THE "HOW TO" GUIDE TO SITING WIND TURBINES TO PREVENT HEALTH RISKS FROM SOUND

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"A subset of society should not be forced to bear the cost of a benefit for the larger society."[1]

I. Introduction

A new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial-scale wind turbines (WT), a common sight in many European countries, are now actively promoted by federal and state governments in the U.S. as a way to reduce coal-powered electrical generation and global warming. The presence of industrial wind projects is expected to increase dramatically over the next few years, given the tax incentives and other economic and political support currently available for renewable energy projects in the U.S.

As a part of the widespread enthusiasm for renewable energy, state and local governments are promoting "Model Ordinances" for siting industrial wind farms which establish limits for noise and other potential hazards. These are used to determine where wind projects can be located in communities, which are predominantly rural and often extremely quiet during the evening and night. Yet, complaints about noise from residents near existing industrial wind turbine installations are common. This raises serious questions about whether current state and local government siting guidelines for noise are sufficiently protective for people living close to the wind turbine developments. Research is emerging that suggests significant health effects are associated with living too close to modern industrial wind turbines. Research into the computer modeling and other methods used to determine the layout of wind turbine developments, including the distance from nearby residences, is at the same time showing that the output of the models may not accurately predict sound propagation. The models are used to make decisions about how close a turbine can be to a home or other sensitive property. The errors in the predicted sound levels can easily result in inadequate setback distances thus exposing the property owner to noise pollution and potential health risks. Current information suggests the models should not be used for siting decisions unless known errors and tolerances are applied to the results.

Our formal presentation and paper on this topic (*Simple guidelines for siting wind turbines to prevent health risks*) is an abbreviated version of this essay. The formal paper was presented to the Institute of Noise Control Engineers (INCE) at its July Noise-Con 2008 conference in Detroit, MI, A copy of

1 George S. Hawkins, Esq., *"One Page Takings Summary: U.S Constitution and Local Land Use,"* Stony Brook-Millstone Watershed Association; *"...nor shall private property be taken for public use, without just compensation."* Fifth Amendment, US Constitution.

the paper is included at the end of this document. The formal paper 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 formal paper also reviewed 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 was to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines for noise and its effects on communities and people. The papers considered in our review included, but were not limited to, those listed in Tables 1-4 on pages 2 through 4 of the Noise-Con document.

This essay expands upon the Noise-Con paper and includes information to support the findings and recommended criteria. We are proposing very specific, yet reasonably simple to implement and assess criteria for audible and non-audible sound on adjacent properties and also present a sample noise ordinance and the procedures needed for pre-construction sound test, computer model requirements and follow-up tests (including those for assessing compliance).

The purpose of this expanded paper is to outline a rational, evidence-based set of criteria for industrial wind turbine siting in rural communities, using:

1) A review of the European and other wind turbine siting criteria and existing studies of the prevalence of noise problems after construction;
2) Primary review of sound studies done in a variety of locations in response to wind turbine noise complaints (Table 1);
3) Review of publications on health issues for those living in close proximity to wind turbines (Table 2);
4) Review of critiques of pre-construction developer noise impact statements (Table 3); and
5) Review of technical papers on noise propagation and qualities from wind turbines (Table 4).

The Tables are on pages 2-4 of the formal paper. We also cite standard international criteria for community noise levels and allowances for low-frequency noise.

The specific sections are:

1. Introduction (This section)
2. Results of Literature Review and Sound Studies
3. Development of Siting Criteria
4. Proposed Sound Limits
5. How to Include the Recommended Criteria in Local or State Noise Ordinances
6. Elements of a Wind Energy System Licensing Ordinance
7. Measurement Procedures (Appendix to Ordinance)
8. The Noise-Con 2008 paper "Simple guidelines for siting wind turbines to prevent health risks" with revisions not in the paper included in the conference's Proceedings.

The construction of large WT (industrial wind turbines) projects in the U.S. is a relatively recent phenomenon, with most projects built after 2000. Other countries, especially in Europe, have been using wind energy systems (WES) since the early 1990's or earlier. These earlier installations generally used turbines of less than 1 MW capacity with hub heights under 61 m (200 feet). Now, many of these earlier turbines reaching the end of their useful life, are being replaced with the larger 1.5 to 3 MW units. Thus, the concepts and recommendations in this article, developed for the 1.5 MW and larger turbines being build in the U.S, may also be applicable abroad.

II. Results of Literature Review and Sound Studies

In the U.K. there are currently about 133 operating WT developments. Many of these have been in operation for over 10 years. The Acoustic Ecology Institute[2] (AEI) reported that a Special Report for the British government titled "Wind Energy Noise Impacts,"[3] found that about 20% of the wind farms in the U.K. generated most of the noise complaints. Another study commissioned by British government, from the consulting firm Hayes, McKensie, reported that only five of 126 wind farms in the U.K. reported problems with the noise phenomenon known as aerodynamic modulation.[4] Thus, experience in the U. K. shows that not all WT projects lead to community complaints. AEI posed an important question: **"What are the factors in *those* wind farms that may be problematic, and how can we avoid replicating these situations elsewhere?"**

As experienced industrial noise consultants ourselves, we would have expected the wind industry, given the U.K. experience, to have attempted to answer this question, conducting extensive research -- using credible independent research institutions – before embarking on wind power development in the U.S. The wind industry was aware, or should have been aware, that 20% of British wind energy projects provoked complaints about noise and/or vibration, even in a country with more stringent noise limits than in the U.S.

The wind industry complies with stricter noise limits in the U.K. and other countries than it does in the U.S., for example[5]:

- Australia: higher of 35 dBA or L_{90} + 5 dBA
- Denmark: 40 dBA
- France: L_{90} + 3 dBA (night) and L_{90} + 5 dBA (day)
- Germany: 40 dBA
- Holland: 40 dBA
- United Kingdom: 40 dBA (day) and 43 dBA or L_{90} + 5 dBA (night)
- Illinois: Octave frequency band limits of about 50 dBA (day) and about 46 dBA (night)
- Wisconsin: 50 dBA
- Michigan: 55 dBA

Industry representatives on state governmental committees have worked to establish sound limits and setbacks that are lenient and favor the industry. In Michigan, for example, the State Task Force (working under the Department of Labor and Economic Growth) recommended in its "Siting Guidelines for Wind Energy Systems" that the limits be set at 55 dBA or L_{90} + 5 dBA, whichever is higher. In Wisconsin, the State Task Force has recommended 50 dBA.

When Wisconsin's Town of Union wind turbine committee made an open records request to find out the scientific basis for the sound levels and setbacks in the state's draft model ordinance, it found that no scientific or medical data was used at all. Review of the meeting minutes provided

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[2] (http://www.acousticecology.org/srwind.html)

[3] AEI is a 501(c)3 non-profit organization based in Santa Fe, New Mexico, USA. The article is available at http://www.acousticecology.org/srwind.html

[4] Study review available at: http://www.berr.gov.uk/files/file35592.pdf

[5] Ramakrishnan, Ph. D., P. Eng., Ramani, "Wind Turbine Facilities Noise Issues" Dec. 2007 Prepared for the Ontario Ministry of Environment.

under the request showed that the limits had been set by Task Force members representing the wind industry.[6] This may explain why state level committees or task forces have drafted ordinances with upper limits of 50 dBA or higher instead of the much lower limits applied to similar projects in other countries. There is no independent, scientific or medical support for claims that locating 400+ foot tall wind turbines as close as 1000 feet (or less) to non-participating properties will not create noise disturbances, economic losses or other risks.[7] But, there is considerable independent research supporting that this will result in public health risks and other negative impacts on people and property.

To illustrate the way a typical WT developer responds to a question raised by a community committee about noise and health the following example is presented and discussed:

> **Q: 19. What sound standards will EcoEnergy ensure that the turbines will be within, based on the setbacks EcoEnergy plans to implement, and what scientific and peer reviewed data do you have to ensure and support there will be no health and safety issues to persons within your setbacks?**
>
> Answer: As mentioned, turbines are sited to have maximum sound level of 45dBA. These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects. The possible effects to a person's health due to "annoyance" are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment.
>
> From EcoEnergy's "Response to the Town of Union Health & Safety Research Questionnaire"
> By Curt Bjurlin, M.S., Wes Slaymaker, P.E., Rick Gungel, P.E., EcoEnergy, L.L.C., submitted to Town of Union, Wisconsin and Mr. Kendall Schneider, on behalf of the Town of Union

A serious question was asked and it deserves a responsible answer. The committee, charged with fact-finding, sought answers they presumed would be based on independent, peer-reviewed studies. Instead, the industry response was spurious and misleading, and did not address the question. It stated that the turbines will be located so as to produce maximum sound levels of 45 dBA, the tone and context implying that 45 dBA is fully compatible with the quiet rural community setting. No acknowledgement is made of the dramatic change this will be for the noise environment of nearby families. No mention is made of how the WT, once in operation, will raise evening and nighttime background sound levels from the existing background levels of 20 to 30 dBA to 45 dBA. There is no disclosure of the considerable low frequency content of the WT sound; in fact, there are often claims to the contrary. They fail to warn that the home construction techniques used for modern wood frame homes result in walls and roofs that cannot block out WT low frequencies.

There is no mention of the nighttime sound level recommendations set by the World Health Organization (WHO) in its reports, *Guidelines for Community Noise* [8] and "Report on the third

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6 Lawton, Catharine M., Letter to Wisconsin's "Guidelines and Model Ordinances Ad Hoc Subcommittee of the Wisconsin Wind Power Siting Collaborative" in Response to Paul Helgeson's 9/20/00 "Wisconsin Wind Ordinance Egroups E-Mail Message," Sept. 20, 2000, a Public Record obtained through Open Meetings Act request by the Town of Union, Wisconsin, Large Wind Turbine Citizens Committee.

7 It is worth noting that the 2007-06-29 version of the Vestas Mechanical Operating and Maintenance Manual for the model V90 – 3.0 MW VCRS 60 Hz turbine includes this warning for technicians and operators:

> "2. Stay and Traffic by the Turbine
>
> Do not stay within a radius of 400m (1300ft) from the turbine unless it is necessary. If you have to inspect an operating turbine from the ground, do not stay under the rotor plane but observe the rotor from the front.
> Make sure that children do not stay by or play nearby the turbine. ...."

