensitivity (again, hypothetically).

The authors used Noise for their study as it is commonly cited as a trigger for headache, and it has been experimentally validated. The 'white noise' consisted of multiple frequencies similar to an un-tuned television set, at high intensity (but with no threat to the auditory systems of the participants).

The authors conclude:

> *'Through the study, headache patients reported that they found the noise stimulus more aversive and it resulted in reports of more pain, than non-headache patients ... For individuals who do not suffer from regular headaches, the analyses strongly supported the avoidance theory ... However, for individuals who do suffer from regular headaches, the results were less clear-cut.'*

Significantly for those who live near wind turbines and suffer headaches, the authors observe:

> *'In the 'very long' noise exposure condition, the non-headache group showed further desensitization beyond the 'long' exposure condition whereas the headache group showed sensitization relative to the 'long' exposure condition.'*

However:

> *'The findings from individuals who suffer from regular headaches do not provide clear guidance as to whether avoidance or exposure to trigger factors is a better strategy from the perspective of desensitization/sensitization.* ***The data hint at the possibility that for the trigger factor of noise, 'long' exposure may be helpful but 'very long' exposure may be unhelpful.*** *This paper has argued for the potential benefits of exposure to triggers* ***but it seems likely that exposure at too high a level will be counterproductive.****'* [emphasis added]

62 On 17 January 2007, The Planning Inspectorate dismissed an appeal to allow two wind turbines at Penpell Farm, Par, Cornwall, near Lanlivery, UK. The Inspector cited these four as among the most significant considerations:

i. The impact upon the landscape, a nearby World Heritage Site, ancient monuments, and listed buildings;
ii. The impact on the quality of life, including the visual and noise effects on those who would live near the wind turbines;
iii. The impact upon the local economy, including tourism, recreation, and a local day centre for the disabled;
iv. The benefit of the proposal to meet Government, Regional, County, and local policy aims for renewable energy.
(emphasis added)

However, critical issues also revolved around the health concerns for a young man with severe autism, who lives with his family in a home that would have been one of the nearest to the wind turbines, as well as the health concerns for the attendees of the day centre for the disabled.

The Inspector concluded that the young man would face serious difficulties adapting to the presence of the wind turbines, which would then have serious consequences and hardship for the family, who are the caregivers:

> *'... there is likely to be harm, and that these are exceptional circumstances that carry some weight as a material consideration against the appeal proposal.'*
> [The Planning Inspectorate, Bristol. Appeal Decision, by RD Hiscox. Appeal ref: APP/Q0830/A/05/1189328, Penpell Farm, Par, St Austell, Cornwall, PL24 2SA, 17 January 2007]

63 It appears that those living near wind turbines and experiencing sleep disturbance, headache, migraine, and/or anxiety and the accompanying physiologic effects are enduring adverse health effects outside their sphere of control. To reiterate the advice of health professional organisations, e.g., the French National Academy of Medicine; health professionals, researchers, and reports such as UKNA's *Location, Location, Location*, **wind turbines should be sited no closer than 2km to a place of residence (with some recommending even greater separation, i.e., 2.4 km).**

64 Indeed, after learning about Dr Harry's pilot study, media reports of noise problems from wind turbines, and research on the adverse effects of noise on health, Prof Ralph Katz, Chair of the Department of Epidemiology and Health Promotion, New York University (USA), expressed concern that wind turbines had been constructed in close proximity to homes without research into their potential effects on health.

> *'No one knows the prevalence of health syndromes where there are pockets of people living next to turbines, so what would be the effects where there are clusters?'*

In 2004, Prof Katz recommended a two-year moratorium on wind turbine construction near dwellings in order 'to allow for a multi-disciplinary team of scientists to research all the health and environmental concerns.' [Young N. Wind power debate blows near and far. Western Morning News, 23 January 2004] A two-year moratorium would give epidemiologists enough time to gather and analyse data in order to determine if there is a causal link, although research beyond two years may be required. Moreover, this would avert needless adverse health impacts and an additional burden on the National Health Service in 15 to 20 years time. [Katz R. Personal communication, 3 February 2007]

65 According to Deepak Prasher, Professor of Audiology at the Ear Institute of University College London:

> ***'Noise not only annoys, it causes stress that can have an impact on our health and well-being. It can lead to anxiety, sleep problems, communication difficulties, even cardiovascular and immune changes, of which, the individual is usually unaware.'*** (emphasis added)
> [Prasher D. Widex Noise Report: traffic noise in England 2007. University College London (UK) and Widex, January 2007, www.widex.co.uk]

66 Wind turbines are not only a matter of renewable energy policy, but also – and no less significantly – a matter of public health policy.

The World Health Organisation's Guidelines for Community Noise 1999 included these recommendations:

> 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.*
>
> *Municipalities should develop low-noise implementation plans.*
>
> *Governments should support more policy-relevant research into noise pollution*
>
> *Development of continuous monitoring systems for direct health effects in critical locations.*
>
> *Development of instruments appropriate for local/regional surveys of people's perceptions of their noise/sound environments.*
>
> *Procedures for evaluating the various health effects of complex combined noise exposures over 24 hours on vulnerable groups and on the general population.*

65 The WHO report also recommended further research related to direct and/or long-term health effects:

> *Identification of potential risk groups.*
>
> *Studies of dose-response relationships for various effects.*
>
> *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.*
>
> *Knowledge on the health effects of low-frequency components in noise and vibration.*
>
> *Studies on the influence of noise-induced sleep disturbance on health, work performance, accident risk and social life.*
>
> *Development of a methodology for the environmental health impact assessment of noise that is applicable in developing as well as developed countries.*
>
> *Studies to assess the effectiveness of noise policies in maintaining and improving soundscapes and reducing human exposures.*

66 Thus, the evidence strongly supports those who complain of adverse health effects when living within close proximity of wind turbines, particularly the impacts from noise and shadow flicker/strobe effects. Their symptoms parallel those found in other areas of research into the physiologic and medical impact of noise on people. Various noise characters, low frequency noise, infrasound, and shadow flicker, all delivered with a pulsating character, over a prolonged period, pose health risks when developers site wind turbines too close to homes.

Section 6.0 HUMAN RIGHTS

1. Landowners have many rights pertaining to their property, but there are legal restrictions, requirements, and liabilities. A property related activity that produces an environmental pollution escaping onto a neighbour's property, causing a mischief and health problems, may trigger an interference with Article 8 of the European Human Rights Act, enacted in the UK as The Human Rights Act 1998. In the UK, a liability may arise in Tort (Rylands v Fletcher). The Environmental Protection Act 1990 (Part 3) may trigger a Statutory Nuisance. This Section of the review looks at the European Community Human Rights Act as a measure of acceptability of the level of violation and in particular considers its application to the UK.

2. In a speech to the Human Rights Lawyers Association in London on 29 September 2006, Lord Falconer of Thornton, Constitutional Affairs Secretary and Lord Chancellor, said:

   "We in government will campaign passionately and defiantly for human rights for everyone in Britain. Because we believe it is the foundation of both our security and our prosperity."

   "It (Democracy) is an acceptance of the values of equality, tolerance and freedom. We are all equal. We are all entitled to have our individual freedoms protected. We can only safeguard our democracy and our freedoms by the rule of law. Those values must be protected and given effect by law." The freedoms set out in the European Convention on Human Rights reflect those values. They are not the property of lawyers."

3. In discussing UK Government departments' responsibilities, the Lord Chancellor said:

   "In essence this involves ensuring an individual's human rights addresses the issues of possible infringement, justification and proportionality."

4. Environmental Pollution becomes significant when the pollution threatens or affects people's health. The UK is party to many Policy initiatives that give a high priority to environmental issues. For example, Article 37 of the European Union's Charter of Fundamental Rights provides:

   "A high level of environmental protection and the improvement of the quality of the environment must be integrated into the policies of the Union and ensured in accordance with the principle of sustainable development."

   These principles are based on Articles 2, 6, &174 of the EC Treaty.

5. Increasingly, noise is recognized as a serious environmental problem. For example, EC Directive 2002/49/EC states: *"Whereas: (1) It is part of the Community Policy to achieve a high level of health and environmental protection, and one of the objectives to be pursued is protection against noise. In the Green Paper on Future Noise Policy,* ***the Commission addressed noise in the environment as one of the main environmental problems in Europe."***

The Human Rights Act and Environmental Pollution.

6 There are two areas of the Human Rights Act 1998 that particularly address Environmental Pollution:

i) Article 8, Right to Respect for Private and Family Life

a) ***Everyone has the right to respect for his private and family life, his home and his correspondence.***

b) ***There shall be no interference by a public authority with the exercise of this right except as in accordance with the law and as necessary in a democratic society in the interests of... the economic well-being of the country for the protection of disorder or crime, or for the protection of health or morals, or for the protection of the rights and freedoms of others.***

7 Article 8 is a Qualified right, i.e., it can be interfered with if the interference is justified. The interference:

i. must be **lawful** (e.g., decisions that the planning acts allow);
ii. must serve one of the **legitimate aims** in Article 8 (2); and,
iii. must be **proportionate**.

The **Legitimate aims** under Article 8 (2) include:

i. National security,
ii. Economic well-being,
iii. Prevention of disorder or crime,
iv. Protection of health or morals,
v. Protection of rights and freedoms of others, e.g., the right of a developer to develop his own land and the right of a neighbour to be protected from noise nuisance, and,
vi. Protection of environment and the interests of the community.

Proportionality must consider:

i. Is the interference the minimum necessary to achieve the legitimate aims being pursued?
ii. Has a fair balance been struck?
iii. Interference with a human right must go no further than is strictly necessary in a pluralistic society to achieve its permitted purpose; or more succinctly, must be appropriate and necessary to its legislative aims.

8. **ii) Article 1 of the First Protocol, Protection of Property.**

a) ***Every natural or legal person is entitled to the peaceful enjoyment of his possessions. No one shall be deprived of his possessions except in the public interest and subject to the conditions provided for by law and by the general principles of international law.***

b) ***The preceding provisions shall not in any way impair the right of the State to enforce such laws as it deems necessary to control the use of property in accordance with the general interest or to secure the payment of taxes or other contributions or penalties.***

i. Article 1 of the First Protocol is a qualified right;
ii. Property and possessions include land, rights, planning permissions, licences and goodwill (business);
iii. Everyone is entitled to peaceful enjoyment of his possessions;
iv. Prevention of development may infringe the right;
v. Diminution in value of property may be relevant; and,
vi. Justification for interference:

    a. must be lawful,
    b. must serve one of the legitimate aims in the Article, and,
    c. must be proportionate.

9. Are there circumstances when a wind turbine, or a cluster of wind turbines, will be a violation of the Human Rights Act? The European Court of Human Rights is the final arbiter of this question, but there are a number of important considerations of fact that should be addressed, and Case Law provides a lead as to how the Court might consider the question.

Evidence supports the proposition that wind turbines create environmental noise pollution, posing a serious health risk to families where wind turbines are built too close to their homes.

10. **Section 3** of this Review, **"The Overview of the Problems"**, reviews the nature of the impacts on people's lives where wind turbines are built too close to their homes.

    The common complaints in response to the noise of wind turbines include: sleep deprivation, fatigue, depression, insomnia, headaches, inability to concentrate, agitating – frustrating – annoying (no escape, infrequent remission, unpredictability of noise), all of which trigger more serious health problems.

11. **Section 4** of this Review, **Acoustics**, reviews research and reports on acoustic radiation from wind turbines. The papers reviewed indicate that UK acousticians working in the wind industry seem to have concentrated their studies upon audible sound. The research and reports confirm that it is the combination of audible sound, infrasound, and vibration, in a pulsating character, that appear to trigger serious reported health problems in those families living near wind turbine installations.

    The health problems appear to be aggravated when at certain times of the year strobing light and shadow flicker from the rotating blades projects at the same pulsation rate as the noise. The UKNA report, ***Location, Location, Location*** [August 2006], which considered both acoustic and medical advice, concluded:

    > ***"It would be prudent that no wind turbine should be sited closer than 1 mile away from the nearest dwellings. This is the distance the Academy of Medicine in Paris is recommending, certainly for the larger turbines and until further studies are carried out. There may even be occasions where a mile is insufficient depending on the scale and nature of the proposed development."***

Wind turbines located too close to dwellings will cause environmental noise pollution.

12. **Section 5** of this Review, **Health Effects**, reviews research and reports on Health. The medical research included in this section is international in scope; most of the citations were retrieved via the databases of the US National Library of Medicine (The National Institutes of Health, Bethesda, Maryland, www.nlm.nih.gov), with additional citations from the major engineering and biologic science databases, e.g., Web of Science. These resources are among the most comprehensive and authoritative available, and articles were published in peer-reviewed journals.

Among the findings of the effects of noise on health, sleep deprivation emerges as a significant factor, which is likely to trigger more serious medical conditions. Some of the physiological changes may be cumulative or irreversible, which can have critical consequences not only in terms of individual health, but also in terms of community health, when the source of the problem is community-based.

The Courts appear to acknowledge that health, as a state of physical, mental and social well-being, is a precondition to any meaningful privacy or intimacy, and inseparable from it. The Courts also recognise that sleep deprivation is a serious condition to the extent that it might be considered as an element of inhuman and degrading treatment under Article 3. In ***Ireland v The United Kingdom,*** the Court held that: *"...holding the detainees in a room where there was a continuous loud and hissing noise ..."* constituted inhuman and degrading treatment.

13 The cause of the violation is shown but the **Legitimate Aims, Article 8 (paragraph 7 above)** need to be considered:

i) **National Security**:
The National Security of a country is not going to be impacted if an onshore wind farm is not built. In fact, it may be argued that because the flow of electricity from a wind farm to the National Grid is not in the control of the Nation, but subject to the control of the weather, in a National emergency the supply of electricity from an onshore wind farm can never be relied upon. Furthermore, electricity flowing to the National Grid from a wind farm is neither secure nor reliable in delivery.