8 Available at http://www.who.int/docstore/peh/noise/guidelines2.html.

meeting on night noise guidelines.[9]" In these documents WHO recommends that sound levels **during nighttime and late evening hours should be less than 30 dBA during sleeping periods to protect children's health.** They noted that a child's autonomic nervous system is 10 to 15 dB more sensitive to noise than is an adult. Even for adults, health effects are first noted in some studies when the sound levels exceed 32 dBA L_{max}. These sounds are 10-20 dBA lower than the sound levels needed to cause awakening.

For sounds that contain a strong low frequency component, which is typical of wind turbines, WHO says that the limits may need to be even lower than 30 dBA to avoid health risks. Further, they recommend that the criteria use dBC frequency weighting instead of dBA for sources with low frequency content. When WT sound levels are 45 dBA outside a home, we may find that the interior sound levels will drop to the 30 dBA level recommended for sleeping areas but low frequency noise only decreased 6-7 dBC from outside to inside. That could create a sleep problem because the low frequency content of the noise can penetrate the home's walls and roof with little reduction. An example demonstrating how WT sound is affected by walls and windows is provided later in this document.

The wind turbine developers in the excerpt above do not disclose that the International Standards Organization (ISO) in ISO 1996-1971 recommends 25 dBA as the maximum night-time limit for rural communities. As can be seen in the table below, sound levels of 40 dBA and above are only appropriate in suburban communities during the day and urban communities during day and night. There are no communities where 45 dBA is considered acceptable at night.

ISO 1996-1971 Recommendations for Community Noise Limits (dBA)			
District Type	Daytime Limit	Evening Limit 7-11pm	Night Limit 11pm-7am
Rural	35dB	**30dB**	**25dB**
Suburban	40dB	35dB	**30dB**
Urban residential	45dB	40dB	35dB
Urban mixed	50dB	45db	40dB

Further, the wind industry claims, "*These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects.*" Concern about sound levels in the 80-90 dBA range is for hearing health (your ears) and not the health-related issues of sleep disturbance and other symptoms associated with prolonged exposure to low levels of noise with low frequency and amplitude modulation such as the sound emitted by modern wind turbines. This type of response is a non-answer. It is an overt attempt to mislead while giving the appearance of providing a legitimate response.

Furthermore, the statement, "*The possible effects to a person's health due to 'annoyance' are impossible to study in a scientific way, as these are often mostly psychosomatic, and are not caused by wind turbines as much as the individuals' obsession with a new item in their environment,*" is both inaccurate and misleading. It ignores the work of researchers such as Pedersen, Harry, Phipps, and Pierpont on wind turbine effects specifically, and the numerous medical research studies reviewed by Frey and Hadden. The studies belie the claims of the wind industry. This "failure to locate" published

[9] Available at: http://www.euro.who.int/Noise/activities/20040721_1 References found in Report on third meeting at pages 13 and others

studies that are readily available on the internet as to make some interpret the claim of "no medical research" as a conscious decision to not look for it. Those companies that do acknowledge the existence of medical research take the position that it is not credible for one or another reason and thus can be ignored.

Making statements outside their area of competence, wind industry advocates, without medical qualifications, label complaints of health effects as "psychosomatic" in a pejorative manner that implies the complaints can be discounted because they are not "really medical" conditions. Such a response cannot be considered to be based in fact. It is, at best, an opinion. It ignores the work of many researchers, including the World Health Organizations, on the effect of sounds during nighttime hours that result in sleep disturbance and other disorders with physical, not just psychological, pathologies.[10,11] Many people find it difficult to articulate what has changed. They know something is different from before the wind turbines were operating and they may express it as feeling uncomfortable, uneasy, sleepless, or some other symptom, without being able to explain why it is happening.

Our review of the studies listed in Tables 1-4 of our Noise-Con paper show that some residents living as far as 3 km (1.86 mi) from a wind farm complain of sleep disturbance from the noise. Many residents living 1/10 of this distance (300 m or 984 ft) from wind farms experience major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions[12] cause the sounds 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 are not appropriate for siting modern industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the repetitive, approximately once-per-second (1 Hz) "swoosh-boom-swoosh-boom" sound of the turbine blades and of "low frequency" noise. It is not clear to us whether the complaints about "low frequency" noise are about the audible low frequency part of the "swoosh-boom" sound, the once-per-second amplitude modulation (amplitude modulation means that the sound varies in loudness and other characteristics in a rhythmic pattern) of the "swoosh-boom" sound, or some combination of the two.

Figure 1 of our Noise Con paper, reproduced as Figure 1, below, shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; A home in the United States at 2km distance, 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 near Ubly, Michigan. This is a quiet rural community located in central Huron County (also called Michigan's Thumb). It is worth noting that this sound measurement sample demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

The line representing the threshold of perception is the focus of this graph. The remaining graphs show sound pressure levels (dB) at each of the frequency ranges from the lowest inaudible sounds at the left, to sounds that "rumble" (20Hz to about 200 Hz) and then those in the range of communication (200Hz through about 4000Hz) through high pitched sounds (up to 10,000 Hz). At

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[10] WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005.

[11] According to Online Etymology Dictionary, *psychosomatic* means "pertaining to the relation between mind and body, ... applied from 1938 to physical disorders with psychological causes."

[12] *Emissions* refer to acoustic energy from the viewpoint of the sound emitter, while *immissions* refer to acoustic energy from the viewpoint of the receiver.

each frequency where the graphs of sound pressures are above (exceed) the graph showing perception the wind turbine sounds would be perceptible or audible. The more the wind turbine sound exceeds the perception curve the more pronounced it will be. When it exceeds the quiet rural background sound level (L_{A90}) it will not be masked or obscured by the rural soundscape.

The over-all sounds from each of the frequency bands are summed and presented on the right hand side of the graph. These are presented with corrections for A-weighting (dBA) and C-weighting (dBC). These show that if only dBA criteria are used to assess and limit wind turbine sound the low frequency content of the wind turbines emissions are not revealed. Note that in many cases the values for dBC are almost 20 dB higher than the dBA values. This is the basis for the WHO warning that when low frequency sound content is present outside a home dBA is not an appropriate method of describing predicted noise impacts, sound limits, or criteria.

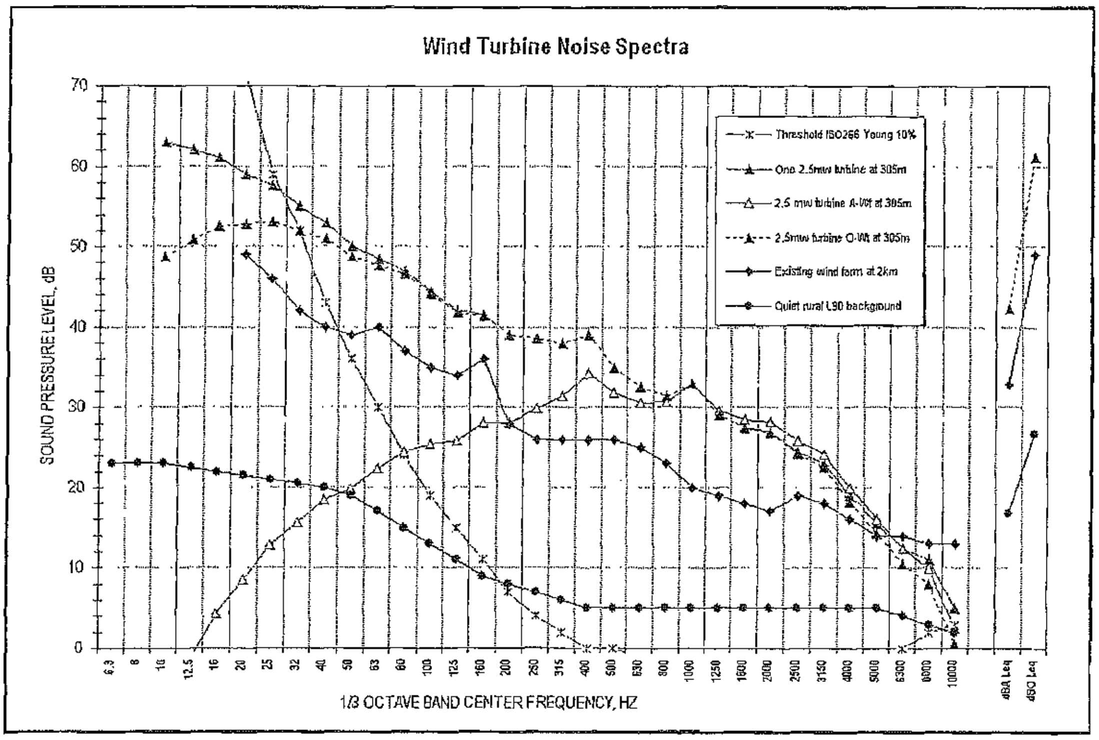

Figure 1-Graph Of Wind Turbine Sounds Vs. Rural Background And Threshold Of Perception

(Note: The lowest L_{Aeq} and L_{Ceq} shown at right are measured background L_{A90} and L_{C90}. The Leq values could be 0-5 dB higher)

Our review of the studies listed in Tables 1-4 in the Noise-Con paper at the end of this document, provided answers to a number of significant questions we had, as acoustical engineers, regarding the development of siting guidelines for industrial-scale wind turbines. They are provided below for easy of reading and continuity:

Do international, national, or local community noise standards for siting wind turbines near dwellings address the low frequency portion of the wind turbines' sound immissions? No. State and local governments are in the process of establishing wind farm noise limits and/or wind turbine setbacks from nearby residents, but the standards incorrectly assume 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 dwellings? Yes. But the industry-recommended 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 pre-construction computer modeling may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

An example of a condition that complies with

Are all residents living near wind farms equally likely to be affected by wind turbine noise? No. Children, people with certain pre-existing medical conditions, and the elderly are likely to be the most susceptible. Some people are unaffected while nearby neighbors develop serious health problems caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Wind turbine-associated symptoms include sleep disturbance, headache, ringing in the ears, dizziness, nausea, irritability, and problems with memory, concentration, and problem solving, as described in the first paper in this volume.

What are the technical options for reducing wind turbine noise immission at residences? There are only two options: 1) increase the distance between the source and receiver, or 2) reduce the source sound power emission. Either solution is incompatible with the objective of the wind farm developer, which is to maximize the wind power electrical generation within the land available.