14 ii) **Economic Well-being**:
The viability of the National Economy will not be impacted if an onshore wind farm is not built. The National Audit Office have questioned the viability of the ROC (Renewable Obligation Certificate), introduced by the State, which provides the attractive financial investment returns to onshore wind farm developers; moreover, the system is not providing value for money to the consumer. [National Audit Office, Auditor General, HC624 Session 2002-2003. The New Electricity Trading Arrangements in England and Wales, 9 May 2003; also NAO HC 210 session, 2004-2005, 11 Feb 2003] Many argue the introduction of ROCs has been an important influence in stimulating rising electricity prices to consumers, which in turn contributes to increasing inflation which is not in the economic well-being of the country. [Refer also to

Renewable Energy Foundation (REF) The Oswald Research, 2006; also REF submission to the Yelland Wind Farm, Devon, Planning Appeal, 2 April 2006]

In 2006, Professor James Lovelock captured the attention of the international community with his book on global warming, 'The Revenge of Gaia'. On page 83, he comments:

> *'According to the Royal Society of Engineers' 2004 report, onshore European wind energy is 2 – 5 times, and offshore wind energy over 3 times, more expensive per kilowatt hour than gas or nuclear energy. No sensible community would ever support so outrageously expensive and unreliable an energy source were it not that the true costs have been hidden from the public by subsidies and the distortion of market forces through legislation.'* [Lovelock J. The Revenge of Gaia: Why the Earth is Fighting Back – and How We Can Still Save Humanity. Allen Lane (Penguin), 2006]

The Dti Report "Our Energy Challenge 2006" refers to the work of Prof David Simpson in his April 2004 report for the David Hume Institute. The Paper: *"Tilting at Windmills: The Economics of Wind Power" (No. 65)*, states:

> *"At the present time the cost of generating electricity from wind power is approximately twice that of the cheapest alternative conventional cost."*

> *"But projections by Government advisers, using relatively optimistic assumptions, show that even by the year 2020 a generation portfolio containing 20% wind power will still be more expensive than a conventionally fuelled alternative."*

> *"No matter how large the amount of wind power capacity installed, the unpredictably variable nature of its output means that it can make no significant contribution to the security of energy supplies."*

There is no evidence to show that onshore wind power makes any real contribution to the economic well being of the UK. If all the onshore wind turbines in the UK were shut down, there is no evidence that this shut down would have any impact on the National economy.

15 iii) **Prevention of Disorder or Crime**:
This is not influenced by wind farm developments.

16 iv) **Protection of Health and Morals:**
Wind farms built too close to peoples' homes are unlikely to have any impact on peoples' morals, but they do create very real health problems as set out in **Section 5, Health Effects.**

Section 4, of this Review, **Acoustics**, contends that the use of guidance ETSU-R-97 fails to protect families where wind turbines have been built too close to their homes, noting that The World Health Organisation's upper limit for bedroom noise at night offers greater protection to people, family life, and amenity. In considering whether a scheme will be a violation of the Human Rights Act, it is necessary for the decision-maker to seriously consider the advice of The World Health Organisation on standards for Community Noise, as its maximum noise levels are designed to limit noise impact on health.

The WHO limits bedroom noise at night to a **combined (total)** noise level of 30dB, and the level is reduced when low frequency content is present and reduced even further when pulsating noise is present. On windy nights, it is the total noise, including background noise, that enters the bedroom, and that should not exceed the maximum level. The difference in approach between ETSU and WHO probably accounts for much of the sleep deprivation described in **Section 3** of this Review, **Overview of the Problems**.

17 In deciding the status of ETSU-R-97 in terms of the Human Rights Act, it is important to remember that the membership of the Committee that produced the ETSU report in 1997, appeared weighted towards members working in or for the wind industry. This may account for the Committee's recommendation of the high level of environmental noise pollution that would have to be suffered by neighbouring families. While admitting the importance of preventing sleep deprivation, the ETSU Committee recommendation was instead weighted at a level that the Committee felt would not restrict the development of wind energy. As a result, it would seem that the Committee tipped the balance disproportionately in favour of wind farm developers over the impact on community quality of life and the protection of the health of people living nearby.

18 Case law has shown that the violation is the key factor; and if the State has a 'bylaw' that fails to provide adequate protection, then the State remains liable.

The Minutes of the new ETSU-R-97 Noise Working Group, (Committee formed by the State and chaired by the State), dated 02 August 2006, fails to mention any discussion on:

1) The need to comply with The Human Rights Act
2) The World Health Organisation ***"Guidelines for Community Noise 1999"***
3) The Report from the National Academy of Medicine, France (March 2006)
4) The Report by the United Kingdom Noise Association ***"Location, Location, Location"*** (Aug 2006).

Evidence shows that families suffer sleep deprivation and other health problems when wind turbines are built too close to dwellings; this is indicative of the State failing to provide adequate health protection. Interference to this extent is not justified.

19 v) **Protection of Rights and Freedom of Others**:
Clearly, the site owner has the right to develop his land in accordance with the provisions of the County and Local Development Plans under the Town Planning Acts.

However, apart from arguments of a Town Planning nature, the landowner has to recognize that the neighbours also have rights. The development of land that creates an environmental noise pollution, which escapes onto a neighbour's land, may create a violation of the Human Rights Act 1998, as well as an infringement of The Environmental Protection Act, and the nuisance might be classed as a strict liability in Tort ***(Rylands v Fletcher)***.

20 Regarding a wind farm, it is incumbent on the site owner to produce a layout design that prevents or limits to reasonable levels the environmental pollution entering the neighbours' properties, which is most likely achieved by ensuring a suitable distance between the noise source and the neighbours' properties.

The landowner may argue that the State has set Guidance on the level of noise pollution that the State believes is at an acceptable level to neighbours. However, compliance with these Guidance levels may not satisfy the Human Rights Act. The status of the Guidance is worth considering:

Planning Policy PPG24: Planning & Noise – General principles (2), states: *"The Planning system has the task of guiding development to the most appropriate locations. It will be hard to reconcile some land uses, such as housing, hospitals and schools, with other activities which generate high levels of noise but the Planning system should ensure that, wherever practicable, noise sensitive developments are separated from major sources of noise (such as road ... and certain types of industrial development). It is equally important that new development involving noisy activities should, if possible, be sited away from noise sensitive land uses."*

Planning Policy Statement 22 (2004) S.22 'Noise', states: *"Renewable technologies may generate small increases in noise levels ... Local Planning authorities* ***should*** *ensure that renewable energy developments have been located and designed in such a way to minimize increases in ambient noise levels ... The 1997 report by ETSU for the Dti* ***should*** *be used to assess and rate noise from wind energy developments".*

The use of the word "**should**" – rather than the phrase 'will be used' – allows the decision maker to use ETSU-R-97 together with any other relevant considerations.

21 vi) **Protection of the Environment and the Interests of the Community.** The attempt to reduce one form of pollution (carbon) by the creation of a new pollution (noise pollution) and visual pollution is not credible. (Visual pollution is mentioned because many will argue that a fixed, motionless, wind turbine standing in a field is unlikely to provoke much interest. The moment the blades start to rotate, the structure captures the eye and it has the ability to mesmerize or distract some people.)

22 A wind farm does not create new jobs, as one engineer can service a number of wind farms. Rural areas depend mainly on agriculture and tourism as the key employment. Countryside Tourism, by its very title, is supported by people seeking solitude, walking, and a contrast to urban and suburban living. Tourism customers will not find solitude and unspoilt rural landscape where wind farms have industrialised the area. Although some wind farm developers make a token financial contribution to a community, this is 'de minimus' compared with the potential loss in property values resulting from the environmental pollution and industrialisation created by the wind turbines. [The Small Business Council. UK Energy Policy: *The Small Business Perspective and the Impact on the Rural Economy.* Report by Whitmill C for the SBC, February 2006] (See also this paper's **Appendix on Property Values**)

23 Referring again to the Report from The David Hume Institute (S6.13), Prof Simpson commented:

> *"Because of the cost of providing additional stand-by generating capacity, it is unlikely that wind power will ever account for more than 20% of electricity generation through the National Grid. That being the case, its development can make no substantial contribution to an overall reduction in carbon emissions."*

The Dti acknowledges that wind turbines require separate balancing power provided by conventional power stations, in order to balance the flow of electricity to the National Grid. Nuclear power is not suitable because of its slow response time. Conventional power, therefore, provides balancing power in the form of gas, oil, or coal. In the UK, it is normally gas (methane). The construction of onshore wind farms with high volatility in supply of electricity require near similar (MW) balancing power. This has the effect of increasing demand for methane. The transportation of methane has inherent issues, since the leakage is about 4% by volume. **Methane is 24 times more destructive as a greenhouse gas than carbon dioxide.** [Lovelock J. The Revenge of Gaia, 2006, pp 74-5]

24 Having in mind the similar MW capacity 'balancing power' will be constantly fired up, demanding methane gas of which about 4% by volume will disperse into the atmosphere, it is difficult to comprehend how onshore wind farms can be considered as protecting the environment – especially when the noise pollution is added to the equation.

25 Many local communities support the production of renewable energy, but they do not support the creation of environmental pollution as an acceptable consequence. Onshore wind turbines built in sparsely populated, wide-open spaces, around the world, cause few noise problems. However, schemes proposed in well-populated areas are those most likely to evoke a huge swell of community objection. In the final equation, the excessive environmental noise pollution escaping onto neighbouring property, plus the visual pollution from the constant rotation of the blades nearby, plus the reliance on back-up balancing power fuelled by methane gas, balanced against a small saving in carbon (using the National power balance rather than coal as the carbon measure), shows the cost imposed on neighbouring families is not justifiable.

Case Law

26 The European Court of Human Rights has made it very clear that environmental considerations may involve a breach of Article 8, even after allowing a margin of appreciation to the State.

27 In ***Lopez Ostra v Spain*** (1994) 20 EHRR 2777:

> *S.51 Naturally, severe environmental pollution may affect individuals well-being and prevent them from enjoying their homes in such a way as to affect their private and family life adversely, without, however, seriously endangering their health.*
>
> *S.58 Having regard to the foregoing, and despite the margin of appreciation left to the respondent State, the Court considers that the State did not*

succeed in striking a fair balance between the interest of the town's economic well-being – that of having a water treatment plant – and the applicant's effective enjoyment of her right to respect for her home and her private and family life.

28 In ***Guerra & Others v Italy*** (1998) 26 EHRR. 3577:

S.58 The Court considers that Italy cannot be said to have " interfered" with the applicants private or family life: they complained not of an act by the State but of its failure to act. However, although the object of Article 8 is essentially that of protecting the individual against arbitrary interference by the public authorities, it does not merely compel the State to abstain from such interference: in addition to this primary negative undertaking, there may be positive obligations inherent in effective respect for private or family life.

S.60 The Court reiterates that severe environmental pollution may affect individuals well being and prevent them from enjoying their homes in such a way as to affect their private and family life adversely ...The Court holds, therefore, that the respondent State did not fulfill its obligation to secure the applicants' right to respect for their private and family life, in breach of Article 8 of the Convention.

29 In ***Fadeyeva v Russia*** (June 2005) ECHR 55723

S.64 The applicant alleged that there had been a violation of Article 8 of the Convention on account of the State's failure to protect her private life and home from severe environmental nuisance arising from the industrial activities of the Severstal steel-plant.

S.132 The Court finds the following. The State authorized the operation of a polluting enterprise in the middle of a densely populated town. Since the toxic emissions from this enterprise exceeded the safe limits established by the domestic legislation and might endanger the health of those living nearby, the State established that a certain territory around the plant should be free of any dwelling. However, these legislative measures were not implemented in practice.

S. 133 It would be going too far to state that the State or the polluting enterprise were under an obligation to provide the applicant with free housing, and, in any event, it is not the Court's role to dictate precise measures which should be adopted by the States in order to comply with their positive duties under Article 8 of the Convention. In the present case, however, although the situation around the plant called for a special treatment of those living within the zone, the State did not offer the applicant any further solution to help her move from the dangerous area. Furthermore, although the polluting enterprise at issue operated in breach of domestic environmental standards, there is no information that the State designed or applied effective measures which would take into account the interests of the local population, affected by the pollution, and which would be capable of reducing the industrial pollution to acceptable levels.

S 134 The Court concludes that, despite the wide margin of appreciation left to the respondent State, it has failed to strike a fair balance between the interests of the community and the applicant's effective enjoyment of her *right to respect for her home and her private life. There has accordingly been a violation of Article 8.*

30. In ***Moreno Gomez v Spain*** (16 November 2004) 4143/02
In this case, the applicant had lived in a residential quarter of Valencia since 1970. In June 1996, the City Council approved a bylaw on noise and vibrations. Article 8 of the bylaw says that in a family residential area (such as the one in which the applicant lives) external noise levels were not to exceed 45 dBA Leq between 10pm and 8am. Article 30 of the bylaw defines 'acoustically saturated zones' as areas in which the large number of establishments, activity of the people frequenting them and passing traffic expose local residents to high noise levels and cause them serious disturbance. The applicant was exasperated by the situation, which prevented her from sleeping and resting and caused her insomnia and serious health problems.

S 57 The present case does not concern interference by public authorities with the right to respect for the home, but their failure to take action to put a stop to third-party breaches of the right relied on by the applicant.

S 60 In view of its volume – at night and beyond permitted levels – and the fact that it continued over a number of years, the Court finds that there has been a breach of the rights protected by Article 8.

S 62 In theses circumstances, the Court finds that the respondent State has failed to discharge its positive obligation to guarantee the applicants right to respect for her home and her private life, in breach of Article 8 of the Convention.

31 The above Cases reveal how the European Court of Human Rights has considered breaches of Article 8 where the root cause of the issue is an environmental pollution. A loss of a view that has triggered a loss in property value has not, in itself, been considered a breach of Article 8 and Article 1 of the First Protocol. This was shown in the Case of ***Lough & Ors v Secretary of State and Bankside Developments***, July 2004, in the UK Court of Appeal, before Pill LJ, Keene LJ, and Scott Baker LJ. The Appellants were objectors to a development proposal that had been permitted following a Planning Appeal. The Appellants submitted that the Inspector had erred, it was claimed, in failing to consider three of the complaints made by the Appellants: loss of a view, interference with television reception during the construction of the proposed building and the diminution in value of 15% to 20% in the properties. The Court of Appeal upheld the previous Court's decision that there was no breach of Article 8. The Court found the creation of a diminution of value as a separate and distinct breach of Article 8 and Article 1 of First Protocol was not proven.

32 However, diminution in value has been an important consideration when noise pollution is the interference: In ***Dennis and Dennis v Ministry of Defence*** (2003) EWHC 793 (QB), Mr Justice Buckley found an interference with the Convention rights of the Claimants whose enjoyment of their home (and its value), Walcott Hall, was impaired by the noise of overflying Harrier jets during pilot training exercises from nearby RAF base at Wittering. Also in ***Hatton v UK*** (2003) 37 EHRR 288, the Court had to consider, in the context of Article 8, the level of noise caused by night flights at Heathrow Airport and its effect on nearby residents.