Is wind turbine noise at a residence much more annoying than traffic noise? Yes. Researchers have found that, "Wind turbine noise was ... found to cause annoyance at sound pressure levels lower than those known to be annoying for other community noise sources, such as road traffic. ...Living in a clearly rural area in comparison with a suburban area increases the risk of annoyance with wind turbine noise.[13]" In other papers by Pedersen wind turbine noise was perceived by about 85% of respondents to the study at sound levels as low as 35.0-37.5 dBA.[14] Currently, this increased sensitivity is believed to be due to the presence of amplitude modulation in the wind turbine's sound emissions which limits the masking effect of other ambient sounds and the low frequency content which is associated with the sounds inside homes and other buildings.

Amplitude modulation is a continuing change in the sound level in synchronization with the turning of the wind turbine's blades. An example of amplitude modulation is shown in the figure 2 below. This figure shows the constantly varying dBA sound level in the graph at the top. The sound level varies from a low of 40 dBA to a high of 45 dBA repeating every 1.3 seconds continuously when the turbine is operating. The turbine is located approximately 1200 feet from the farmhouse. The photo shows the turbine that was dominant during this test.

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[13] Pedersen E, Bouma J, Bakker R and Van den Berg F, "Wind Farm perception- A study on acoustic and visual impact of wind turbines on residents in the Netherlands;" 2nd International Meeting on Wind Turbine Noise, Lyon France; Sept. 20-21, 2007 (Pages 2 and 3)

[14] Pedersen E and Persson Waye K. 2004. Perceptions and annoyance due to wind turbine noise -- a dose-response relationship. J Acoust Soc Am 116(6): 3460-3470

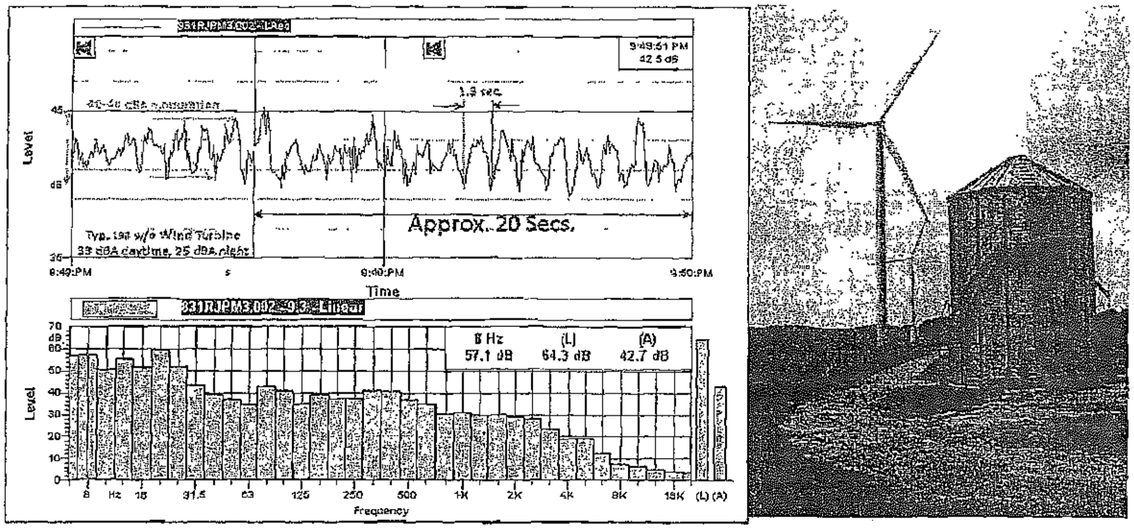

Figure 2 Amplitude Modulation at a farmhouse (Study sponsored by CCCRE, Calumet, Wisconsin)

It is worth noting that this measurement averages about 43 dBA (L_{eq}) which is very close to the sound level predicted for a single turbine at 1000 feet in Figure 1 (solid red line with solid triangle markers). The lower graph shows the frequency spectrum at approximately 9:49 PM at a low point in the amplitude modulation. (The frequency chart's cursor is the vertical line at the upper graph's midpoint.) Note the dominance of sound energy in the lower frequency range. This was also present in the model's predictions in Figure 1.

It is not hard to understand why many people in this community feel that they have been forced to accept noise pollution as a side effect of the wind project. Even though the 40 to 45 dBA sound levels in this example may comply with the 50 dBA limits adopted by the host county from the Wisconsin Model Ordinance the impact on the people near the wind project are subjected to noise pollution. This example demonstrates why criteria set at 50 dBA or higher do not protect the health and economic welfare of people living in the host communities. Adopting criteria such as those recommended later in this essay can prevent these situations from occurring.

Low frequency noise is a problem inside buildings

When low frequency sound is present outside homes and other occupied structures, it is often more an indoor problem than an outdoor one. This is very true for wind turbine sounds.

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? Affected residents complain of the middle- to high-frequency, repetitive swooshing sounds of the rotating turbine blades at a constant rate of about 1 Hz, plus low frequency noise. The amplitude modulation of the "swooshing" sound changes continuously. Residents also describe a thump or low frequency banging sound that varies in amplitude up to 10 dBA in the short interval between the swooshing sounds. This may be a result of sounds from multiple wind turbines with similar spectral content combining to increase and decrease the sound over and above the effects of modulation. [Note: These effects (e.g. phasing and coherence effects) are not normally considered in predictive models.] It may also be a result of turbulence of the air and wind on wind turbine operations when the blades are not at an optimum angle for noise emissions and/or power generation. It is also a result of sounds penetrating homes and other buildings at night and at other times where quiet is needed. When low frequency sound is present outside homes and other occupied structures, it is

Prepared for: Windaction.org

often more likely to be an indoor problem than an outdoor one. This is very true for wind turbine sounds.

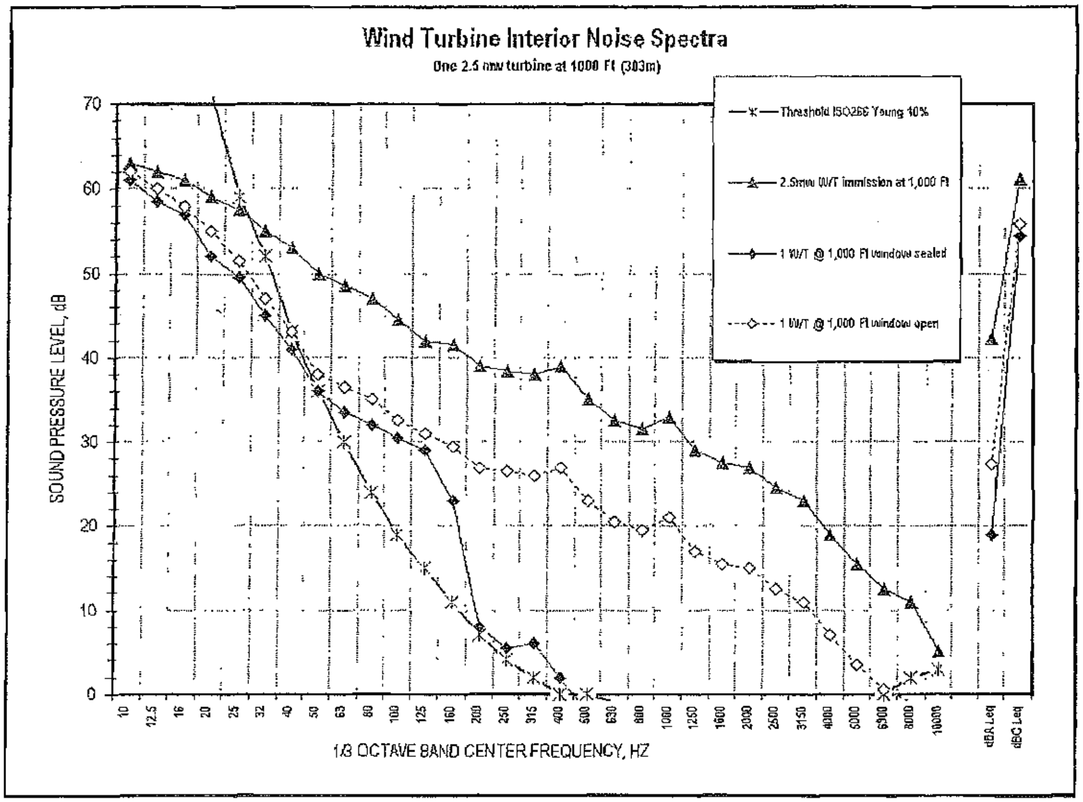

Figure 3-A Single Wind Turbine Sound Inside Home @ 1000 Feet

The usual assumption about wall and window attenuation being 15 dBA or more, which is valid for most sources of community noise, may not be sufficiently protective given the relatively high amplitude of the wind turbines' low frequency immission spectra. Figures 2 and 3 demonstrate the basis for this concern.

To demonstrate the effects of outdoor low frequency content from wind turbines we prepared Figure 1 showing the effect of a single turbine (propagation model based on sound power level test data) at 1000 feet and then in Figure 4 projected the impact of ten (10) similar turbines at one (1) mile. We applied the façade sound isolation data from the Canada Research Council to the wind turbine example used in our Noise-Con 2008 paper and shown in Figure 1 above. The graphs each show the outdoor sound pressure levels predicted for the distance of 1000 feet and one mile as the upper graph line respectively. The curve showing the threshold of human perception for sounds at each 1/3 octave band center is also plotted. When the graphs representing wind turbine sound have data points above this threshold curve the sounds will be perceptible to at least 10% of the population (which includes most children).

In addition to the top graph line representing the sounds outside the home there are two other graph lines for the sounds inside the home[15]. One curve represents the condition of no open windows and the other represents one open window.

With just one turbine at 1,000 feet there is a significant amount of low frequency noise above hearing threshold within rooms having exterior walls without windows or very well sealed windows. Even with the windows closed the sound pressure levels in the 63 Hz to 200 Hz one-octave bands still exceed the perception curve, in many cases by more than 10 dB. Note the perceptible sound between 50 and 200 Hz with a wall resonance frequency at 125 Hz (2 X 4 studs on 16 inch centers) for the "windows closed" condition. This would be perceived as a constant low rumble, which would be present inside homes whenever the turbines are operating.