In S.96:

Article 8 protects the individual's right to respect for his or her private and family life, home and correspondence. There is no explicit right in the Convention to clean and quiet environment, but where an individual is directly and seriously affected by noise or other pollution, an issue may arise under Article 8.

33 The **Hatton** judgment also clarifies the nature of the State – or regulatory authority's "positive obligations" to regulate private parties and the balancing exercise it is called upon to perform.

S118: It is clear that in the present case the noise disturbance complained of were not caused by the State or State organs, but that they emanated from the activities of private operators. It may be argued that the changes brought about by the 1993 Scheme are to be seen as a direct interference by the State with the Article 8 rights of the persons concerned. On the other hand, the State's responsibility in environmental cases may also arise from a failure to regulate private industry in a manner securing proper respect for the rights enshrined in Article 8 of the Convention. As noted above (S98), broadly similar principles apply whether a case is analysed in terms of a positive duty on the State or in terms of an interference by a public authority with Article 8 rights to be justified in accordance with paragraph (2) of the provision... The question is whether, in the implementation of the 1993 policy on night flights at Heathrow airport, a fair balance was struck between the competing interests of the individuals affected by the night noise and the community as a whole.

34 Mr Justice Buckley in ***Dennis & Dennis v MOD*** **[2003]** made a further point on "proportionality". The decision established an important principle in domestic law in relation to proportionality and compensation. First, he found that the evidence of severe noise nuisance and consequent loss in value of the estate established an interference with both Article 8 and Article 1 of the First Protocol. In these circumstances, he held that a fair balance would not be struck in the absence of compensation.

*"I believe it is implicit in the decision **S v France**, that the public interest is greater than the individual private interests of Mr and Mrs Dennis but it is not proportionate to pursue or give effect to the public interest without compensation for Mr and Mrs Dennis ... in my view, common fairness demands that where the interests of a minority, let alone an individual, are seriously interfered with because of an overriding public interest, the minority should be compensated."*

35 Without an acceptable scheme for compensating those directly or seriously affected by the noise and economic loss, a proposed development of wind turbines cannot be said to achieve a fair balance, as per ***S v France***. As a consequence, if there is a violation of Article 8, it follows there is most likely to be a violation of Article 1 of the First Protocol, and it is submitted that the damage will flow from the escape of the environmental noise pollution plus an element of value directly attributable to the visual pollution (flicker/strobing).

36 **Justification for Interference**

Once an interference with the families' Convention rights is considered likely, the question is then whether that interference can be justified in order to avoid a violation of the Convention right. To justify the interference it must be shown to be "in accordance with the law and … necessary in a democratic society" in the interests of one of the recognized categories listed in Article 8(2) or in the public interest under Article 1 of the First Protocol. It is accepted that if the decision makers for the State approved the development by granting a Planning permission, in accordance with the Town and Country Planning Act, it would be in accordance with the law. However, the development may not satisfy other elements of justification.

37 The interference might be "necessary in a democratic society" only if:

a) It was in response to a pressing social need; and,
b) It involved no greater interference than required to address that need (this is the proportionality principle).

38 It is difficult to see how a wind farm development satisfies any of the Article 8(2) social need categories: "national security, public safety, the economic well-being of the country, the prevention of disorder or crime, the protection of health or morals or for the protection of the rights and freedoms of others".

39 The stated purpose of most wind farm developments is to promote renewable energy in order to reduce carbon emissions and thus protect the global environment. Conceivably this could involve protecting the rights or freedoms of others, but it would be a weak claim and not sufficient to justify interfering with an individual's valuable rights of privacy under the Article 8.

Moreover, it could be argued that the wind turbine developer could attain the same goal of reducing carbon emissions, with an increased buffer zone between homes and the wind turbines. Thus, the developers' and communities' needs would both be met.

Other options might include using smaller wind turbines, fewer wind turbines, controlling blade rotation speed, and turning them off at night.

40 Whether onshore wind turbines satisfy the "public interest" requirement of Article 1 of the First Protocol is a separate question. It is arguable that the wind turbines do not satisfy primary Government Energy Policy and are therefore not in the public interest.

41 Government Policy, as set out in the Energy White Paper [Dti. *Energy White Paper: Our Energy Future: Creating a Low-Carbon Economy.* Dti: London, 2003], strives to maintain the ***"reliability of energy supplies"*** (S. 1.18.) and states that ***"reliable energy supplies are fundamental to the economy as a whole and to sustainable development. An adequate level of energy security must be satisfied at all times in both the short and long term futures."***

42 The national importance of reliability in energy supply is taken forward in *"Our Energy Challenge"*, the Dti consultation document issued in 2006. The State set several goals for the country's energy supply:

a. *"To maintain the reliability of energy supplies."* [p 11, S.1]
b. *"The Regulatory framework must give high priority to reliability."* [p 32, S.2.2.2, Reliable energy supplies]
c. *"Maintaining the reliability of electricity supplies will require very substantial levels of new investment ..."* [p 50, S.3.1., Looking ahead]

The key feature of onshore wind generation is its total unreliability in the supply of electricity. Furthermore, because the Dti 2006 document is a major review of UK energy policy, within its 72 pages, there is little mention of onshore wind power, which demonstrates just how insignificant it is to the State as a future electricity-generating source.

43 Furthermore, in his report, *"Power to the People"*, Professor MA Laughton noted the innate unreliability of wind as a secure source of energy:

> *"... a more detailed examination of one aspect is necessary, namely that concerning the interaction of random, intermittency of supply with security, bearing in mind that security of electricity requires continuity of power delivery, not energy."*
>
> *"Large weather systems, particularly high pressure windless systems, can cover most of the country, as seen during the January 2003 cold spell for several days and again during the subsequent July heatwave. At such times the contribution from any wind ... are severely curtailed."*
> [Laughton MA. Power to the People: future-proofing the security of UK power supplies. ASI Adam Smith Institute, London 2003]

44 The unreliability of electricity supply and flow from wind turbines is further emphasised in the following reports:

a) *"An Engineering Appraisal of the PIU Energy Review"*, The Royal Academy of Engineering for the Energy Minister, August 2002; and,

b) *"Energy at the crossroads, The Chemical Engineering Contribution to the UK Energy Debate"*, The Institution of Chemical Engineers for the Energy Minister, September 2002.

45 The generation of electricity from wind turbines depends entirely upon the weather. Because this resource is uncontrollable by man, the electricity flow is unreliable and unpredictable. In failing to provide a reliable and secure electricity supply, wind turbine generation thus does not comply with Government Energy Policy.

46 It is however necessary to recognize that the Dti Energy Review [2006] supports offshore wind farms because firstly the wind offshore is more reliable than onshore wind, thereby producing substantially higher effective electricity generation. Secondly, an array of several hundred wind turbines linked to a central collecting pod on the seabed can feed electricity by a single cable to the shore, where a hydrogen generation plant could be located. With a large hydrogen storage capacity, this hydrogen plant would then generate electricity by burning hydrogen in a controlled, reliable, and sustainable form supplying electricity directly to the National Grid. This combination only then meets the National Policy for the reliability and security of electricity supply, i.e., the source of electricity supply is from hydrogen storage.

47 It is also necessary to recognize that the Dti Energy Review supports onshore solace wind turbines serving an industrial unit, commercial premises and small communities. This works because the amount of electricity generated is 'de minimus' and destined for direct commercial consumption. This system allows the National Grid to act as provider of balancing power to the industrial/commercial user without disruption to the network supply.

48 Wind turbine developers often argue that wind turbines are State Policy. It has not been possible to find documentation to support this proposition. It may be more correct to say that State Policy takes the form of setting targets for renewable energy generation and that industry's response to meeting these targets is the wind turbine as it is available technology. Furthermore, the State has set targets in the form of 'installed capacity', and apparently it matters not to the State that in some locations, actual electricity production on an annualised basis is merely circa 24% of installed capacity. While State Policy clearly identifies 'reliability' and 'security' of supply as critical objectives, wind turbines will not satisfy this Policy. The EU Court of Human Rights might wonder at the remoteness of wind turbines from fulfilling Policy.

49 There is **no justification** in allowing wind turbines to be built so close to peoples' homes with the result that they fail to meet the noise limitations set out by the World Health Organisation *Guidelines for Community Noise 1999*, a consequence of which is to create serious health damage and a likely violation of the Human Rights Act 1998.

50 In considering the question of Tort, it is a well established principle of UK law that if a landowner collects something onto his land that is likely to do mischief if it escapes onto adjoining land; then if it does escape, the landowner is liable for the damage ***(Rylands v Fletcher)*** (L.R.1. Ex 265, 279 – 80):

> *"The person who for his own purposes brings on his lands and collects and keeps there anything likely to do mischief if it escapes, must keep it in at his peril, and if he does not do so, is prima facie answerable for all the damage which is the natural consequence of its escape."*

51 In the House of Lords, Lord Cairns added that in order for the Rule to apply, the defendant's use of the land must be "non-natural". P James on Law of Torts points out:

> *"The Rule applies to things likely to do mischief if they escape, e.g. water, gas, electricity, fumes, rusty wire from fencing, explosions…. To give liability there must be an escape from the premises/land."*

52 The owner of land operating a wind turbine to generate electricity is performing an industrial activity by installing the turbines, collecting the wind, using the wind to manufacture electricity, and discharging the wind (and the resulting wind vortices) over his land. During the manufacturing process, the wind changes its form, velocity, and character, and collects sound characters of its own and in combination with the design and engineering of wind turbines, creates environmental pollution. Over distance, the pollution dissipates and within large sites, the pollution dissipates before leaving the land boundaries. However, on small sites in well-populated areas, the pollution will still be present when the wind – and the resulting wind vortices created by the wind turbines – enters a neighbour's property, mischief is likely to occur with consequent damage to health. The liability may be a strict liability under the Rule of ***Rylands v Fletcher*** and not covered by indemnities or insurance cover. Cases that are more recent include: ***Bottomley v Todmorden***, High Court 2003, and ***Transco v Stockport Metropolitan Borough Council***, House of Lords 2003.

53 Others have noted that perhaps the wind farm developers' contractual indemnities are qualified by the requirement of proof of negligence and based upon strict liability under ***Rylands v Fletcher***, which would mean that in such circumstances liability falls on the landowner.

54 The failure of the State to properly protect the health of people from environmental noise pollution that is a consequence of development permitted by the State, is not justified.

55 This section considered the application of the EU Human Rights Act, Article 8 and Article 1 of the First Protocol, to the physiological and medical suffering of families caused by a decision by the State that allows developers to build wind turbines too close to homes. The weakness of the Human Rights Act is exposed by the fact that decision makers of the State rely on the argument 'balance in favour of the State', to justify serious violations of family to the right of respect for private and family life. Yet applying the dictum of Justice Buckley (S.6.34), if the State considers wind turbines are public policy, then the 'minority' interest should be compensated. If wind turbines are not State policy, then decision makers may be challenged when they use the 'balance in favour of the State' to justify giving an approval that risks a violation of basic Human Rights.

The UK Lord Chancellor has said that:

> *"We in Government will campaign passionately and defiantly for human rights for everyone in Britain. Because we believe it is the foundation of both our security and our prosperity."* [S. 6.02]

On 10 May 2006, The British Consulate, New York, sent an email entitled, *"UK Elected to UN Human Rights Council"*. The last paragraph states:

> *"The UK remains committed to striving for the highest standards of human rights both at home and around the world. We are committed to fulfilling the detailed pledges we made as part of our election campaign to promote and protect human rights in the UK and globally. We will play the fullest part in making the new Human Rights Council a success."*

It is for the reader to judge the evident disparity between the words and the deeds of the UK State when it permits developers to build wind turbines too close to dwellings. The disparity might possibly be explained by the enthusiasm of Departments of State to achieve renewable energy targets set by the State, and in order to achieve those targets, treat the Human Rights Act as an obstacle to circumvent.

Peter Hadden

[Note: Sentences emboldened within quotations are the author's emphases.]

Section 7.0 CONCLUSION

The environmental noise pollution from wind turbines built too close to dwellings causes serious discomfort, and often health injury, to families. Oftentimes those affected did not object to the construction, accepting the developer's assurances that noise would not be problematic.

Section 4 of this Review, **Acoustics**, explores the research on noise radiation from wind turbines. Locating wind turbines close to families demands a precision, accuracy, and certainty of acoustic prediction and calculation that is just not available to the wind energy engineers and acousticians. The ETSU-R-97 Noise Working Group (UK) concluded that it would be too restrictive on wind farm developments to provide the protection necessary [i.e., to prevent sleep deprivation].

The challenges in designing a predictive model for wind turbine noise are complex. Factors include the very nature of wind turbine design itself, e.g., the rotation of the blades through the air, each passing the tower rhythmically, creating a characteristic pulsating sound as well as a vortex of air; moreover, there is an interaction among the turbines, so the placement of each turbine within an array can influence noise emission. Other factors include the constantly changing atmosphere and wind speed, temperature, and terrain. Noise, particularly low frequency noise, travels not only seismically but also airborne over terrain. On occasion, the local geography can act like a giant microphone. Thus, when wind turbines are located too close to dwellings, their noise may have an adverse impact on residents, because the methods and models used to predict wind turbine noise have distinct design limitations.

The result is an adverse impact not only to quality of life, but those who live near wind turbines may also suffer adverse health effects. Research links noise to adverse health effects, e.g., sleep deprivation and headache. Sleep deprivation itself may lead to physiologic affects, such as a rise in cortisol levels, a sign of physiologic stress, as well as headache, mood changes, and inability to concentrate. Initial research into the health impact of wind turbine noise (including the 'visual noise' of shadow flicker) reveals similar findings. Indeed, while many studies in work environments or laboratory simulations confirm these responses, those living near wind turbines endure continuous, long-term exposure.

Thus, the personal and media reports, emerging clinical evidence, and published research combine to offer urgent and compelling reasons for Government to reconsider policy on wind turbine developments. Several reports offer guidance, including the World Health Organisation *Guidelines for Community Noise 1999*; the UK Noise Association's report, *Location, Location, Location* (2006); and the statement by the French National Academy of Medicine (2006).