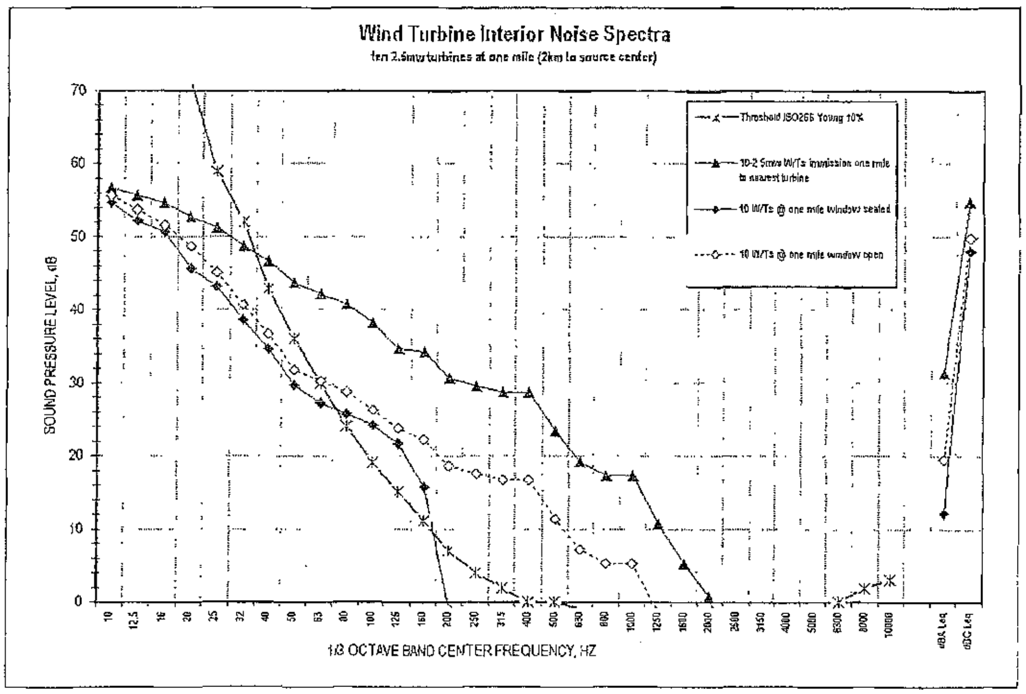

Figure 4-Sound from Ten (10) Wind Turbines inside home at One Mile

When comparing the dBC values the difference between inside sounds and outside is much less. The maximum difference in this example is only 7 dBC and that is for the situation with windows closed. With windows open the sound inside the home would be 56 dBC while it is 61 dBC outside; a difference of only 5 dBC[16,17,18]. If we looked only at dBA it would appear that the home's

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[15] The typical wood stud exterior used in modern home construction is vinyl siding over 1/2 inch OSB or rigid fiberglass board applied to 2 X 4 studs with the stud space filled with thermal and 1/2 inch gypsum board applied on the exposed interior side. This has a mass of about 3-4 lbs/sq ft and low 26 STC.

[16] The basis for these predictions includes reports on aircraft sound insulation for dwellings and façade sound isolation data from the Canada Research Council.

[17] "On the sound insulation of wood stud exterior walls" by J. S. Bradley and J. S. Birta, institute for Research in Construction, National Research Council, Montreal Road, Ottawa K1A 0R6, Canada, published: J.Acoust. Soc. Am. 110 (6), December 2001

walls and roof provide a reduction of 15 dBA or more. But, that that would be misleading because it ignores the effects of low frequency sound.

We next increased the number of 2.5 Mw turbines from one to ten and moved the receiver one mile from the closest turbine. We assumed the acoustic center for the ten turbines to be 2km (1-1/4 miles) from the receiver. These results are presented in Figure 4. We were surprised to find that the one mile low frequency results are only 6.3 dB below the 1,000 foot one turbine example.

There is one other characteristic of wind turbine sound that increases the sleep disturbance potential above that of other long-term noise sources. The amplitude modulation of the sound emissions from the wind turbines create a repetitive rise and fall in sound levels synchronized to the blade rotation speed. Many common weather conditions increase the magnitude of amplitude modulation. Most of these occur at night. The graph in Figure 5 shows this effect in the first floor bedroom of a farm home in the U.K. The home is located 930 meters (3,050 feet) from the nearest turbine. The conditions documented by an independent acoustical consultant show the sound level varying over 9 dBA range from 28 to 37 dBA. The pattern repeats approximately every second, often for hours at a time. For many people, especially seniors, children and those with pre-existing medical conditions, this represents a major challenge to restful sleep.

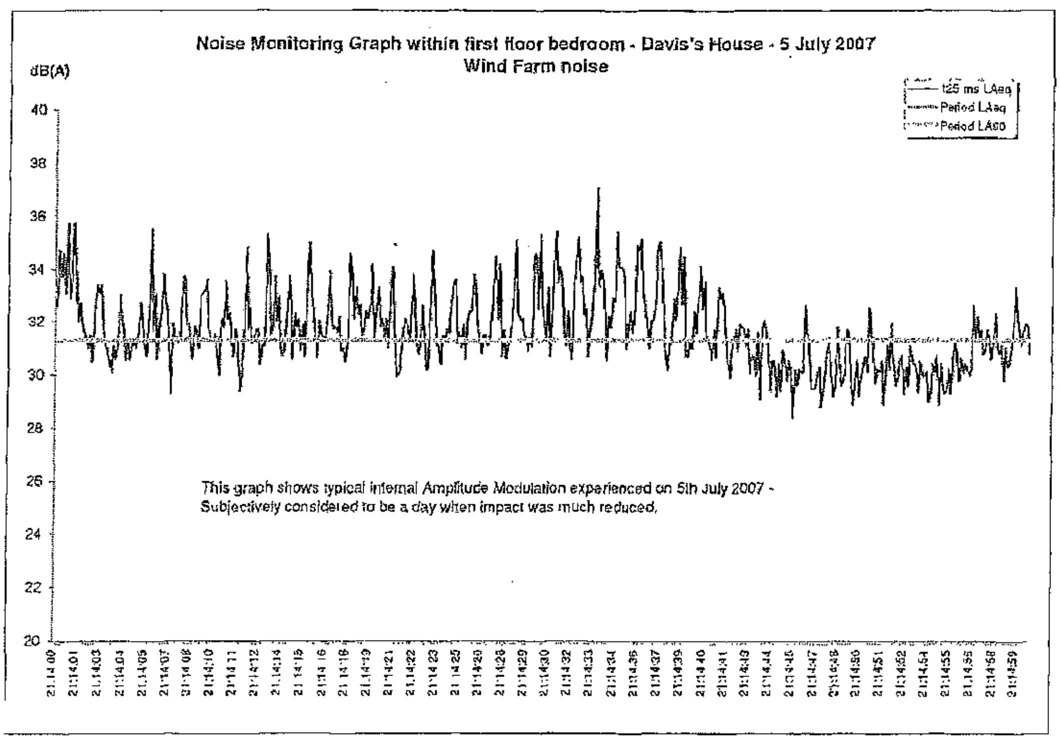

Figure 5- Amplitude modulation in a home 930 meters (3000 feet) from the nearest turbine.[19]

This may explain why some residents as far as two (2) miles from a wind farm find the wind turbines sounds highly annoying. It also demonstrates the primary reason why relying on dBA

[18] Dan Hoffmeyer, Birger Plovsing: "Low Frequency Noise from Large Wind Turbines, Measurements of Sound Insulation of Facades." Journal no. AV 1097/08, Client: Danish Energy Authority, Amaliegade 44, 1256 Copenhagen
[19] This chart used with permission of Mike Stigwood, MIOA, FRSH, MAS Environmental, U.K. and the Davis family.

alone will not work for community noise criteria. It is the low frequency phenomena associated with wind turbine emissions that makes the dBC test criteria an important part of the proposed criteria[20].

III. Development of Siting Criteria

Basis For Using L_{A90} To Determine Pre-Construction Long-Term Background Sound

We began our research into guidelines for proper siting by reviewing guidelines used in other countries to limit WT sound emissions. A recent compendium of these standards was presented in the report "Wind Turbine Facilities Noise Issues."[21] We found common ground in many of them. Some set explicit not-to-exceed sound level limits, for example, in Germany, 40 dBA nighttime in residential areas and 35 dBA nighttime in rural and other noise-sensitive areas. Other countries use the existing background sound levels for each community as the basis for establishing the sound level limits for the WES project. This second method has the advantage of adjusting the allowable limits for various background soundscapes. It makes use of a standard method for assessing background sound levels by measuring over a specified period of observation to determine the sound level exceeded 90% of the time (L_{90}) during the night. The night is important because it is the most likely time for sleep disturbance. Then, using the background sound level as the base, the WES project is allowed to increase it by 5 dBA. It is this second method (L_{90} + 5 dBA) that was adopted for the criteria in this document. It has the advantage of adjusting the criteria for each community without the need for tables of allowable limits for different community types. The focus is only on the nighttime criteria. This is because the WES will operate 24 hours a day and the nighttime limits will be the controlling limits whether or not there are other limits for daytime.

Wind turbine noise is more annoying than other noises and needs lower limits
Since many rural communities are very quiet, it is possible that some will have L_{90} values of 25 dBA or lower. This may seem extreme when compared to limits usually imposed on other sources of community noise. However, wind turbine sounds are not comparable to the more common noise sources of vehicles, aircraft, rail, and industry. Several studies have shown that annoyance to wind turbine sounds begins at levels as low as 30 dBA.[22] This is especially true in quiet rural communities that have not had previous experience with industrial noise sources. This increased sensitivity may be due to the periodic 'swoosh' from the blades in the quiet rural soundscape, or it may be more complex. In either case, it is a legitimate response to wind turbine sound documented in peer-reviewed research.

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[20] Hessler Jr., George F., "Proposed criteria in residential communities for low-frequency noise emissions from industrial sources," 52(4), 179-185, (July-Aug 2004)

[21] Ramani Ramakrishnan, Ph.D., P. Eng., "Wind Turbine Facilities Noise Issues," December 2007. Prepared for the Ontario Ministry of Environment.

[22] Eja Pedersen, "Human response to wind turbine noise: perception, annoyance and moderating factors." Dissertation, Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Goteborg University, Goteborg, Sweden, 2007, and

Van den Berg F, Pedersen E, Bouma J, and Bakker R, Wind Farm Perception, Final Report Project no. 044628, University of Gothenburg and Medical Center Groningen, Netherlands June 3, 2008

Noise criteria need to take into account low frequency noise
In the table to the right are a series of observations and recommendations by the World Health Organization (WHO) supporting the need for stricter limits when there is substantial low frequency content in outdoor sound. Our review of other studies, and our own measurements, has demonstrated that wind turbine sound includes considerable low frequency content. We include a dBC limit in our guidelines to address the WHO recommendation that when low frequency sound may be present, criteria based on measurements using a C-weighting filter on the sound level meter (dBC) are needed in addition to dBA criteria.