These are also compelling reasons for the Government to seek expert independent medical advice and epidemiologic research to assess the health impacts in order to prevent additional injury and to redress the injury to those already affected. Indeed, to express this more forcefully: The question the Government must address is whether they – the Government – are prepared to knowingly subject its people to substandard conditions when these could easily have been avoided, e.g., by following the level of health protection advised by the World Health Organisation *Guidelines for Community Noise 1999*.

Although the Government may conclude that they must wait for the scientific evidence to unfold, this approach ignores those many families – and those who will unfortunately and inevitably follow – who are experiencing genuine distress, and whose predicament could so easily have been avoided.

As this is a matter of public health policy, proceeding with wind turbine developments and applications that violate the public's health may also be a violation of the Human Rights Act by the landowners, the wind turbine developers, and the State.

The Review addresses the issue of Human Rights in Section 6. Although European States have 'Bylaws' or 'Guidances' and the United States has 'Ordinances' that provide guidance to Planning decision makers, in the final analysis it is contended that the responsibility of the decision maker is not merely to seek compliance with a Bylaw/Guidance/Ordinance in arithmetical terms, but also to establish beyond reasonable doubt that the families' right to respect for their homes and their private lives is not violated. If the State decides that the public interest in building wind turbines is greater than the individual private interest, then the violation is not proportionate without compensation for the individual (S6.34).

RECOMMENDATIONS:

- The Government would be prudent to institute an immediate and mandatory minimum buffer of 2km between a dwelling and an industrial wind turbine, and with greater separation from a dwelling for a wind turbine with greater than 2MW installed capacity.

- There is a need for a multidisciplinary team of experts – independent of the wind energy industry – to assess clinically and to investigate epidemiologically, the health impacts on people where industrial wind turbines have been located too close to their dwellings.

- Governments are appealing to the social and ethical conscience of commerce to become carbon neutral and mitigate the effects of global warming. In an appeal to the ethical and social conscience of bankers and investment institutions, we recommend that before providing finance to wind turbine developments that are near family homes, the Investors should demand from the developers a Guarantee Bond that unreservedly guarantees that the operation of the wind turbines will not violate the families' right to respect for their homes and private lives. This would be a prudent caution to take in order to lessen the risk of potential environmental and medical claims at some future time.

REFERENCES

Note: Web addresses are accurate as of January 2007. However, the authors cannot guarantee that these links will remain active or accurate.

Aitch I.
Keep it down.
Telegraph [UK] Magazine, 2 December 2006.

Babisch W.
The noise/stress concept, risk assessment, and research needs.
Noise and health 2002; 4(16): 1 – 11.

Babisch W.
Stress hormones in the research on cardiovascular effects of noise.
Noise and health 2003 Jan-Mar; 5(18): 1 – 11.

Barber M.
Letter to Energiekontor AG (Germany).
Bradworthy, Devon, UK: 12 July 2005.

Bell A.
Noise: an occupational hazard and public nuisance.
Geneva: World Health Organization, 1966.

Bengtsson J; Persson Waye K; Kjellberg A.
Evaluation of effects due to low-frequency noise in a low demanding work situation.
Journal of sound and vibration 2004; 278(1/2): 83 – 99.

Berglund B; Hassmen P; Soames Job RF.
Sources and effects of low-frequency noise.
JASA Journal of the acoustical society of America 1996 May; 99(5): 2985 – 3002.

Bolton R.
Evaluation of Environmental Shadow Flicker Analysis
for "Dutch Hill Wind Power Project".
Environmental Compliance Alliance, New York, USA, 30 January 2007.

Bowdler D.
ETSU-R-97: why it is wrong.
New Acoustics, July 2005.

Brierley D.
Public presentation.
Askam, Cumbria, UK, 2006.

The British Consulate, New York, New York, USA.
UK elected to UN Human Rights Council.
The British Consulate, e-mail newsletter, 10 May 2006.

Bunker RJ, ed.
Nonlethal weapons: terms and references.
USAF Institute for National Security Studies, INSS Occasional Paper 15.
Colorado (USA): United States Air Force INSS, July 1997 www.usafa.af.mil/inss .

Burkhardt G.
Complaints are not new.
Wales, UK: Journal, http://www.thisissouthwales.co.uk , 1 June 2005.

Castelo Branco NA; Rodriguez E; Alves-Pereira M; Jones DR.
Vibroacoustic disease: some forensic aspects.
Aviation, space, and environmental medicine 1999 Mar; 70(3 Pt2): A145 – 151.

Chouard C-H.
Le retentissement du fonctionnement des eoliennes sur la sante de l'homme
[Repercussions of wind turbine operations on human health].
French National Academy of Medicine.
Panorama du medecin, 20 March 2006.

Couple driven out of home by wind farm.
Spalding Today, 21 December 2006,
http://www.spaldingtoday.co.uk/ViewArticle2.aspx?SectionID=829&ArticleID=1941028

Crespo A; Hernandez J; Frandsen S.
Survey of modelling methods for wind turbine wakes and wind farms.
Wind energy 1999; 2: 1-24.

The cutting edge: military use of sound.
Toronto Star [Canada], 6 June 2005.

The Darmstadt Manifesto.
Germany: German Academic Initiative Group, 1998.

Davis J.
Personal communication, 19 January 2007.

Defra (Department of the Environment, Farming, and Rural Affairs).
Low frequency noise.
Consultation report by Casella Stanger, Technical research support for Defra Noise Programme.
Defra [UK], 2001.

Defra.
Proposed criteria for the assessment of low frequency noise disturbance.
Consultation report by Dr Andy Moorhouse et al.
Defra [UK], February 2005.

'Did turbines make you sick?'
Wales, UK: Journal, http://www.thisissouthwales.co.uk , 18 May 2005.

Drummond PD.
Sensitivity to light and noise in tension-type and cervicogenic headache.
Cephalalgia 1998; 18: 303.

Dti (Department of Trade and Industry, UK).
Energy white paper: our energy future: creating a low-carbon economy.
Dti, 2003.

Dti executive summary of the measurement of low frequency noise at three UK wind farms, contract number W/45/00656/00/00, URN number 06/1412, Contractor: Hayes McKenzie Partnership Ltd, 2006.

Dti.
Our energy challenge 2006.
Dti, 2006.

Dti Noise Working Group.
ETSU-R-97.
Dti 1997.

Energiekontor AG (Germany)
Letter to M Barber.
19 July 2005.

Ervin K.
Letter to 'Interested Parties'.
Meyersdale, Pennsylvania, USA, http://www.pbase.com/wp/image/39285457 ,
7 March 2006.

European Union.
Charter of Fundamental Rights of the European Union.
Official journal of the European communities 18.12.2000 EN 2000/C364/01,
http://ec.europa.eu/justice_home/unit/charte/index_en.html .

Flurry of complaints after wind change.
New Zealand: TV1 News http://tvnz.co.nz/view/page/411749/599657 , 25 July 2005.

Garrett A.
Ugly side of wind power.
The Observer [UK], Sunday, 2 March 2003.

Glegg SAL, Baxter SM, and Glendinning AG.
The prediction of broadband noise from wind turbines.
Journal of sound and vibration 1987; 118(2): 217-39.

Gregg N.
Wind energy not resident-friendly.
Queensland, Australia: The Courier-Mail, 4 October 2005.

Griefahn B; Spreng M.
Disturbed sleep patterns and limitations of noise.
Noise and health 2004 Jan-Mar; 6(22): 27 – 33.

Harry A.
Wind Turbines, Noise and Health.
In process for publication, 2007.

Hedge A.
Whole body vibration [course description, DEA350].
Cornell University, April 2002, c January 2006.

Herlihy M.
Windmills 'are a nightmare'.
The Corkman [Ireland], 6 April 2006.

Hubbard HH.
Noise induced house vibrations and human perception.
Noise control engineering 1982; 19(2): 49 – 55.

Hubbard HH; Shepherd KP.
Aeroacoustics of large wind turbines.
JASA Journal of the acoustical society of America 1991 June; 89(6): 2495 – 2508.

Hubbard HH; Shepherd KP.
Wind turbine acoustics.
NASA Technical Paper 3057, December 1, 1990.
NASA National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia (USA), Document ID 19910007366, DOE/NASA/20320-77, www.sti.nasa.gov/products.html#db or http://ntrs.nasa.gov/search.jsp .

Hutzell RA Jr.
Letter.
Meyersdale, Pennsylvania, USA: http://www.pbase.co/wp/image/39285457 , 13 February 2005.

The Institution of Chemical Engineers [UK].
Energy at the crossroads, the chemical engineering contribution to the UK energy debate.
The Institution of Chemical Engineers for the Energy Minister, September 2002.

International Standards Organisation.
Equal loudness level contours, ISO 226:2003.
ISO, 2003.

Ising H; Babisch W; Kruppa B.
Noise-induced endocrine effects and cardiovascular risk.
Noise and health 1999; 1(4): 37 – 48.

Ising H; Braun C.
Acute and chronic endocrine effects of noise: review of the research conducted at the Institute for Water, Soil and Air Hygiene (Berlin, Germany).
Noise and health 2000; 2(7): 7 – 24.

Katz RV.
Personal communication, 3 February 2007.

Keller J.
Nova Scotians flee home, blame vibrations from 17 turbines for loss of sleep, headaches.
Canadian Press http://thestar.com , 13 November 2006.

Larivee R.
Letter to the County Commissioners, Meyersdale, Pennsylvania, USA.
http://www.pbase.com/wp/image/39285457 , 2005.

Laughton MA.
Power to the people: future-proofing the security of UK power supplies.
ASI Adam Smith Institute, London (UK), 2003,
www.adamsmith.org/policy/publications/pdf-files/powerpeople.pdf .

LeFanu J.
In sickness and in health.
Daily Telegraph [UK], 14 March 2004.

Leishman JG.
Challenges in modelling the unsteady aerodynamics of wind turbines.
Wind energy 2002; 5: 85 – 132.

Leventhall G.
Infrasound from wind turbines – fact, fiction and deception.
Canadian acoustics 2006 Jun; 34(2): 29 – 36.

Leventhall G; Pelmear P; Benton S.
A review of published research on low frequency noise and its effects.
Report for DEFRA Department for Environment, Food, and Rural Affairs (UK), May 2003,
www.defra.gov.uk/environment/noise/research/lowfrequency/pdf/lowfreqnoise.pdf

Lockett P.
Letter.
Plymouth, UK: Western Morning News, 15 November 2003.

Lockett P.
Letter, personal communication.
15 November 2003.

Lockett P and Lockett P.
Letter.
Plymouth, UK: Western Morning News, 16 October 2001.

Lovelock J.
The revenge of Gaia: why the Earth is fighting back – and how we can still save humanity.
Allen Lane (Penguin), 2006.

Lundberg U.
Coping with stress: neuroendocrine reactions and implications for health.
Noise and health 1999; 1(4): 67 – 74.

Manley DMJP; Styles P.
Infrasound generated by large sources.
Proceedings of the Institute of Acoustics 1995; 17: 239 – 246.

Manley DMJP; Styles P; Scott J.
Perceptions of the public of low frequency noise.
Journal of low frequency noise, vibration and active control 2002; 21(1): 37 – 44.

Martin PR.
How do Trigger Factors acquire the capacity to precipitate headaches?
Behaviour research and therapy 2001; 39: 545 – 554.

Martin PR; Reece J; Forsyth M.
Noise as a trigger for headaches: relationship between exposure and sensitivity.
Headache 2006; 46: 962 – 972.

Martin PR; Teoh H-J.
Effects of visual stimuli and a stressor on head pain.
Headache 1999; 39: 705 – 715.

Martin PR; Todd J; Reece J.
Effects of noise and a stressor on head pain.
Headache 2005; 45: 1353 – 1364.

Maschke C; Hecht K.
Stress hormones and sleep-disturbances – electrophysiological and hormonal aspects.
Noise and health 2004 Jan-Mar; 6(22): 49-54.

McKendrick AM; Badcock DR.
An analysis of the factors associated with visual field deficits measured with flickering stimuli in-between migraine.
Cephalalgia 2004; 24: 389 – 397.

McManus S.
Turbines still causing a problem, neighbors say.
Michigan, USA: Mackinaw Journal, 29 August – 26 September 2002, p 3.

Moller H; Andresen J.
Loudness of pure tones at low and infrasonic frequencies.
Journal of low frequency noise and vibration 1984; 3(2): 78 – 87.

Moller H; Lydolf M.
A questionnaire survey of complaints of infrasound and low frequency noise.
Journal of low frequency noise, vibration and active control 2002; 21(2): 53 – 63.

Morris PJ; Long LN; Brentner KS.
An aeroacoustic analysis of wind turbines.
American Institute of Aeronautics and Astronautics: AIAA-2004-1184; 42nd AIAA Aerospace Sciences Meeting, 5-8 January 2004, Reno, Nevada [USA], 2004.

Mott M.
Did animals sense tsunami was coming?
National Geographic News 4 January 2005.

National Audit Office [UK].
The new electricity trading arrangements in England and Wales, 9 May 2003.
Auditor General, HC624 Session 2002-2003, 11 February 2003; also NAO HC210 Session, 2004-2005.

Navy adapts sonar to protect whales.
The Sunday Times [UK], 26 March 2006.

Neighbors complain of wind farm nuisances.
New Mexico, USA: The Albuquerque Tribune, 28 April 2006.

Pawlaczyk-Luszczynska M; Dudarewicz A; Waszkowska M; Sliwindska-Kowalska M.
Assessment of annoyance from low frequency and broadband noises.
International journal of occupational medicine and environmental health 2003; 16(4): 337 – 343.

Pawlaczyk-Luszczynska M; Dudarewicz A; Waszkowska M; Szymczak W; Kamedula M; Sliwinska-Kowalska M.
The effect of low frequency noise on human mental performance [Polish].
Medycyna pracy 2004; 55(1): 63 – 74.

Pawlaczyk-Luszczynska M; Dudarewicz A; Waszkowska M; Szymczak W; Sliwinska-Kowalska M.
The impact of low frequency noise on human mental performance.
International journal of occupational medicine and environmental health 2005; 18(2): 185 – 198.

Pedersen E.
Noise annoyance from wind turbines – a review. Report 5308.
Naturvårdsverket Swedish Environmental Protection Agency, August 2003, www.naturvardsverket.se/bokhandeln .

Pedersen E; Persson Waye K.
Audio-visual reactions to wind turbines.
Proceedings of Euronoise 2003; 5th European Conference on Noise Control, 19 – 21 May, 2003, Naples, Italy, 2003.