> The World Health Organization recognizes the special place of low frequency noise as an environmental problem. Its publication "Community Noise" (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:
>
> - "It should be noted that low frequency noise... can disturb rest and sleep even at low sound levels.
> - For noise with a large proportion of low frequency sounds a still lower guideline (than 30dBA) is recommended.
> - When prominent low frequency components are present, noise measures based on A-weighting are inappropriate.
> - 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.
> - It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health."
>
> WHO also states: "The evidence on low frequency noise is sufficiently strong to warrant immediate concern."
>
> Available at http://www.who.int/docstore/peh/noise/guidelines2.html, References found at pages ix, xii through xv and others.

IV. 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 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 generally 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 allowing the wind turbine development to increase this by 5 dB (e.g. L_{90A} +5) by the audible sounds from wind turbines. According to the New York State Energy Research & Development Authority:

- "... A change in sound level of 5 dB will typically result in a noticeable community response; and
- "... A 10 dB increase is subjectively heard as an approximate doubling in loudness, and almost always causes an adverse community response." [23]

To address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC that follow the same scheme as used for dBA limits. The Proposed Sound Limits are presented in the text box at the end of this section.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt (or over) range, the addition of the dBC requirement may result in an increased distance between wind turbines and the nearby

[23] (*Wind Energy Development: A Guide for Local Authorities in New York;* page 30; New York State Energy Research & Development Authority, Albany, NY October 2002)

residents. For the conditions shown in Figure 1, the distances would need to be increased significantly. This would 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 with little or no low frequency sound from man-made noise sources and where the L_{A90} background sound levels are 30 dBA or lower. 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 smaller setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

Following are some additional Questions and Answers that summarize the major points of this discussion relevant to criteria.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Examples are listed above in the section on Results of Literature and Sound Studies.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing a not-to-exceed immission limit of 35 L_{Aeq} and a site-specific limit of L_{A90} + 5 dBA at the closest property line, whichever is exceeded first. We also propose the use of C-weighted criteria to address complaints of wind turbine low frequency noise. For the C-weighted criteria, we propose a site-specific limit of L_{C90} + 5 dBC. We also require that the site-specific L_{Ceq} (dBC) sound level at a receiving property line not exceed the pre-existing L_{A90} dB background sound level + 5dB by more than 20 dB. In other words, the dBC operating immission limit (as L_{Ceq}) at the receiving property line should not be more than 20 dB above the measured dBA (as L_{A90}) pre-construction long-term background sound level + 5dB.[24] This criterion prevents an Immission Spectra Imbalance that often leads to complaints about rumble or other low frequency problems. We also include a not-to-exceed immission limit of 55 and 60 L_{Ceq} at the receiving property line.[25] Use of the multiple metrics and weightings will address the audible and inaudible low frequency portions of wind turbine sound emissions. Exceedances of any of the limits establish non-compliance.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{A90}+5 dB? The World Health Organization and others[26] have determined that if a noise has a measured difference between dBC and dBA more than 20 dB, the noise is highly likely to create an annoyance because of the low frequency component.

Isn't L_{A90} the __minimum__ background noise level? Not exactly. This is the sound level that represents the quietest 10% of the time. It is often considered to be the sound level that represents the sounds one hears late in the evening or at night when there are no near-by or short term sounds present. It is very important to establish this "long term background" noise environment at the property line for a potentially impacted residence (L_{A90}) during the **quietest** sleeping hours of the night, between 10 p.m. and 4 a.m.. Why? Because nighttime sleep disturbance has generated the majority of wind farm noise complaints throughout the world those conditions should guide the design of wind projects. ANSI standards define the "long term background sound" as excluding all short term sounds from the test sample using carefully selected sampling times and conditions using ten (10) minute long samples. This means that nature sounds not present during all seasons and wind noise are not to be included in the measurement. Following the procedures in ANSI S12.9, Part 3 for long term background sound the L_{A90} and L_{C90} can be measured with one or more 10-minute

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[24] Hessler Jr., George F., Proposed criteria in residential communities for low-frequency noise emissions from industrial sources, Noise Control Engineering Journal; 52(4), pg. 180 in "2. Purpose of Proposed Criteria," (July-Aug 2004)
[25] Ibid, pg. 180 in "3. Proposed Criteria."

[26] Ibid

measurements during any night when the atmosphere is classified as stable with a light wind from the area of the proposed wind farm. The basis for the immission limits for the proposed wind farm would then be the Nighttime Immission Limits, which we propose to be the minimum ten (10) minute nighttime L_{A90} and L_{C90} plus 5 dB, a test for Spectra Imbalance, and not-to-exceed limits for the period of 10 p.m. to 7 a.m. Daytime Limits (7 a.m. to 10 p.m.) could be set using daytime measurements, but unless the wind utility only operates during the day, the nighttime limit will always be the limiting sound level. Thus, daytime limits are not normally needed.

A nearby industrial scale wind utility meeting these noise immission criteria would occasionally be audible to the residents during nighttime and daytime. However, it would be unlikely for it to be an indoor problem.

The method used for establishing the background sound level at a proposed wind farm in many of the studies in Table 1, does not meet the requirements set by ANSI S12.9 Part 3 for outdoor measurements and determination of long-term background sound levels. Instead, they use unattended noise monitors to record hundreds of 10-minute or one-hour un-observed measurements that include the short term sounds from varying community and wind conditions over a period of days or weeks. The results for daytime and nighttime are usually combined to determine the average wind noise at the microphone 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 wind turbine sound immissions or to potential for turbine noise impacts on nearby residents. They also do not comply with ANSI standards for methodology or quality and as such are not suitable for use in measurements that will be used to assess compliance with other standards and guidelines. This exhaustive exercise often only demonstrates how much 'pseudo-noise' is generated by instruments located in a windy environment that exceeds the capability of the instrument's wind screen to protect the microphone. In many cases, this unqualified data is used to support a claim that the wind noise masks the turbines' sound immissions.

The major complaints of residents living near wind farms is sleep disruption at night when there is little or no wind near ground level and the wind turbines located at a much higher elevation are turning and generating near or at maximum power and maximum noise emission. There is usually more surface wind and turbulence during daytime caused by solar radiation. Thus, the use of averaged data involving one or more 24-hour periods is of little value in predicting conditions that will result in people who cannot sleep in their homes during the night because of loud intrusive wind turbine noise.

The methodology used to predict the sound propagation from the turbines into the community also fails to represent the conditions of maximum turbine noise impact on nearby residents. This should be expected given the limitations of models based on ISO 9613-2[27]. They also do not consider the effects of a frequent nighttime condition when winds at the ground are calm and the winds at the hub are at or above nominal operating speed. This condition is often referred to as a "stable" atmosphere. During this condition, the wind turbines can be producing the maximum or near maximum power while the wind at ground level is calm and the background noise level is low. The Michigan rural night test data in the earlier figure shows how quiet a night can be in the absence of wind at the ground. This common condition is known to directly cause chronic sleep

[27] The ISO 9613-2 sound propagation model formulas have known errors of 3 dB even when the conditions being modeled are a perfect match to the limiting conditions specified in the standard. Wind turbines operate far outside the limits for wind speed, height of the noise source above the ground, and other factors identified in the standard thus increasing the likelihood for error above the specified 3 dB. In addition, there are known measurement errors in the IEC61400-11 test that add another 2 dB of uncertainty to the model's predictions.

disruption. Further, the studies report average sound levels and do not disclose the effects of amplitude modulation or low frequency sound which makes the turbine's sound more objectionable and likely to cause sleep problems.

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes. The precision measuring sound level meter(s) need to be programmed to include measurement of L_{Aeq}, L_{A10}, L_{A90}, L_{Ceq}, L_{C10}, and L_{C90}, with starting time and date for each 10-minute sample. The L_{10} results will be used to validate the L_{90} data. For example, on a quiet night one might expect L_{10} and L_{90} to show similar results within 5 to 10 dB between L_{10} and L_{90} for each weighting scale. On a windy night or one with nearby short term noise sources the difference between L_{10} and L_{90} may be more than 20 dB. There is also often a need to obtain a time-averaged, one-third octave band analysis over the frequency range from 6.3 Hz to 10 kHz during the same ten minute sample. The frequency analysis is very helpful for identifying and correcting for extraneous sounds such as interfering insect noise. An integrating averaging sound level meter meeting ANSI or IEC Type 1 standards has the capability to perform all of the above acoustic measurements simultaneously and store the results internally. There is also a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each 10-minute recorded noise sample. The 10-minute maximum wind speed near the microphone must be less than 2 m/s (4.5 mph) during measurements of background noise (L_{90}), and the maximum wind speed for noise measurements during turbine operation must be less than 4 m/s (9 mph). Measurements should be observed (without contaminating the data) and notes identifying short-term noises should be taken 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 the standard 10 meter height above ground. It is critical that the weather be recorded every 10 minutes, synchronized with the clocks in the sound level recorders without ambiguity, at the start and end time of each 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_{90} + 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. The background noise level does indeed increase with surface wind speed. When this happens, it can be argued that the increased wind noise provides some masking of wind turbine noise. However, this is not true if the surface winds are calm. After sunset, when the ground cools (e.g. in the middle of the night), the lower level atmosphere can separate from the higher-level atmosphere. Then, the winds at the ground will be calm while wind at the turbine hub is very strong. Under this condition, the wind velocity at a 10-meter high wind monitoring station (such as those often used for weather reporting) may be ¼ to ½ the speed of the wind at the hub, yet drop to calm at ground level. The result is that no ground level wind noise is present to mask the sound of the wind turbines, which can be operating at or close to full capacity.

This condition is one of the major causes of wind turbine related noise complaints for residents within 3 km (1.86 miles) of a wind farm. When the turbines are producing high sound levels, it is quiet outside the surrounding homes. The PhD thesis of G.P. van den Berg, *The Sounds of High*

Winds, is very enlightening on this issue (Table 3). See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines.[28]"

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar set of sound tests using the ten (10) minute series of measurements would be repeated, with and without the operation of the wind turbines, at the location where noise was measured before construction, which is closest to the resident registering the wind turbine noise complaint. If the nighttime background (L_{90}) 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 operating must be corrected using standard acoustical engineering methods to determine compliance with the pre-turbine established sound limits.

Who should conduct the sound measurements? An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert should be responsible for all the acoustic measurements including setup and calibration of instruments and interpretation of recorded results. He or she should 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, and to monitor compliance.