Pedersen E; Persson Waye K.
Perception and annoyance due to wind turbine noise – a dose-response relationship.
Journal of the acoustical society of America 2004 Dec; 116(4): 3460 – 3470.

Pedersen E; Persson Waye K; Hallberg LRM.
Living close to wind turbines – a qualitative approach to a deeper understanding.
Proceedings of Internoise2004, Prague, 2004.

Persson Waye K; Bengtsson J; Rylander R; Hucklebridge F; Evans P; Clow A.
Low frequency noise enhances cortisol among noise sensitive subjects during work performance.
Life sciences 2002 Jan 4; 70(7): 745 – 758.

Persson Waye K; Clow A; Edwards S; Hucklebridge F; Rylander R.
Effects of nighttime low frequency noise on the cortisol response to awakening and subjective sleep quality.
Life sciences 2003 Jan 10; 72(8): 863 – 875.

Persson Waye K; Ohrstrom E.
Psycho-acoustic characters of relevance for annoyance of wind turbine noise.
Journal of sound and vibration 2002; 250(1): 65 – 73.

Persson Waye K.
Low frequency noise pollution interferes with work performance.
Noise and health 2001 Oct-Dec; 4(13): 33 – 49.

Pierpont N.
Wind turbine syndrome: testimony before the New York State [USA] Legislature Energy Committee, March 7, 2006.

The Planning Inspectorate, Bristol.
Appeal Decision, by RD Hiscox.
Appeal ref: APP/Q0830/A/05/1189328,
Penpell Farm, Par, St Austell, Cornwall, PL24 2SA,
17 January 2007

Podoshin L; Ben-David J; Pratt H; Fradis M; Sharf B; Weller B; Wajsbort J; Zellinger M.
Auditory brainstem evoked potentials in patients with migraine.
Headache 1987 Jan; 27(1): 27 – 29.

Prasher D.
Widex Noise Report: traffic noise in England 2007.
University College London (UK) and Widex, January 2007, www.widex.co.uk.

Pratt H.
Personal communication, 14 March 2006.

Pratt H.
Personal communication, 15 March 2006.

Rasmussen F; Hartvig Hansen M; Thomsen K; Larsen TJ; Bertagnolio F; Johansen J; Aagaard Madsen H; Bak C; Melchior Hansen A.
Present status of aeroelasticity of wind turbines.
Wind energy 2003; 6(3): 213 – 228.

Renewable Energy Foundation (REF; London, UK).
Studies on wind turbine noise raise further concerns.
REF press release, 4 August 2005.

Renewable Energy Foundation (REF)
Submission to Yelland wind farm planning appeal, Devon, 2 April 2006.

Renewable Energy Foundation (REF).
UK Renewable energy data, Issue 1 (08.12.06): vol. 5: Wind.
Research conducted by Oswald Consultancy Ltd., August 2006,
www.ref.org.uk/energydata.php .

Royal Academy of Engineering.
An engineering appraisal of the PIU energy review.
Royal Academy of Engineering for the Energy Minister, August 2002.

SafetyLine Institute of WorkSafe Western Australia, Department of Consumer and Employment Protection.
Identification of whole-body vibration: effects on health.
Government of Western Australia, 1998.

SafetyLine Institute of WorkSafe Western Australia, Department of Consumer and Employment Protection.
Whole body vibration effects on health.
Government of Western Australia, 1998.

Schomer PD.
For purposes of environmental noise assessment, A-weighting needs to be retired.
JASA Journal of the acoustical society of America 2002 Nov; 112(5, pt 2): 2412.

Sezer-Uzol N; Long LN.
3-D time-accurate CFD simulations of wind turbine rotor flow fields.
[CFD: computational fluid dynamics]
American Institute of Aeronautics and Astronautics: AIAA Paper No. 2006-0394, 2006.

Shepherd KP; Hubbard HH.
Physical characteristics and perception of low frequency noise from wind turbines.
Noise control engineering journal 1991 Jan/Feb; 36(1): 5 – 15.

Shultz T.
Community noise rating, 2nd ed.
Applied Science Publishers, 1982.

Simpson D.
Tilting at windmills: the economics of wind power.
David Hume Institute, no.65, April 2004.

Small Business Council [UK]
UK energy policy: the small business perspective and the impact on the rural economy. Report prepared by C Whitmill.
Small Business Council, February 2006.

Spreng M.
Central nervous system activation by noise.
Noise and health 2000; 2(7): 49 – 58.

Spreng M.
Noise induced nocturnal cortisol secretion and tolerable overhead flights.
Noise and health 2004 Jan-Mar; 6(22): 35 – 47.

Spreng M.
Possible health effects of noise induced cortisol increase.
Noise and health 2000; 2(7): 59 – 64.

Stephens DG; Shepherd KP; Hubbard HH; Grosveld F.
Guide to the evaluation of human exposure to noise from large wind turbines.
NASA National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia (USA), NASA-TM-83288, March 1, 1982.

Stewart J.
Location, location, location.
UKNA United Kingdom Noise Association, August 2006.

Stop Cambridge Wind Farm (UK)
www.stopcambridgewindfarm.org.uk/pages/deeping_st_nicholas.htm
News item about Jane Davis and wind turbine noise issues at Deeping St Nicholas. 2006.

"Stop lying about these turbines." (Kelly Alexander)
Michigan, USA: Holland Sentinel, 31 December 2002.

Styles P.
Summary report to Defence Estates.
Keele University (UK), Report for the Ministry of Defence, 3 March 2004.

Styles P; Manley DMJP.
Low frequency noise and vibration levels at a modern wind farm.
Funded by ETSU on behalf of the Dti, 1996.

Styles P; Stimpson I; Toon S; England R; Wright M.
Microseismic and infrasound monitoring of low frequency noise and vibrations from windfarms: recommendations on the siting of windfarms in the vicinity of Eskdalemuir, Scotland.
Keele University (UK), Report for the Ministry of Defence, 18 July 2005.

Takahashi Y; Yonekawa Y; Kanada K; Maeda S.
A pilot study on the human body vibrations induced by low frequency noise.
Industrial health 1999 Jan; 37(1): 28 – 35.

Tasker J.
'Wind farm noise is driving us out of our house.'
Hunt is on for the source of the elusive 'Whoosh'.
Farmers weekly 12 January 2007.

Turitea man fears he'll have to go.
http://stuff.co.nz , 10 November 2006.

United States Department of Defense.
The effect of windmill farms on military readiness. Report to the Congressional Defense Committees.
Office of the Director of Defense Research and Engineering, US Department of Defense, 2006.

van den Berg GP.
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 2005 Mar; 24: 1 – 24.

van den Berg GP.
Effects of the wind profile at night on wind turbine sound.
Journal of sound and vibration 2004; 277(4-5): 955 – 970.

van den Berg GP.
Do wind turbines produce significant low frequency sound levels?
11th International Meeting on Low frequency noise and vibration and its control, Maastricht, The Netherlands, 30 August – 1 September 2004.

Vanagaite Vingen J; Pareja JA; Støren O; White LR; Stovner LJ.
Phonophobia in migraine.
Cephalalgia 1998; 18: 243 – 249.

Whittle LS; Collins SJ; Robinson DW.
The audibility of low frequency sounds.
Journal of sound and vibration 1972; 21: 431 – 448.

Wolach I; Pratt H.
The mode of short-term memory encoding as indicated by event-related potentials in a memory scanning task with distractions.
Clinical neurophysiology 2001 Jan; 112(1): 186 – 197.

World Health Organisation.
Occupational and community noise. Fact sheet no. 258.
Geneva: WHO, February 2001.

World Health Organisation.
Guidelines for community noise.
Geneva: WHO, 1999.

Wust S; Wolf J; Hellhammer DH; Federenko I; Schommer N; Kirschbaum C.
The cortisol awakening response – normal values and confounds.
Noise and health 2000; 2(7): 79 – 88.

Young N.
Wind power debate blows near and far.
Western Morning News, 23 January 2004

APPENDIX – PROPERTY VALUES

1. INTRODUCTION

This Appendix provides global evidence of the negative impact of wind farms on residential property values where the wind turbines are built nearby.

The valuation of a residential property is what it will fetch in an open market sale. The value will depend upon a number of factors and not least will be the number of potential buyers in the market for that type of property in that location. More than one buyer is likely to trigger a bidding-up situation. Wind farms are normally built in rural locations, therefore apart from accommodation size, important influences on value will often be the view, the peace and serenity, and a rural environment.

It is established that in many rural locations a wind farm will reduce the value of properties located nearby; but as the distance between wind turbines and dwellings increases, the valuation impact is lessened and the prospect of consequent health problems reduced. A part of the loss in value will be attributable to the loss of a quality view. However, a substantial apportionment of the loss in value flows directly from the environmental noise pollution and indeed the consequent health impact that flows directly from the environmental noise pollution. A further smaller part of the loss will be attributable to the rotation of the turbine blades, which in certain circumstances will cause strobing light/shadow flicker, which again can have health repercussions. In a high value area of the country, the potential valuation impact is likely to be higher.

It is important to establish the part of the valuation loss that directly flows from the environmental noise pollution as this, in most instances, will reflect the property damage resulting from the escape of the noise pollution. In a well-populated rural area the cumulative financial damage, the loss imposed on the community, will substantially exceed the 'de minimus' public interest that will be served from the wind farm. The following are samples of reported property devaluations from three continents.

2. U.K.

Case A

TURBINE PLAN CUT VALUE OF OUR HOME BY A THIRD

Western Morning News (Plymouth) 9 December 2004

"A Westcountry farming couple have seen the value of their home slashed by a third since controversial plans were submitted to build three giant wind turbines in one of the region's beauty spots, it has been revealed.

Richard and Lynne Lethbridge say they discovered the devastating news after deciding to sell the home their family has farmed from for decades, because of the plans for the turbines.

Two independent agricultural valuers, which visited the large four bedroom bungalow in East Allington last week, both concluded that since the planning application for the turbines at Goveton was submitted earlier this year, the price of the Lethbridge's near £500,000 home had fallen by £165,000.

NPower's plans, which have been submitted to South Hams District Council, are for three generators, each 100 metres high, to be built on land off the A381 between Kingsbridge and Totnes, next to the turning for Goveton.

Mrs Lethbridge, 57, whose property is the closest to the proposals at just 540 metres away from the development, said she had envisioned living in the area with her husband Richard, 58, for the rest of their lives. But she said that it looked extremely likely they would have to move on. "If the plans go through we will have to sell," she said.

"We're upset because it's detrimental to our health and we are so close that we would hear them and to me it would also be a great eyesore. We decided to have the house valued with a view to selling because we're concerned about our livelihood. Richard is a farmer and has been all his life and for the last 15 years or so I've been a farmer's wife. His parents have been here for over 60 years and he was born here and built the home we are in at the moment on the same land in the early 1970s. I thought we would live here all of our lives and this would then go to our family. We would not have thought of moving but we feel we are being forced out because of this. Mrs Lethbridge said the only way the family would consider staying at their home would be if the plans did not go ahead.

"When we found out about the application we realised it was just 540 metres away. It's too close to us. If the plans go ahead we will move. I don't think anyone could change our minds, which is really sad. Her husband Richard added: "I don't really want to leave here, but the noise will be a big problem and with the health issues and the loss of view it will be too much. It doesn't matter how much compensation we would get, if any, because it would be the view and the way of life we would lose."

Case B

In a survey of its members in November 2004, **The Royal Institution of Chartered Surveyors** issued 1942 questionnaires and received 405 responses, of which 20% (81) had dealt with transactions affected by wind farms. The Report stated:

"Actual effect:

-- there are negative influences on the values of residential properties, though a sizeable minority report no impact on prices.
-- nowhere is it considered that wind farms positively affect residential property values ...."

"The regional results vary from 44% of surveyors in Wales reporting that residential property values are lower as a result of wind farm developments to a high of 77% in the South West."

"Conclusions:

The three main reasons for this negative impact on property values are the visual impact after completion, the fear of blight and the proximity of residential property to a wind farm development"
The negative impact of wind farms on property values appears to decline over time. This may suggest that the impact lessens as wind farms become more established."

The last conclusion appears tentative and there is no evidence in the report to support this view.

Once the zone of pollution falls in value its lower relative position to other nearby similar but unaffected properties becomes established. From this new relationship of property values, the market residential property inflation will apply to the polluted zone, but in some locations, it may be argued that the pollution is sufficiently severe that a lower inflation level will apply.

A simple example:

Consider similar properties, one in village A valued at £460,000 and a second in village B valued at £460,000. A wind farm is built close to the property in village A decreasing the price the property would fetch in a sale to £280,000. The property in village B is unaffected. After 5 years of 6% compound property inflation, the village A property will rise in value to £374,700 but the house in village B will have risen in value to £615,580, a loss to the house in village A of £240,880.

Some might argue that the rise in value of the house in village A represents a recovery from the initial impact of the wind farm. Others will contend the damage in terms of financial loss remains with the property.

Case C

WINDFARM BLOWS HOUSE VALUE AWAY

Westmorland Gazette, 9 January 2004

"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 that they had vigorously opposed the initial application for the wind farm in 1995.

District Judge Buckley decided that this amounted to material misrepresentation and ordered the Holdings to pay compensation of 20% 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."

Case D

In a letter to a client about the effect of wind turbines on property values, dated May 1998, Estate Agent **FPD Savills** [Norfolk Office] 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."*

Case E

PRICES FALLING

Lynwen Evans, Cambridge News, 11 April 2005

"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
http://www.cambridge-news.co.uk/news/letters/2005/04/11/529e6c57-a1ec-428b-ad0c-855515b543cc.lpf

Case F

In a letter to the ***Brecon and Radnor Express and Powys County Times***, 27 July 1995, Mrs Moores of Bucks wrote:

> *"My mother lives in Wales within sight of a wind factory. For two years we have been trying to sell her house as she is old and frail and wishes to buy a place near us in Bucks ... So be warned – it seems that once a wind factory is built within sight of your home , the value drops considerably. We have been forced to drop nearly to half the original price and have still not sold."*

Case G

The Managing Director of Bradleys, (Chartered Surveyors), wrote the following letter in November 2004, to the Denbrook Valley Action Group, which is opposing wind turbines in Mid Devon.