At present, the acoustical consultants are retained by, and work directly for, the wind farm developers. This presents a serious problem with conflict of interest on the part of the consultants. The wind farm developer would like to show that a significant amount of wind noise is present to mask the sounds of the wind turbine immissions. The community is looking for authentic results showing that the wind turbine noise will be only barely perceptible, and then only occasionally, during the night or daytime.

Is frequency analysis required either during the pre-construction background noise 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. Although only standardized dBA and dBC measurements are required to meet the proposed criteria, the addition of one-third octave band analysis is often useful to validate the dBA and dBC results.

The following summarizes the criteria necessary when siting wind turbines to minimize the risk of adverse impacts from noise on the adjacent community[29]. For those not familiar with acoustical annotation the table and its formulas may seem overly complex, but the criteria are defined in this manner to be as unambiguous as possible. They will be clear for those who are familiar with acoustical terminology. Definitions are provided in a later section of this essay.

[28] Harrison, J., *Wind Turbine Guidelines*, available at http://amherstislandwindinfo.com/

[29] The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

NOISE CRITERIA FOR SITING WIND TURBINES TO PREVENT HEALTH RISKS[29]

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 except as noted in Section 4. below.

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 is less than 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}. Record 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 is less than 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 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 (ANSI 12.9 Part 3 with Amendments) of the most recent version of "The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound" by Kamperman and James and the apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing Nighttime 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 except as noted in Section 4. The effect of instrumentation limits for wind and other factors must be recognized and followed.

4. ANSI S12.9 Part 3 Selected Options and Requirement Amendments

For measurements taken to assess the preceding criteria specific options provided for in ANSI S12.9-Part 3 (2008) shall be followed along with any additional requirements included below:

5.2 Background Sound: Use definition (1): 'long-term'

5.2 long-term background sound: The L_{90} excludes short term background sounds

5.3 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$

5.6 Sound Measuring Instrument: Type 1 Precision meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of accurately measuring low-level background sounds down to 20 dBA.

6.5 Windscreen: Required

6.6(a) An anemometer accurate to ± 10% at 2m/s to full-scale accuracy. The anemometer shall be located 1.5 to 2 meters above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each ten (10) minute sound measurement period observed within 5 m. of the measuring microphone.

7.1 Long-term background sound

7.2 Data collection Methods: Second method with observed samples to avoid contamination by short term sounds (purpose: to avoid loss of statistical data)

8. Source(s) Data Collection: All requirements in ANSI S12.18 Method #2, Precision to the extent possible while still permitting testing of the conditions that lead to complaints. The meteorological requirements in ANSI S12.18 may not be applicable for some complaint tests. For sound measurements in response to a complaint, the compliance sound measurements should be made under conditions that replicate the conditions that caused the complaint without exceeding instrument and windscreen limits and tolerances.

8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5 preferred) above the ground and greater than 8 m. from large sound reflecting surface.

8.3(a) All meteorological observations required at both (not either) microphone and nearest 10 m. weather reporting station.

8.3(b) For a ten (10) minute background sound measurement to be valid the wind velocity shall be less then 2m/s (4.5 mph) measured less than 5 m. from the microphone. Compliance sound measurements shall be taken when winds are less than 4m/s at the microphone.

8.3(c) In addition to the required acoustic calibration checks, the sound measuring instrument internal noise floor, including microphone, must also be checked at the end of each series of ten minute measurements and no less frequently than once per day. Insert the microphone into the acoustic calibrator with the calibrator signal off. Record the observed dBA and dBC reading on the sound level meter to determine an approximation of the instrument self noise. Perform this test before leaving the background measurement location. The calibrator-covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten (10) minute acoustic test results, for the acoustic background data to be valid. This test is necessary to detect undesired increase in the microphone and sound level meter internal self-noise. As a precaution sound measuring instrumentation should be removed from any air conditioned space at least an hour before use. Nighttime measurements are often performed very near the meteorological dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the measured background data.

8.4 The remaining sections, starting at 8.4 in ANSI S12.9 Part 3 Standard do not apply.

V. How to Include the Recommended Criteria in Ordinances and/or Community Noise Limits

The following two sections present the definitions, technical requirements, and complaint resolution processes that support the recommended criteria. Following the formal elements is a section discussing the measurement procedures and requirements for enforcement of these criteria. For the purpose of the following sections the government authority will be referred to as the Local Government Authority (LGA) as a place marker for State, County, Township or other authorized authority. The abbreviation 'WES' is used for industrial scale wind energy system.

The authors have based these criteria, procedures, and language on their current understanding of wind turbine sound emissions, land-use compatibility, and the effects of sound on health. However, use of the following, in part or total, by any party is strictly voluntary and the user assumes all risks. Please seek professional assistance in applying the recommendations of this document to any specific community or WES development.

VI. ELEMENTS OF A WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Purpose and Intent.

Based upon the findings stated above, it is the intended purpose of the LGA to regulate Wind Energy Systems to promote the health, safety, and general welfare of the citizens of the Town and to establish reasonable and uniform regulations for the operation thereof so as to control potentially dangerous effects of these Systems on the community.

II. Definitions.

The following terms have the meanings indicated:

"**Aerodynamic Sound**" means a noise that is caused by the flow of air over and past the blades of a WES.

"**Ambient Sound**" Ambient sound encompasses all sound present in a given environment, being usually a composite of sounds from many sources near and far. It includes intermittent noise events, such as, from aircraft flying over, dogs barking, wind gusts, mobile farm or construction machinery, and the occasional vehicle traveling along a nearby road. The ambient also includes insect and other nearby sounds from birds and animals or people. The near-by and transient events are part of the ambient sound environment but are <u>not to be considered part of the long-term background sound.</u>

"**American National Standards Institute (ANSI)**" Standardized acoustical instrumentation and sound measurement protocol shall meet all the requirements of the following ANSI Standards:

ANSI S1.43 Integrating Averaging Sound Level Meters: Type-1 (or IEC 61672-1)

ANSI S1.11 Specification for Octave and One-third Octave-Band Filters (or IEC 61260)

ANSI S1.40 Verification Procedures for Sound Calibrators

ANSI S12.9 Part 3 Procedures for Measurement of Environmental Sound

ANSI S12.18 Measurement of Outdoor Sound Pressure Level

IEC 61400-11 Wind turbine generator systems –Part 11: Acoustic noise measurements

"**Anemometer**" means a device for measuring the speed and direction of the wind.

"**Applicant**" means the individual or business entity that seeks to secure a license under this section of the Town municipal code.

"**A-Weighted Sound Level (dBA)**" A measure of over-all sound pressure level designed to reflect the response of the human ear, which does not respond equally to all frequencies. It is used to describe sound in a manner representative of the human ear's response. It reduces the effects of the low with respect to the frequencies centered around 1000 Hz. The resultant sound level is said to be "A-weighted" and the units are "dBA." Sound level meters have an A-weighting network for measuring A-weighted sound levels (dBA) meeting the characteristics and weighting specified in ANSI Specifications for Integrating Averaging Sound Level Meters, S1.43-1997 for Type 1 instruments and be capable of accurate readings (corrections for internal noise and microphone response permitted) at 20 dBA or lower. In this document dBA means L_{Aeq} unless specified otherwise.

"**Background Sound (L_{90})**" refers to the sound level present at least 90% of the time. Background sounds are those heard during lulls in the ambient sound environment. That is, when transient sounds from flora, fauna, and wind are <u>not</u> present. Background sound levels vary during different times of the day and night. Because WES operates 24/7 the background sound levels of interest are those during the quieter periods which are often the evening and night. Sounds from the WES of interest, near-by birds and animals or people must be excluded from the background sound test data. Nearby electrical noise from streetlights, transformers and cycling AC units and pumps etc must also be excluded from the background sound test data.

Background sound level (dBA and dBC (as L_{90})) is the sound level present 90% of the time during a period of observation that is representative of the quiet time for the soundscape under evaluation and with duration of ten (10) continuous minutes. Several contiguous ten (10) minute tests may be performed in one hour to determine the statistical stability of the sound environment. Measurement periods such as at dusk when bird and insect activity is high or the early morning hours when the 'dawn chorus' is present are not acceptable measurement times. Longer term sound level averaging tests, such as 24 hours or multiple days are not at all appropriate since the purpose is to define the quiet time background sound level. It is defined by the $L_{A\,90}$ and $L_{C\,90}$ descriptors. It may be considered as the quietest one (1) minute during a ten (10) minute test. $L_{A\,90}$ results are valid only when $L_{A\,10}$ results are no more than 10 dB above $L_{A\,90}$ for the same period. $L_{C\,10}$ less $L_{C\,90}$ are not to exceed 10 dB to be valid.

The background noise environment consists of a multitude of distant sources of sound. When a new nearby source is introduced the new background noise level would be increased. The addition of a new source with a noise level 10 below the existing background would increase the new background 0.4 dB. If the new source has the same noise level as the existing background then the new background is increased 3.0 dB. Lastly, if the new source is 3.3 dB above the existing background then the new background would have increased 5 dB. For example, to meet the requirement of L_{90A} + 5 dB = 31 dBA if the existing quiet nighttime background sound level is 26 dBA, the maximum wind turbine noise immission contribution independent of the background cannot exceed 29.3 dBA L_{eq} at a dwelling. When adding decibels, a 26 dBA background combined with 29.3 dBA from the turbines (without background) results in 31 dBA.

Further, background L_{90} sound levels documenting the pre-construction baseline conditions should be determined when the ten (10) minute maximum wind speed is less than 2 m/s (4.5 mph) near ground level/microphone location 1.5 m height.

"**Blade Passage Frequency**" (BPF) means the frequency at which the blades of a turbine pass a particular point during each revolution (e.g. lowest point or highest point in rotation) in terms of events per second. A three bladed turbine rotating at 28 rpm would have a BPF of 1.4 Hz. [E.g. ((3 blades times 28rpm)/60 seconds per minute = 1.4 Hz BPF)]

"C-Weighted Sound Level (dBC)" Similar in concept to the A-Weighted sound Level (dBA) but C-weighting does not de-emphasize the frequencies below 1k Hz as A-weighting does. It is used for measurements that must include the contribution of low frequencies in a single number representing the entire frequency spectrum. Sound level meters have a C-weighting network for measuring C-weighted sound levels (dBC)meeting the characteristics and weighting specified in ANSI S1.43-1997 Specifications for Integrating Averaging Sound Level Meters for Type 1 instruments. In this document dBC means L_{Ceq} unless specified otherwise.

"Decibel (dB)" A dimensionless unit which denotes the ratio between two quantities that are proportional to power, energy or intensity. One of these quantities is a designated reference by which all other quantities of identical units are divided. The sound pressure level (Lp) in decibels is equal to 10 times the logarithm (to the base 10) of the ratio between the pressure squared divided by the reference pressure squared. The reference pressure used in acoustics is 20 MicroPascals.

"Emission" Sound energy that is emitted by a noise source (wind farm) is transmitted to a receiver (dwelling) where it is immitted (see "immission).

"Frequency" The number of oscillations or cycles per unit of time. Acoustical frequency is usually expressed in units of Hertz (Hz) where one Hz is equal to one cycle per second.

"Height" means the total distance measured from the grade of the property as existed prior to the construction of the wind energy system, facility, tower, turbine, or related facility at the base to its highest point.

"Hertz (Hz)" Frequency of sound expressed by cycles per second.

"Immission" Noise immitted at a receiver (dwelling) is transmitted from noise source (wind turbine) that emitted sound energy (see "emission").

"Immission spectra imbalance" The spectra are not in balance when the C-weighted sound level is more than 20 dB greater than the A-weighted sound level. For the purposes of this requirement, the A-weighted sound level is defined as the long-term background sound level (L_{A90}) +5 dBA. The C-weighted sound level is defined as the L_{Ceq} measured during the operation of the wind turbine operated so as to result in its highest sound output. A Complaint test provided later in this document is based on the immission spectra imbalance criteria.

"Infra-Sound" sound with energy in the frequency range of 0-20 Hz is considered to be infra-sound. It is normally considered to not be audible for most people unless in relatively high amplitude. However, there is a wide range between the most sensitive and least sensitive people to perception of sound and perception is not limited to stimulus of the auditory senses. The most significant exterior noise induced dwelling vibration occurs in the frequency range between 5 Hz and 50 Hz. Moreover, levels below the threshold of audibility can still cause measurable resonances inside dwelling interiors. Conditions that support or magnify resonance may also exist in human body cavities and organs under certain conditions. Although no specific test for infrasound is provided in this document, the test for immission spectra imbalance will limit low frequency sound and thus, indirectly limit infrasound. See low-frequency noise (LFN) for more information.

"Low Frequency Noise (LFN)" refers to sounds with energy in the lower frequency range of 20 to 200 Hz. LFN is deemed to be excessive when the difference between a C-weighted sound level and an A-weighted sound level is greater than 20 decibels at any measurement point outside a residence or other occupied structure. The criteria for this condition is the "Immission Spectra Imbalance" entry in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**"

"**Measurement Point (MP)**" means location where sound measurements are taken such that no significant obstruction blocks sound from the site. The Measurement Point should be located so as to not be near large objects such as buildings and in the line-of-sight to the nearest turbines. Proximity to large buildings or other structures should be twice the largest dimension of the structure, if possible. Measurement Points should be at quiet locations remote from street lights, transformers, street traffic, flowing water and other local noise sources.

"**Measurement Wind Speed**" For measurements conducted to establish the background noise levels ($L_{A90\ 10\ min}$, $L_{C90\ 10\ min}$, and etc.) the maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 2 m/s (4.5 mph) for valid background measurements. For valid wind farm noises measurements conducted to establish the post-construction sound level the maximum wind speed, sampled within 5m of the microphone and at its height, shall be less than 4m/s (9 mph). The wind speed at the WES blade height shall be at or above the nominal rated wind speed and operating in its highest sound output mode. For purposes of enforcement, the wind speed and direction at the WES blade height shall be selected to reproduce the conditions leading to the enforcement action while also restricting maximum wind speeds at the microphone to less than 4 m/s (9 mph).

For purposes of models used to predict the sound levels and sound pressure levels of the WES to be submitted with the Application, the wind speed shall be the speed that will result in the worst-case L_{Aeq} and L_{Ceq} sound levels at the nearest non-participating properties to the WES. If there may be more than one set of nearby sensitive receptors, models for each such condition shall be evaluated and the results shall be included in the Application.

"**Mechanical Noise**" means sound produced as a byproduct of the operation of the mechanical components of a WES(s) such as the gearbox, generator and transformers.

"**Noise**" means any unwanted sound. Not all noise needs to be excessively loud to represent an annoyance or interference.

"**Project Boundary**" means the external property boundaries of parcels owned by or leased by the WES developers. It is represented on a plot plan view by a continuous line encompassing all WES(s) and related equipment associated with the WES project.

"**Property Line**" means the recognized and mapped property parcel boundary line.

"**Qualified Independent Acoustical Consultant**" Qualifications for persons conducting baseline and other measurements and reviews related to the application for a WES or for enforcement actions against an operating WES include, at a minimum, demonstration of competence in the specialty of community noise testing. An example is a person with Full Membership in the Institute of Noise Control Engineers (INCE). There are scientists and engineers in other professional fields that have been called upon by their local community for help in the development of a WES Noise Ordinance. Many of these scientists and engineers have recently spent hundreds of hours learning many important aspects of noise related to the introduction of WES into their communities. Then with field measurement experience with background data and wind turbine noise emission, they have become qualified independent acoustical consultants for WES siting. Certifications such as Professional Engineer (P.E.) do not test for competence in acoustical principles and measurement and are thus not, without further qualification, appropriate for work under this document. The Independent Qualified Acoustical Consultant can have no financial or other connection to a WES developer or related company.

"**Sensitive Receptor**" means places or structures intended for human habitation, whether inhabited or not, public parks, state and federal wildlife areas, the manicured areas of recreational establishments designed for public use, including but not limited to golf courses, camp grounds and other nonagricultural state or federal licensed businesses. These areas are more likely to be sensitive to the exposure of the noise, shadow or flicker, etc. generated by a WES or WESF. These areas include, but are not limited to: schools, daycare centers, elder care facilities, hospitals, places of seated assemblage, non-agricultural businesses and residences.

"**Sound**" A fluctuation of air pressure which is propagated as a wave through air

"**Sound Power**" The total sound energy radiated by a source per unit time. The unit of measurement is the watt. Abbreviated as L_w. This information is determined for the WES manufacturer under laboratory conditions specified by IEC 61400-11 and provided to the local developer for use in computer model construction. There is known measurement error in this test procedure that must be disclosed and accounted for in the computer models. Even with the measurement error correction it cannot be assumed that the reported L_w values represent the highest sound output for all operating conditions. They reflect the operating conditions required to meet the IEC 61400-11 requirements. The lowest frequency is 50 Hz for acoustic power (L_w) requirement (at present) in IEC 61400-11. This Ordinance requires wind turbine certified acoustic power (L_w) levels at rated load for the total frequency range from 6.3 Hz to 10k Hz in one-third octave frequency bands tabulated to the nearest 1 dB. The frequency range of 6.3 Hz to 10k Hz shall be used throughout this Ordinance for all sound level modeling, measuring and reporting.

"**Sound Pressure**" The instantaneous difference between the actual pressure produced by a sound wave and the average or barometric pressure at a given point in space.

"**Sound Pressure Level (SPL)**" 20 times the logarithm, to the base 10, of the ratio of the pressure of the sound measured to the reference pressure, which is 20 micronewtons per square meter. In equation form, sound pressure level in units of decibels is expressed as SPL (dB) = 20 log p/pr.

"**Spectrum**" The description of a sound wave's resolution into its components of frequency and amplitude. The WES manufacturer is required to supply a one-third octave band frequency spectrum of the wind turbine sound emission at 90% of rated power. The published sound spectrum is often presented as A-weighted values but C-weighted values are preferred. This information is used to construct a model of the wind farm's sound immission levels at locations of interest in and around the WES. The frequency range of interest for wind turbine noise is approximately 6 Hz to 10k Hz.

"**Statistical Noise Levels**" Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{NA}, where L_{NA} is the A-weighted sound level exceeded for N% of a given measurement period. For example, L_{10} is the noise level exceeded for 10% of the time. Of particular relevance, are: L_{A10} and L_{C10} the noise level exceed for 10% of the ten (10) minute interval. This is commonly referred to as the average maximum noise level. L_{A90} and L_{C90} are the A-weighted and C-weighted sound levels exceeded for 90% of the ten (10) minute sample period. The L_{90} noise level is defined by ANSI as the long-term background sound level (i.e. the sounds one hears in the absence of the noise source under consideration and without short term or near-by sounds from other sources), or simply the "background level." L_{eq} is the A or C-weighted equivalent noise level (the "average" noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

"**Tonal sound or tonality**" Tonal audibility. A sound for which the sound pressure is a simple sinusoidal function of the time, and characterized by its singleness of pitch. Tonal sound can be simple or complex.

"**Wind Energy Systems (WES)**" means equipment that converts and then transfers energy from the wind into usable forms of electrical energy.

"**Wind Turbine" or "Turbine" (WT)** means an industrial scale mechanical device which captures the kinetic energy of the wind and converts it into electricity. The primary components of a wind turbine are the blade assembly, electrical generator and tower.

III. APPLICATION PROCEDURE FOR WIND ENERGY SYSTEMS AND TECHNICAL REQUIREMENTS FOR LICENSING

This ordinance is intended to promote the safety and health of the community through criteria limiting sound emissions during operation of Wind Energy Systems. It is recognized that the requirements herein are neither exclusive, nor exhaustive. In instances where a health or safety concern is known to the wind project developer or identified by other means with regard to any application for a Wind Energy System, additional and/or more restrictive conditions may be included in the license to address such concerns. All rights are reserved to impose additional restrictions as circumstances warrant. Such additional or more restrictive conditions may include, without limitation (a) greater setbacks, (b) more restrictive noise limitations, or (c) limits restricting operation during night time periods or for any other conditions deemed reasonable to protect the community.

A. Application

Any Person desiring to secure a Wind Energy Systems license shall file an application form provided by the LGA Clerk, together with two additional copies of the application with the LGA Clerk.

B. Information to be submitted with Application

1. Information regarding the:

- Make and model of all turbines potentially used in this project,
- Sound Power Levels (L_w) for each 1/3 octave band from 6.3 Hz to 10,000 Hz, and
- A sound propagation model predicting the sound levels immitted into the community computed using at minimum 1/1 octave band sound power levels to compute the L_{Ceq} and L_{Aeq} levels to generate L_{Aeq} and L_{Ceq} contours in 5 dB increments overlaying an aerial view and property survey map from the WES property out to a distance to include all residential property within two (2) miles of the WES Property. Appropriate corrections for model algorithm error, IEC61400-11 test measurement accuracy, and directivity patterns of for each model of WT shall be disclosed and accounted for in the model(s). Predictions shall be made at all property lines within and outward for two (2) miles from the project boundary for the wind speed, direction and operating mode that would result in the worst case WT nighttime sound emissions.