> *"Dear Sirs*
> *Thank you for your e.mail dated 3rd November 2004, with respect to a proposal to develop a site of 10 or more (approximate) 300-400 foot wind turbines in the Denbrook Valley between Spreyton, Bow and North Tawton.*
>
> *You have requested that I comment on various matters with respect to this proposed development.*
>
> *There is no doubt that no added value would be brought to a property sited within the locality of such a development.*
>
> *It is likely that properties sited within the locality of such a development will be devalued , although the amount of devaluation will depend heavily on not just the proximity but also on individual matters affecting the uniqueness of each property such as spoiling the view or being affected by noise pollution. If, for example, a wind turbine is only 300 metres away from a property it may be in such a position that it cannot be heard or seen. But another property, say 800 metres away could be in full view of the turbine and also subject to its noise pollution.*
>
> *Under certain circumstances it would be possible for a property within 600 - 800 metres to be devalued by some 30%, property within 1 mile possibly 20% and property within 2 miles possibly 10%. It is important to stress that each individual property would be affected in a different way.*
>
> *Although it is conceivable that a property within 600/800 metres of such a development would be un-saleable there is no doubt that the property could be significantly devalued, and no doubt its marketability adversely affected.*
>
> *It should be taken into account that the area in question is one of high desirability and high value and one of the most important reasons for this is its beautiful mid Devon countryside location. Therefore the area around the proposed development would be significantly affected.*
>
> *With regard to the two comments that "there is no evidence of a general devaluation of local property prices caused by a wind farm", and "the lack of*

a house price affect is also confirmed by the Royal Institution of Chartered Surveyors who state that there are no studies that suggest an affect either way", these comments are not actually saying that property prices are not being devalued, they are only stating that there are no studies which have been carried out with regard to the price affect.

I would also point out that any Chartered Surveyor carrying out a valuation on a property in the West Country, where in the proximity there are features such as electricity pylons, radio masts and wind turbines, then there will be a comment in that report that it could affect value, marketability, and/or resaleability.

Yours sincerely
BRADLEYS SURVEYORS

Case H

In a letter of 22 October 2003, South West Estate Agent J Carslake of **Kivells Estate Agents**, Holsworthy, wrote to a client advising:

"It is the case that a wind turbine within sight or sound of a residential property will affect the value of the property detrimentally. The affect on value would, in my opinion, be up to 50% of ordinary open market value, but it is difficult to provide proof of this."

"It is certainly also the case that the threat of a windfarm close to a property can make it un-saleable (I have a case in Bradworthy for example) and would certainly assert that the marketing becomes much more problematic when a wind turbine is situated within sight or sound."

Case I

Evidence of reduced house prices as a direct result of the threat and/or presence of wind turbines can be found on the website of the **Mynydd Llansadwrn Action Group (Wales)** [http://www.turbineaction.co.uk/wind-turbine-facts.htm#refs]

"In May 2005, a local resident near Brechfa reported in the Carmarthen Journal that:

"Our property, in the middle of the proposed TAN8 site (Strategic Area G) had a firm offer of £318,000. One week later our prospective purchaser, who incidentally knew about the turbines and had no problem with them, said they would do us a favour and 'take it off our hands at a big financial risk - for a reduced £250,000 which was higher than the 40 per cent we could expect to get, being near turbines!' "

Case J

Surveyor and Valuer Gareth Scourfield inspected a number of properties in July 2005 near a proposed development of 10 wind turbines at Esgairwen Fawr, Lampeter Wales.

In his report entitled *'Report on a sample of properties inspected near a proposed wind farm at Esgairwen Fawr, near Lampeter, Ceredigion'* (July 11, 2005), he wrote:

"The proposed development also towers over houses in Mydroilyn village. Given a sample of properties inspected and reported as above [i.e., in his Report] *this represents an immediate loss of £1,528,000 for the 8 properties mentioned, let alone all those which may be affected by the turbines, both by seeing them and hearing them."*

Case K

Giant blades are slicing prices

Sunday Telegraph, 17th October 2004, House and Home supplement, page 2
[Excerpts from article by Ross Clark]

Homeowners on the damp expanses of Romney Marsh in Kent have long had to contend with the presence of Dungeness nuclear power station, asking themselves what would happen if it blew its top. Rather less might they have suspected that they would one day find themselves cursing the nuisance posed by "green" renewable energy. Last week, the DTI began an inquiry into plans for a wind farm whose 27 turbines will spread over 1,000 acres of the marsh and stretch into the sky 370ft.

Much of the recent debate over wind farms has revolved around whether they lower the value of nearby properties. Until earlier this year, the British Wind Energy Association (BWEA) maintained that wind farms do not affect values - in fact, the association listed this as one of the "top 10 myths about wind farms" on its website.

In January, however, came the case of Barry Moon, who won £15,000 in damages against the previous owners of his four- bedroom home at Marton, near Ulverston, Cumbria. The vendors had failed to warn Moon about plans for a wind farm on a nearby hill. After hearing evidence from chartered surveyors, the judge made an award on the basis of a 20 per cent reduction in value of Moon's home due to the visual impact of the turbines and the annoying, low-frequency hum. "I've lived a similar distance from the M3 as we live from the wind turbines," says Moon, "but this was a lot worse. What is irritating is the way the whooshing keeps increasing and decreasing in magnitude."

While the Moon case established in law for the first time that a wind farm can lower the value of a home, it did nothing to help homeowners win compensation from the builders and operators of wind farms.

What residents can do is ask the environmental health officer at their local authority to measure the sound produced by the turbines and declare a statutory noise nuisance. As a result of measurements taken by Barrow District Council, Moon managed to persuade Powergen, the operator of the wind farm, *to install a noise management system, which shuts down three of the turbines when the wind is coming from a certain direction.*

Three other couples, who live within half a mile of the turbines, had a less happy experience. In January, they took Powergen to Kendal Magistrates Court to win a noise abatement order - and lost. "We were told that our evidence lacked specificity, even though we had 26 recorded cases of noise nuisance," says David Brierley, a former policeman who wasn't named in the case, but who helped the residents compile their evidence.

"The noise management system doesn't work. I live 1,000m 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 synchronise with the thump of the blades."

If the experience of Cumbrian homeowners is anything to go by residents within a mile or so of the proposed Romney Marsh wind farm will have an uphill struggle selling their properties from now on.

Kyle Blue, a Penrith estate agent, runs a protest group objecting to a proposed 27-turbine wind farm at Whinash, Cumbria. In May, the Advertising Standards Authority (ASA) upheld a complaint against him by the BWEA for claiming, on the group's website, that the wind farm would affect property values (the ASA indicated it would have been happy with <u>might</u> affect property values).

Yet when his company auctioned Bretherdale Hall, a semi-derelict farmhouse half a mile from the proposed turbines; it fetched £200,000 - £80,000 less than its valuation before the plans for wind farms were announced.

Another nearby property, a freshly restored £340,000 farmhouse, found a buyer who said the wind farm wouldn't bother him because he was keen on renewable energy. "Then, he went away, did some research and changed his mind," says Blue. The house remains unsold.

<u>Case L</u>

In May 2000, Estate Agents Russell Baldwin & Bright, Brecon in Powys, wrote the following to letter a client:

> *"Further to our telephone conversation last week I confirm that I have withdrawn your property from the market.*
>
> *As discussed since the proposed Wind farm 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 earlier marketing which resulted in an excellent number of viewings. There is however, little point in continuing to market your property 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 at Merthyr Cynog having serious doubts over its 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."*

3. AUSTRALIA

Case A

HOUSE VALUES DECLINE WITH TURBINES CLOUDS GATHERING OVER WIND FARM PLAN

The Australian, January 9, 2006, by Natasha Robinson

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.
*Web link: http://www.theaustralian.news.com.au/common/story_*

Case B

In **'Research of property devaluations'**, the author, Eleanor Tillinghast (Green Berkshires, Inc, Massachusetts, 2004), reports:

"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'*
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."

4. Denmark

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'*.

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 facility to US $16,800 for a 12-turbine site. [Tillinghast, 2004]

5. Germany

Case A

The Darmstadt Manifesto (1 Sept. 1998), signed by more than 100 university professors in Germany, states:

"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 ..."

Case B

FIGHT AGAINST WIND POWER

Olympic and World Champions have got together: they demand that Wind Power Stations be Built Away from Riding Stables

"Riders, friends of the riding community and owners of equestrian and breeding businesses are anxiously watching the encroachment of wind power installations over the landscape both in the Lander and throughout the country as a whole - chief among them Judith and Klaus Balkenhol. They want to prevent wind power stations from creeping even closer to riding stables. The signatories of the Memorandum are particularly concerned that equestrian businesses which will be affected are not consulted during the application process. The construction of wind power stations close to such establishments puts into jeopardy the livelihoods of numerous businesses and endangers many jobs. Constructions in the open countryside threaten not only trekking but also recreational riding. Noise and flicker from the turbines do considerable harm to horse and rider and endanger them equally. It is not for nothing that a statutory separation was made compulsory over 200 years ago between windmills and open roads, otherwise the horse shies ("spooks"). The effect of breeding means that there is now a considerably greater number of highly sensitive horses." (Quote from the Memorandum).

The riding community demand a separation of 2,500 - 3,000 metres [2.5 - 3.0 kilometres] between horses and windfarms.

All sensible people are in favour of alternative energy. But when these wind mills – which may be environmentally but not visually friendly – shoot out of the ground like mushrooms right before your very door, then it is quite a different matter. They are particularly unloved by horse people because the noise the blades make at various times and at various volumes, drives the horses wild, at least in the case of sensitive types such as dressage horses. Klaus Balkenhol, former Federal (German) trainer and now a national US team trainer, has himself now experienced this. The wind turbine which is 1 km away from his stables at Rosendahl in Munsterland often irritates the horses he is training to such an extent that any sensible work, to say nothing of hacking in the vicinity of the turbine, is out of the question.

A further 6 turbines are now being planned – something that Balkenhol discovered only by accident. "The Americans are not willing to train under these conditions," Balkenhol's wife, Judith said. "The (US National) team has made that clear to us.

The equestrian establishment, which lies in the shadow of the wind mills, is up for sale, "only at half the price, at the most, of what we invested in it."

A petition signed by numerous top German riders and 17 thoroughbred studs is expected to draw the attention of the authorities to the dangers and damage caused to riding establishments by wind installations. Not only competition riders but recreational riders as well, find little joy in riding beneath the whirlwind. "And all the time Munsterland advertises its ideal conditions for riders," said Judith Balkenhol.

6. New Zealand

TURITEA MAN FEARS HE'LL HAVE TO GO

The Daily News Watch, New Zealand, by Helen Harvey, November 10, 2006

A Turitea man says he will be forced from his home because Mighty River Power told him noise from wind turbines in the reserve will make his house uninhabitable.

Mark Nicholls has been living in his slice of paradise for 10 years. He has 20 hectares of native bush, 13ha of pasture, which he farms, and a view to die for. It is so private that he can bathe on his veranda.

He doesn't want to move, he said. "It's hard to achieve what I have here on my budget."

He first heard the news 12 months ago that four wind turbines from the proposed Mighty River Power/Palmerston North City Council wind farm would be 500m from his boundary.

The state-owned power company's representatives told him the noise from the turbines would make his house uninhabitable, he said.

In city council documents on the wind farm, it said that at 500m from a turbine, the accepted standard of noise should be between 40 and 50 decibels.

The report, presented at the infrastructural well-being committee on October 18, said 40 decibels is equivalent to that of a public library and a loud radio would be 70 decibels. An Ashhurst family had to leave their house last year because noise and vibration from the Te Apiti wind farm made it impossible for them to stay.

Mr Nicholls said his life has been on hold for a year and he is angry that an SOE (Mighty River) and a city council (he lives in the Tararua district) can destroy his idyllic rural paradise.

"Mighty River Power has made a lot of noise that in the fullness of time they will discuss a relocation package. This has been going on for 12 months."

He has asked the energy company what is happening, because he wants to get on with his life. "(They say) talks will take place in due course when the final location of the turbines has been established," he said.

"When you are told you can't live in your property, it changes your life. It's being told your life is going to change, but there is no qualification, no time frame. I don't know where I'm going to be in six months' time, one year's time. I can't plan. I feel that it's frustrating that one's life can be put on hold, not just mine, but my family's as well."

7. <u>U.S.A.</u>

<u>Case A</u>

Potential lessors get warning letters about turbine plan

Several residents oppose wind project in Cherry Valley
by Tom Grace Cooperstown News Bureau [New York, USA] 03/30/05

The attorney for residents opposed to wind turbines in Cherry Valley has sent warning letters to those who might lease their land for the project. The letters are intended to dissuade prospective lessors from participating in the project, said the writer, lawyer Peter Henner of Clarksville.

In the event the project, under consideration by Reunion Power of Montvale, N.J., goes forward, lawsuits may be filed. Henner said Tuesday that his clients want to be in the position of having warned their neighbors in advance.

Among the recipients of a letter from Henner is Daniel Wightman of Portlandville. His property east of the village of Cherry Valley is under active consideration by Reunion.

In a letter dated March 23 and provided to The Daily Star, Henner wrote to Wightman:

"I represent Raymond J. and Susan C. Rivard, Andrew and Kathleen Minnig, Linda VanSchaick, Philip and Leila Durkin, Patrick Shearer, Lynae Quimby, Steven and Angela Witham, Mark and Eliza Oursler, Diana Wells, Roy J. Hall and Paul Petersen, who own property that is in close proximity to your property in the town of Cherry Valley."

"It is my understanding that you are considering leasing a portion of your land to be used for the construction of wind turbines. Because these turbines may have an adverse impact upon my clients, I am writing to you to warn you that my clients will hold you responsible for any damage to their property that may result from these wind turbines."

Henner wrote that the windmills might cause his clients' property to depreciate, in which case, they "may have little choice but to commence an action to recover for the diminution in value of their property. They may also hold you liable for any adverse impacts, including the diminution of the quality of life that may result from the wind turbines."

Even if the windmills are built out of sight of his clients' homes, they may sustain a loss if the turbines can be heard from their residences, Henner said."

<u>http://www.thedailystar.com/news/stories/2005/03/30/win5.html</u>

Case B

Wind farm opponents speak out
More testimony set for tonight

By Mike Johnston, Kittitas Valley News [Washington, USA]
12 January 2006

Opponents of the Kittitas Valley Wind Power Project dominated Wednesday's second hearing on the wind farm proposed for 12 miles northwest of Ellensburg. They said the damage to scenic views from the wind turbines can't be lessened and will reduce property values.

Horizon has applied for up to 80 turbines ranging in height from 250 to 410 feet high, but company officials say they will only build 64.

The Desert Claim project, proposed by EnXco USA Inc. and centered eight miles north of Ellensburg, planned 120 turbines.

Slothower said those factors include conflicts with an increasing number of rural residences being built nearby and the subdivision of land for future homes and recreation, damage to the scenic views and others.

Colleen Anderson of Peavine Road, a real estate agent with Coldwell Banker-Kittitas Valley Realty, said she has compared average land sales near the wind farm with overall average county land sales involving parcels ranging from three to 20 acres. The sales took place in the last six months.

Anderson said land sales near the project area averaged $66,038, but the average countywide sale price was $126,223, a difference of $60,185. She also said lands for sale near the project area linger on the market longer.

'Based on this information,' Anderson said, 'it is my professional opinion that real estate values are adversely affected by the wind farms.'

She called on the two commissions to deny the project.

http://www.kvnews.com/articles/2006/01/12/news/news02.txt

Case C

The Wayward Wind

by Jon Boone, Silver Lake, New York, USA, 19 June 2006

"Do you believe industrial facilities stretching many miles across your landscape, with 105 spinning sky-scraper sized structures creating a cascade of noise are not going to negatively affect property values for those in the neighborhood, as the wind industry maintains a government study proves? One of the most validated real estate precepts is that prominent natural views and historic scenery have premium value, and intrusions restricting those views erode value ...

There are few windplants in the world, let alone the United States, with turbines over 400 feet tall placed so prominently near a resort community ...

Independent inquiry in Britain, Denmark, and New England suggest the likelihood of significant property devaluations. In his June 10, 2005 direct testimony before the Wisconsin Public Service Commission, Kevin Zarem, an appraiser, estimated that residential property near a proposed windplant "will likely be in the 17% -- 20% loss range." And this is based solely upon visual impact. He did not assess potential loss due to wind turbine noise, motion, or shadows.

Russell Bounds, one of Garrett County's leading realtors in large property transactions ... has already lost sales in the area of proposed windplants. Mr. Bounds testified in a PSC hearing 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 wind facilities, not one of those people expressed further interest."

... I have seen contracts which require land owners and encourage neighbors to sign a "memorandum of non-disturbance easement agreement," which absolves the wind company from liability for what the owners might regard as wind turbine-related nuisances."

<u>**Case D**</u>

Hearing for a proposed wind turbine development in Maryland, in 2006,

The panel heard the testimony of Russell Bounds, Railey Realty, McHenry, Garrett County, Maryland, a licensed estate agent and property appraiser. The following is taken from his recorded testimony at the hearing.

'In 2004, Mr Bounds' sales totaled more than $15,000,000; his volume of sales has averaged about $12,000,000 per year. His work in Garrett County covers mountain or acreage properties in a place of natural beauty. In his testimony, Mr Bounds was asked if had visited areas where wind turbines are 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 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."

Mr Bounds had viewed properties with the turbines at a distance of three miles to "very close by." Asked "What effect, if any, has the wind turbines had on the special characteristics of properties that are nearby the wind turbines?", Mr Bounds responded:

"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."
Mr Bounds answered "Yes," when he was asked if he had heard from people living near wind turbines and if they had told him about any problems:

"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 ... 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 asked if the noise had any substantial impact on the use of the property, Mr Bounds replied:

"Yes. It takes away the enjoyment of their property. It doesn't allow them to sleep at night."

"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."

Mr Bounds testified that he knew of property transactions in Somerset, Pennsylvania that were sold for substantially less than their prior sale price because of the proximity and impact of wind turbines. Mr Bounds continued,

"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 of the properties were presented as exhibits.) Somerset Windpower, LLC purchased the property of David Ray Sass for $104,447.50 and sold it to Jeffrey A. Ream for $65,000 ... Keith and Billie Sarver sold their property to Somerset Windpower LLC for $101,049.00. Shortly thereafter it sold for only $20,000."

'Another property -- unimproved, was purchased for $12,600 only a few years earlier, The house was five years old when sold for $67,000, at about the same time as the other houses were sold. Mr Bounds noted that, "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."

Mr Bounds also replied that he had heard the wind turbine noise himself:

"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."

With his research and professional expertise, Mr Bounds concluded:

"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 un-developable. Some parcels may be rendered un-saleable. 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."

Case E

In Michigan, David Maturen, a real estate appraiser and Kalamazoo (Michigan) County Commission, wrote the following letter to the Michigan Wind Working Group, 9 September 2004:

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.

The REPP study, The Effect of Wind Development on Local Property Values, is a 78 page report which was published in May 2003. They studied 10 areas of the country. The study surveyed assessed values and properties within 5 miles of a wind farm and showed no diminution in value to those properties due to the presence of the wind farms. Critiques have been made regarding the methodology used in that study.

The Beacon Hill Institute issued an initial 53 page report in October 2003 - Blowing in the Wind: Offshore Wind and the Cape Cod Economy and a follow up 34 page report in March 2004 - Free but Costly: An Economic Analysis of a Wind Farm in Nantucket Sound. The studies focus on Nantucket Sound in Massachusetts relative to the Cape Wind Associates proposed 130 wind turbine generator (WTG) offshore wind farm. The 2003 study projected 1) a small decline in tourism resulting in a loss of 1,173 to 2,533 jobs and 2) a decline in property values of 4.6% (10.9% for waterfront property) or $1.35 billion and a concomitant loss in tax revenue to the area of $8 million. Criticisms of that report have also been made.

The Tennessee Valley Authority (TVA) study on a proposed wind farm in Tennessee consisting of 13 to 16 WTGs reviewed literature on the issue. Appendix F of the study cites several studies on wind farms and their impacts. Among those are:

1. The April 1996 Danish study: Social Assessment of Windpower – Visual Effect and Noise from Windmills – Quantifying and Evaluation. It concluded that 13% of people living near windmills considered them a nuisance. Property values showed a loss in housing prices from $2,900 (for one WTG) to $16,000 (for a 12 unit wind farm).
2. The ongoing study in Wisconsin thought to be done in 2003. My conversation with Steve Brick of the Energy Center of Wisconsin indicated that as of this Spring their study was not finished.
3. The TVA study does mention the value of a viewshed as a percentage of the value of improved property at 8% in Fairfax, Virginia and a South Carolina analysis regarding vacant lot premiums of 147% for an ocean view, 115% for a creek or marsh view, and 39% for a golf course view.

The 2002 Strutt & Parker study of the Edinbane Windfarm on the Isle of Skye notes that the proposed 41 turbines would have a major impact on the locality. They estimated that nearby property values would decline by over $1 million. They also note at 6.18 of their report that "In Germany, Estate Agents report diminution in values of between 20% to 30% for properties in sight of wind farms. We understand that FPD Savills have reported similar levels of depreciation for properties in Norfolk."

The report of the Township of Lincoln Wind Turbine Moratorium Committee, Kewaunee, Wisconsin (2000 to 2002) notes that the Town of Lincoln building inspector compiled a list of home sales. The list compared the property's selling price as a function of the distance to an existing 22 WTG farm in the area. His 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

<u>Case F</u>

"Wind turbines don't make good neighbors : some problems of wind power in the Berkshires"

By Eleanor Tillinghast, Green Berkshires, Inc., Massachusetts, May 14, 2004

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.

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. "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."

As part of a study of the proposed Cape Wind [Massachusetts] 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.

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 Sound 'slightly' or 'a lot'.

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.

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.

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.

It's worth noting that of the home owners surveyed, 94% did not have homes with a view of the Sound. 76% were not members of a conservation or environmental organization. Regardless, their main reasons for living in the area were the 'beauty of the region,' 'the beaches,' and 'the ocean views.'

Comment

In the various reports included in this Appendix, it is clear that individuals from rural communities within the three Continents considered in this **Appendix** are experiencing or are likely to experience economic loss through the potential or actual impact of wind turbines located close their homes.

The continual economic survival of rural communities depends both on 'old' and 'new' wealth creation. Many rural communities have enjoyed economic growth and social benefits from the influx of 'life style' families, young and old, who have brought with them wealth and economic opportunity to their chosen new communities. 'Life style' families are often seeking the pleasures of rural life and unspoilt countryside, away from the commercial and industrial development that is characteristic of our towns and cities. The devaluation of assets such as property by rural industrialisation is likely to deter further migrations to the countryside, and over time, this will inevitably reduce new economic injection into these areas.

State development-control decision-makers, who allow the industrialisation of rural settlements, with the consequent environmental pollution, are likely to trigger a slide back into rural economic deprivation as the lifetime savings of people living in these communities are eroded by the devaluation of their properties.

Peter Hadden

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VIII. Noise-Con 2008 Paper

Dearborn, Michigan

NOISE-CON 2008

2008 July 28-31

Simple guidelines for siting wind turbines to prevent health risks[30]

By:

George W. Kamperman, INCE Bd. Cert. Emeritus
Kamperman Associates, Inc.
george@kamperman.com

Richard R. James, INCE
E-Coustic Solutions
rickjames@e-coustic.com

Revision: 2.1[31]

Industrial scale wind turbines are a familiar part of the landscape in Europe, U.K. and other parts of the world. In the U.S., however, similar industrial scale wind energy developments are just beginning operation. The presence of industrial wind projects will increase dramatically over the next few years given the push by the Federal and state governments to promote renewable energy sources through tax incentives and other forms of economic and political support. States and local governments in the U.S. are promoting what appear to be lenient rules for how industrial wind farms can be located in communities, which are predominantly rural and often very quiet. Studies already completed and currently in progress describe significant health effects associated with living in the vicinity of industrial grade wind turbines. This paper reviews sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance problems. The purpose is to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines. Findings of the review and recommendations for sound limits will be presented. A discussion of how the proposed limits would have affected the existing sites where people have demonstrated pathologies apparently related to wind turbine sound will also be presented.

Background

A relatively new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial grade wind turbines, a common sight in many European countries, are now being promoted by Federal and state governments as the way to minimize coal powered electrical energy and its effects on global warming. But, the initial developments using the newer 1.5 to 3 MWatt wind turbines here in the U.S. has also led to numerous complaints from

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31 The criteria table at the end of this paper and portions of the narrative have been revised to reflect our current understanding of how to specify the sound limits with less ambiguity and to use the new format for presenting them.

residents who find themselves no longer in the quiet rural communities they were living in before the wind turbine developments went on-line. Questions have been raised about whether the current siting guidelines being used in the U.S. are sufficiently protective for the people living closest to the developments. Research being conducted into the health issues using data from established wind turbine developments is beginning to appear that supports the possibility there is a basis for the health concerns. Other research into the computer modeling and other methods used for determining the layout of the industrial wind turbine developments and the distances from residents in the adjacent communities are showing that the output of the models should not be considered accurate enough to be used as the sole basis for making the siting decisions. .

The authors have reviewed a number of noise studies conducted in response to community complaints for wind energy systems sited in Europe, Canada, and the U.S. to determine if additional criteria are needed for establishing safe limits for industrial wind turbine sound immissions in rural communities. In several cases, the residents who filed the complaints have been included in studies by medical researchers who are investigating the potential health risks associated with living near industrial grade wind turbines 365 days a year. These studies were also reviewed by the authors to help in identifying what factors need to be considered in setting criteria for 'safe' sound limits at receiving properties. Due to concerns about medical privacy, details of these studies are not discussed in this paper. Current standards used in the U.S. and in most other parts of the world rely on not-to-exceed dBA sound levels, such as 50 dBA, or on not-to-exceed limits based on the pre-construction background sound level plus an adder (e.g. L_{90A} + 5 dBA).

Our review covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The papers are listed in Tables 1-4.

Table 1-List of Studies Related to Complaints

Resource Systems Engineering, Sound Level Study - Ambient & Operations Sound Level Monitoring, Maine Department of Environmental Protection Order No. L-21635-26-A-N, June 2007
ESS Group, Inc., Draft Environmental Impact Statement For The Dutch Hill Wind Power Project - Town of Cohocton, NY, November 2006
David M. Hessler, Environmental Sound Survey and Noise Impact Assessment - Noble Wethersfield Wind park - Towns of Wethersfield and Eagle NY For: Noble Environmental Power, LLC January 2007
George Hessler, "Report Number 101006-1, Noise Assessment Jordanville Wind Power Project," October 2006
HGC Engineering, "Environmental Noise Assessment Pubnico Point Wind Farm, Nova Scotia, Natural Resources Canada Contract NRCAN-06-0046," August 23, 2006
John I. Walker, Sound Quality Monitoring, East Point, Prince Edward Island" by Jacques Whitford, Consultants for Prince Edward Island Energy Corporation, May 28, 2007

Table 2- List of Studies related to Health

Nina Pierpont, "Wind Turbine Syndrome - Abstract" from draft article and personal conversations. www.ninapierpont.com
Nina Pierpont, "Letter from Dr. Pierpont to a resident of Ontario, Canada, re: Wind Turbine Syndrome," Autumn 2007
Amanda Harry, "Wind Turbine Noise and Health" (2007)
Barbara J. Frey and Peter J. Hadden, "Noise Radiation from Wind Turbines Installed Near Homes, Effects on Health" (2007)
Eja Pedersen, "Human response to wind turbine noise - Perception, annoyance and moderating factors, Occupational and Environmental Medicine," The Sahlgrenska Academy, Gotenborg 2007
Robin Phipps, "In the Matter of Moturimu Wind Farm Application, Palmerston North, Australia," March 2007
WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005

Table 3-List of Studies that review Siting Impact Statements

Richard H. Bolton, "Evaluation of Environmental Noise Analysis for 'Jordanville Wind Power Project,'" December 14, 2006 Rev 3.
Clifford P. Schneider, "Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility," Lowville, NY - 2007

Table 4-List of Research and Technical papers included in review process

Anthony L. Rogers, James F. Manwell, Sally Wright, "Wind Turbine Acoustic Noise," Renewable Energy Research Laboratory, Dept. of ME and IE, U of Mass, Amherst, amended June 2006
ISO. 1996. Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation. International Organization of Standardization. ISO 9613-2. p. 18.
G.P. van den Berg, "The Sounds of High Winds - the effect of atmospheric stability on wind turbine sound and microphone noise," Ph.D. thesis, 2006
Fritz van den Berg, "Wind Profiles over Complex Terrain," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
William K. G. Palmer, "Uncloaking the Nature of Wind Turbines-Using the Science of Meteorology," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Soren Vase Legarth, "Auralization and Assessment of Annoyance from Wind Turbines," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Julian T. and Jane Davis, "Living with aerodynamic modulation, low frequency vibration

and sleep deprivation - how wind turbines inappropriately placed can act collectively and destroy rural quietitude," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
James D. Barnes, "A Variety of Wind Turbine Noise Regulations in the United States - 2007," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
M. Schwartz and D. Elliott, Wind Shear Characteristics at Central Plains Tall Towers, NREL 2006
IEC 61400 "Wind turbine generator systems, Part 11: Acoustic noise measurement techniques,".rev:2002

Discussion

After reviewing the materials in the tables; we have arrived at our current understanding of wind turbine noise and its impact on the host community and its residents. The review showed that some residents living as far as 3 km (two (2) miles) from a wind farm complain of sleep disturbance from the noise. Many residents living one-tenth this distance (300 m. or 1000 feet) from a wind farm are experiencing major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions cause the sounds heard at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources do not appear to be appropriate for siting industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the approximately one (1) second repetitive swoosh-boom-swoosh-boom sound of the turbine blades and "low frequency" noise. It is not apparent to these authors whether the complaints that refer to "low frequency" noise are about the audible low frequency part of the swoosh-boom sound, the one hertz amplitude modulation of the swoosh-boom sound, or some combination of both acoustic phenomena.

To assist in understanding the issues at hand, the authors developed the 'conceptual' graph for industrial wind turbine sound shown in Figure 1. This graph shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; Young's threshold of perception for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening in near Ubly, Michigan a quiet rural community located in central Huron County. (Also called: Michigan's "Thumb.") It is worth noting that this rural community demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

During our review we posed a number of questions to ourselves related to what we were learning. The questions (italics) and our answers are:

Do National or International or local community Noise Standards for siting wind turbines near dwellings address the low frequency portion of the wind turbine's sound immissions?[32] No! State and Local governments are in the process of establishing wind farm noise limits and/or wind turbine

[32] Emissions refer to acoustic energy from the 'viewpoint' of the sound emitter, while immissions refer to acoustic energy from the viewpoint of the receiver.

setbacks from nearby residents, but the standards incorrectly presume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby residents? Yes! But the Wind Industry recommended residential wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for implementing pre-construction computer models may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

Are all residents living near wind farms equally affected by wind turbine noise? No, children, people with pre-existing medical conditions, especially sleep disorders, and the elderly are generally the most susceptible. Some people are unaffected while some nearby neighbors develop serious health effects caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Initially, the most common problem is chronic sleep deprivation during nighttime. According to the medical research documents, this may develop into far more serious physical and psychological problems

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between source and receiver, and/or 2) reduce the source sound power immission. Either solution is incompatible with the objective of the wind farm developer to maximize the wind power electrical generation within the land available.

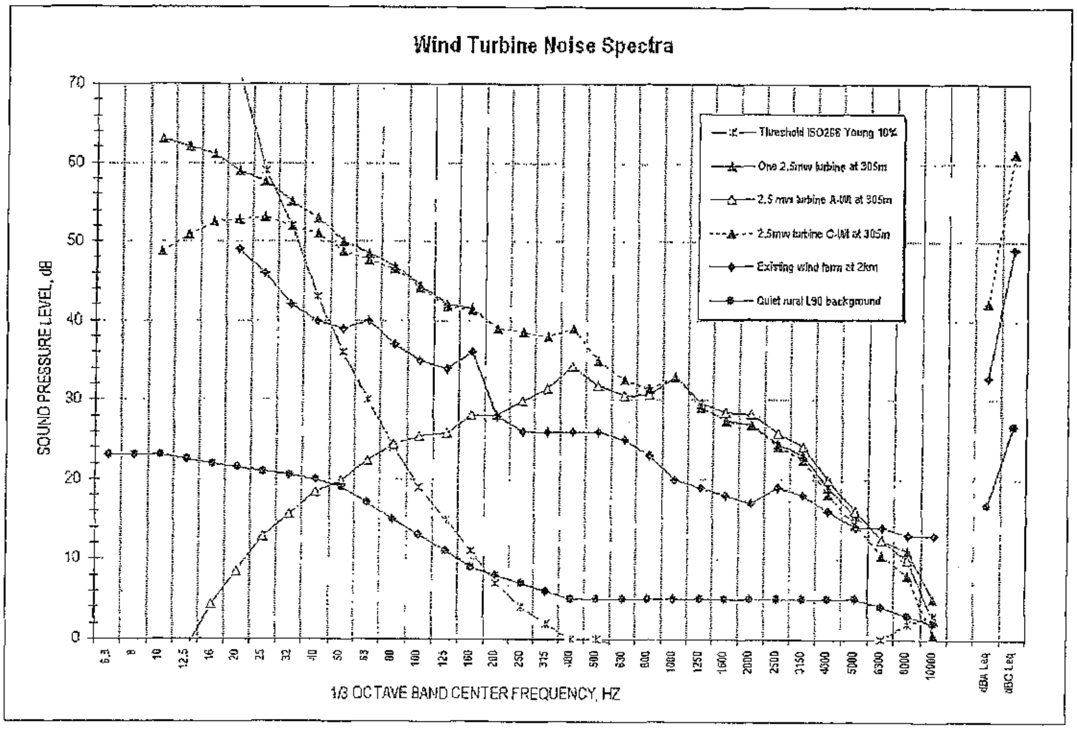

Figure 1-Generalized Sound Spectra vs. perception and rural community L_{90A} background 1/3 octave SPL

Is wind turbine noise at a residence much more annoying than traffic noise? Yes, researchers have found that "Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0-37.5 dB. This could be due to the presence of amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise." [JASA 116(6), December 2004, pgs 3460-3470, "Perception and annoyance due to wind turbine noise-a dose-relationship" Eja Pedersen and Kerstin Persson Waye, Dept of Environmental Medicine, Goteborg University, Sweden]

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? This issue is now being studied by the medical profession. The affected residents complain of the middle to high frequency swooshing sounds of the rotating turbine blades at a constant repetitive rate of about 1 hertz plus low frequency noise. The amplitude modulation of the swooshing sound changes continuously. The short time interval between the blade's swooshing sounds described by residents as sometimes having a thump or low frequency banging sound that varies in amplitude up to 10 dBA. This may be a result of phase changes between turbine emissions, turbulence, or an operational mode.. The assumptions about wall and window attenuation being 15 dBA or more may not be sufficiently protective considering the relatively high amplitude of the wind turbine's low frequency immission spectra.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Example criteria include: Australia-the lower of 35 dBA or L_{90} + 5 dBA, Denmark-40 dBA, France L_{90} + 3 (night) and L_{90} + 5 (day), Germany-40 dBA, Holland-40 dBA, United Kingdom-40 dBA (day) and 43 dBA (night) or L_{90} + 5 dBA, Illinois-55 dBA (day) and 51 dBA (night), Wisconsin-50 dBA and Michigan-55 dBA. Note: Illinois statewide limits are expressed only in nine contiguous octave frequency bands and no mention of A-weighting for the hourly l_{eq} limits. Typically, wind turbine noise just meeting the octave band limits would read 5 dB below the energy sum of the nine octave bands after applying A-weighting. So the Illinois limits are approximately 50 dBA (daytime 7 AM to 10 PM) and 46 dBA at night, assuming a wind farm is a Class C Property Line Noise Source.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing an immission limit of 35 dBA or L_{90A} + 5 dBA whichever is lower and also a C-weighted criteria to address the impacted resident's complaints of wind turbine low frequency noise: For the proposed criteria the dBC sound level at a receiving property shall not exceed L_{90A} + 20dB. In other words, the dBC operating immission limit shall not be more than 20 dB above the measured dBA (L_{90A}) pre-construction nighttime background sound level. A maximum not-to-exceed limit of 50 dBC is also proposed.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{90A}? The World Health Organization and others have determined a sound emitter's noise that results in a difference between the dBC and dBA value greater than 20 dB will be an annoying low frequency issue.

Is not L_{90A} the minimum dBA background noise level? This is not exactly correct. The L_{90} is the statistical descriptor representing the quietest 10% of the time. It may be understood as the sounds one hears when there are no nearby or short-term sounds from man-made or natural sources. It excludes sounds that are not part of the soundscape during all seasons. It is very important to establish the statistical average background noise environment outside a potentially impacted residence during the quietest (10 pm to 4 am) sleeping hours of the night. This nighttime sleep disturbance has generated the majority of the wind farm noise complaints throughout the world. The basis for a community's wind turbine sound immission limits would be the minimum 10 minute nighttime L_{90A} plus 5 dB for the time period of 10 pm to 7 am. This would become the Nighttime Immission Limits for the proposed wind farm. This can be accomplished with one or several ten (10) minute measurements during any night when the atmosphere is classified stable with a light wind from the area of the proposed wind farm. The Daytime Limits (7 am to 7 pm) could be set 10 dB above the minimum nighttime L_{90A} measured noise, but the nighttime criteria will always be the limiting sound levels.

A nearby wind farm meeting these noise immission criteria will be clearly audible to the residents occasionally during nighttime and daytime. Compliance with this noise standard would be determined by repeating the initial nighttime minimum nighttime L_{90A} tests and adding the dBC ($L_{eq}C$) noise measurement with the turbines on and off. If the nighttime background noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines on must be corrected to determine compliance with the pre-turbine established sound limits.

The common method used for establishing the background sound level at a proposed wind farm used in many of the studies in Table 1 was to use unattended noise monitors to record hundreds of ten (10) minute measurements to obtain a statistically significant sample over varying wind conditions or a period of weeks. The measured results for daytime and nighttime are combined to determine the statically average wind noise as a function of wind velocity measured at a height of ten (10) meters. This provides an enormous amount of data but the results have little relationship to the wind turbine sound immission or turbine noise impact in nearby residents. The purpose of this exhaustive exercise often only demonstrates how much noise is generated by the wind. In some cases it appears that the data is used to 'prove' that the wind noise masks the turbine's sound immissions.

The most glaring failure of this argument occurs during the frequent nighttime condition of a stable atmosphere. Then, the wind turbines operate at full or near full power and noise output while the wind at ground level is calm and the background noise level is low. This is the condition of maximum turbine noise impact on nearby residents. It is the condition which most directly causes chronic sleep disruption. Furthermore, the measurement methodology is usually faulty, as much of the wind noise measured by unattended sound monitors is the pseudo-wind noise generated by failure of the microphone's windscreen. This results in totally erroneous background sound levels being used for permitting and siting decisions. (See studies in Table 3, esp. Van den Berg)

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes, The measuring sound level meter(s) need document the L_{Aeq} , L_{A10}, L_{A90} and L_{Ceq} , L_{C10}, L_{C90} sound levels plus start time & date for each 10 minute sample. The L_{10} results will be utilized to help validate that conditions were appropriate for measuring the L_{90} long term background sound levels. For example, on a quiet night one would expect L_{A10} to be less than 10 dB higher than the L_{A90} long-term background sound level. On a windy night or day the difference may be more than 20 dB. There is a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each ten (10) minute recorded noise sample. The ten (10) minute average of the wind speed near the microphone shall not exceed 2 m/s (4.5 mph) and the maximum wind speed for operational tests shall not exceed 4 m/s (9 mph). It is strongly recommended that observed samples be used for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at standard ten (10) meter height above ground. It is critical the weather be recorded every ten (10) minutes synchronized with the clocks in the sound level recorders without ambiguity in the start and end time of each ten (10) minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{A90} + 5 dBA immission level? First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. Indeed the background noise level does increase with surface wind speed. When it does occur, it can be argued that the increased wind noise provides some masking of the wind farm turbine noise emission. However, in the middle of the night when the atmosphere is defined as stable (no vertical flow from surface heat radiation) the layers of the lower atmosphere can separate and permit wind velocities at the turbine hubs to be 2 to 4 times the wind velocity at the 10m high wind monitor but remain near calm at ground level. The result is the wind turbines can be operating at or close to full capacity while it is very quiet outside the nearby dwellings.

This is the heart of the wind turbine noise "problem" for residents within 3 km (approx. two miles) of a wind farm. When the turbines are producing the sound from operation it is quietest outside the surrounding homes. The PhD thesis of P.G. van den Berg "The Sounds of High Winds" is very enlightening on this issue. See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines."

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar sound and wind 10 minute series of measurements would be repeated at the pre-wind farm location nearest the resident registering the wind turbine noise complaint, with and without the operation of the wind turbines. An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert shall be responsible for all the acoustic measurements including instrumentation setup, calibration and interpretation of recorded results. An independent acoustical consultant shall also perform all pre-turbine background noise measurements and interpretation of results to establish the Nighttime (and Daytime if applicable) industrial wind turbine sound immission limits. At present the acoustical consultants are retained by, and work directly for, the wind farm developer.

This presents a serious problem with conflict of interest on the part of the consultant. The wind farm developer would like to show the significant amount of wind noise that is present to mask the sounds of the wind turbine immissions. The wind farm impacted community would like to know that wind turbine noise will be only barely perceptible and then only occasionally during the night or daytime.

Is frequency analysis required either during pre-wind farm background survey or for compliance measurements? Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm.

Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on all sound level meters is C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is well accepted that dBC readings are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels plus a 5 dB allowance for the wind turbine's immissions (e.g. L_{90A} +5) for the audible sounds from wind turbines. In addition, to address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC. The Proposed Sound Limits are presented in the text box at the end of this paper.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt range, the addition of the dBC requirement will result in an increased distance between wind turbines and the nearby residents. For the generalized graphs shown in Figure 1, the distances would need to be approximately double the current distance. This will result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas where the L_{90A} background sound levels are 30 dBA or lower. When no man-made sounds are audible they can even be under 20 dBA. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or less setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone does not exceed 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. The maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone did not exceed 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]

Criteria	Condition	dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} (background)+5) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB

Notes

1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine noise emission as received at a property
2	A "Quiet rural environment" is a location 2 miles from a state road or other major transportation artery without high traffic volume during otherwise quiet periods of the day or night.
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.

[1] Procedures provided in Section 7. Measurement Procedures (Appendix to Ordinance) of the most recent version of "The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound" by Kamperman and James apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing the Long-Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9-Part 3 apply as amended. Instrumentation limits for wind and other factors must be recognized and followed.