The prediction model shall assume that the winds at hub height are sufficient for the highest sound emission operating mode. The projection shall include a description of all assumptions made in the model's construction and algorithms. If the model does not consider the effects of wind direction, geography of the terrain, and/or the effects of reinforcement from coherent sounds or tones from the turbines all these items should be identified and all other means used to adjust the model's output to account for these factors. The results shall be displayed as a contour map of the predicted levels as over-all L_{Aeq} and L_{Ceq} contours out to 2 miles from the WES property, and shall also include a table showing the 1/3 or 1/1 octave band sound pressure as L_{Ceq} levels for the nearest property line(s) for sensitive receptor sites (including residences) within the model's boundaries. The predicted values must include the over-all sound levels and 1/1 or 1/3 octave band sound pressure levels from 6 Hz to 10k Hz in data tables that include the location of each receiving point by GPS location or other repeatable means.

C. Preconstruction Background Noise Survey

1. The Town reserves the right to require the preparation of (a) a preconstruction noise survey for each proposed Wind Turbine location conducted per procedures provided in the section on Measurement Procedures showing long-term background L_{A90} and L_{C90} sound levels. This must be completed and accepted prior to approval of the final layout and issuance of project permits.

   a. If any proposed wind farm project locates a WES within two miles of a sensitive receptor these studies are mandatory. The preconstruction baseline studies shall be conducted by an Independent Qualified Acoustical Consultant selected and hired by the LGA.

   b. The applicant shall be responsible for paying the consultant's fees and costs associated with conducting the study. These fees and cost shall be negotiated with the consultant and determined prior to any work being done on the study. The applicant shall be required to set aside 100% of these fees in an escrow account managed by the LGA, before the study is commenced by the consultant. Payment for this study does not require the WES developer's acceptance of the study's results.

   c. If the review shows that the predicted L_{Aeq} and L_{Ceq} sound levels exceed any of the criteria specified in the **Table of Not-To-Exceed Property Line Sound Immission Limits** then the application cannot be approved.

2. The LGA will refer the application to the LGA engineer (if qualified in acoustics) or an independent qualified acoustical consultant for further review and comparison of the long-term background sound levels against the predicted L_{Aeq} and L_{Ceq} sound levels reported for the model using the criteria in the **Table of Not-To-Exceed Property Line Sound Immission Limits**. The reasonably necessary costs associated with such a review shall be the responsibility of the applicant, in accord with the terms of this ordinance.

D. Post Construction Noise Measurement Requirements

1. **Sound Regulations Compliance**: A WES shall be considered in violation of the conditional use permit unless the applicant demonstrates that the project complies with all sound level limits using the procedures specified in this ordinance. Sound levels in excess of the limits established in this ordinance shall be grounds for the LGA to order immediate shut down of all non-compliant WT units.

2. **Post-Construction Sound Measurements**: Within twelve months of the date when the project is fully operational, and within four weeks of the anniversary date of the pre-construction background noise measurements, repeat the existing sound environment measurements taken before the project approval. Post-construction sound level measurements shall be taken both with all WES's running and with all WES's off. At the discretion of the Town, the Pre-construction background sound levels (L_{A90} and L_{C90}) can be substituted for the "all WES off" tests if a random sampling of 10% of the pre-construction study sites shows that background L_{90A} and L_{90C} conditions have increased less than 3 dB from those measured under the pre-

construction nighttime conditions. The post-construction measurements will be reported to the LGA (available for public review) using the same format as used for the preconstruction sound studies. Post-construction noise studies shall be conducted by a firm chosen and hired by the LGA. Costs of these studies are to be reimbursed by the Licensee in a similar manner to that described above. The wind farm developer's may ask to have its own consultant observe the publicly retained consultant at the convenience of the latter. The WES Licensee shall provide all technical information and wind farm data required by the qualified independent acoustical consultant before, during, and/or after any acoustical studies required by this document and for acoustical measurements.

3. Sound Limits

1. Establishing Long-Term Background Sound 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 and Measurement Procedures Appendix to Ordinance following next Section.

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 maximum wind speed at the microphone must be less than 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 is less than 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 (C - A $\leq$ 20dB)	L_{Ceq} (immission) minus (L_{A90} (background) +5 dB) $\leq$ 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 sound emission as received at a property.		
2	A "quiet rural environment" is a location 2 miles from a 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] Required Procedures provided in VIII Reference Standards including ANSI 12.9 Part 3 as Amended			

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing 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 in the Appendix to Ordinance. The effect of instrumentation limits for wind and other factors must be recognized and followed.

3. Operations

The WES/WT is non-compliant and must be shut down immediately if it exceeds any of the limits in the **Table of Not-To-Exceed Property Line Sound Immission Limits.**

4. Complaint Resolution

1. The owner/operator of the WES shall respond within five (5) business days after notified of a noise complaint by any property owner within the project boundary and a one-mile radius beyond the project boundary.
2. The tests shall be performed by a qualified independent acoustical consultant acceptable to the complainant and the local agency charged with enforcement of this ordinance.
3. Testing shall commence within ten (10) working days of the request. If testing cannot be initiated within ten (10) days, the WES(s) in question shall be shut down until the testing can be started.
4. A copy of the test results shall be sent to the property owner, and the LGA's Planning or Zoning department within thirty (30) days of test completion.
5. If a Complaint is made, the presumption shall be that it is reasonable. The LGA shall undertake an investigation of the alleged operational violation by a qualified individual mutually acceptable to the LGA.

a) The reasonable cost and fees incurred by the LGA in retaining said qualified individual shall be reimbursed by the owner of the WESF.

b) Funds for this assessment shall be paid or put into an escrow account prior to the study and payment shall be independent of the study findings.

6. After the investigation, if the LGA reasonably concludes that operational violations are shown to be caused by the WESF, the licensee/operator/owner shall use reasonable efforts to mitigate such problems on a case-by-case basis including such measures as not operating during the nighttime or other noise sensitive period if such operation was the cause of the complaints.

5. Reimbursement of Fees and Costs.

Licensee/operator/owner agrees to reimburse the LGA 's reasonable fees and costs incurred in the preparation, negotiation, administration and enforcement of this Ordinance, including, without limitation, the LGA 's attorneys' fees, engineering and/or consultant fees, LGA meeting and hearing fees and the costs of public notices. If requested by the LGA the funds shall be placed in an escrow account under the management of the LGA. The preceding fees are payable within thirty (30) days of invoice. Unpaid invoices shall bear interest at the rate of 1% per month until paid. The LGA may recover all reasonable costs of collection, including attorneys' fees.

VII. MEASUREMENT PROCEDURES

SUPPLEMENT TO WIND ENERGY SYSTEMS LICENSING ORDINANCE FOR SOUND

I. Introduction

The potential impact of sound and sound induced building vibration associated with the operation of wind powered electric generators is often a primary concern for citizens living near proposed wind energy systems (WES(s)). This is especially true of projects located near homes, residential neighborhoods, businesses, schools, and hospitals in quiet residential and rural communities. Determining the likely sound and vibration impacts is a highly technical undertaking and requires a serious effort in order to collect reliable and meaningful data for both the public and decision makers.

This protocol is based in part on criteria published in American National Standards S12.9 -Part 3 Quantities and Procedures for Description and Measurement of Environmental Sound, and S12.18 and for the measurement of sound pressure level outdoors.

The purpose is to first, establish a consistent and scientifically sound procedure for evaluating existing background levels of audible and low frequency sound in a WES project area, and second to use the information provided by the Applicant in its Application showing the predicted over-all sound levels in terms of L_{Aeq} and L_{Ceq} and 1/3 or 1/1 octave bands as part of the required information submitted with the application.

The over-all values shall be presented as overlays to the applicant's iso-level plot plan graphics and, for 1/1 or 1/3 octave data, in tabular form with location information sufficient to permit comparison of the baseline results to the predicted levels. This comparison will use the level limits of the ordinance to determine the likely impact operation of a new wind energy system project will have on the existing community soundscape. If the comparison demonstrates that the WES project will not exceed any of the level limits the project will be considered to be within allowable limits for safety and health. If the Applicant submits only partial information required for this comparison applicant, sensitive receptors (homes) and locations selected for the baseline sound tests whichever are the controlling metric. The test points shall be located at the property line bounding the property of the turbine's host closest to the wind turbine. Additional sites may be added if appropriate. A grid comprised of one (1) mile boundaries (each grid cell is one (1) square mile) should be used to assist in identifying between two (2) to ten (10) measurement points per cell. The grid shall extend to a minimum of two (2) miles beyond the perimeter of the project boundary. This may be extended to more than two (2) miles at the discretion of the LGA. The measurement points shall be selected to represent the noise sensitive receptor sites based on the anticipated sound propagation from the combined WT in the project. Usually, this will be the closest WT. If there is more than one WT near-by then more than one test site may be required.

The intent is to anticipate the locations along the bounding property line that will receive the highest sound immissions. The site that will most likely be negatively affected by the WES project's sound emissions should be given first priority in testing. These sites may include sites adjacent to occupied dwellings or other noise sensitive receptor sites. Sites shall be selected to represent the locations where the background soundscapes reflect the quietest locations of the sensitive receptor sites. Background sound levels (and 1/3 octave band sound pressure levels if required) shall be obtained according to the definitions and procedures provided in the ordinance and recognized acoustical testing practice and standards.

All properties within the proposed WES project boundaries will be considered for this study.

One test shall be conducted during the period defined by the months of April through November with the preferred time being the months of June through August. These months are normally associated with more contact with the outdoors and when homes may have open windows during the evening and night. Unless directed otherwise by the LGA the season chosen for testing will represent the background soundscape for other seasons. At the discretion of the LGA, tests may be scheduled for other seasons.

All measurement points (MPs) shall be located with assistance from the LGA staff and property owner(s) and positioned such that no significant obstruction (building, trees, etc.) blocks sound and vibration from the nearest proposed WES site.

Duration of measurements shall be a minimum of ten (10) continuous minutes for all criteria at each location. The duration must include at least six (6) minutes that are not affected by transient sounds from near-by and non-nature sources. Multiple ten (10) minute samples over longer periods such as 30 minutes or one (1) hour may be used to improve the reliability of the L_{A90} and L_{C90} values. The ten (10) minute sample with the lowest valid L_{90} values will be used to define the background sound.

The tests at each site selected for this study shall be taken during the expected 'quietest period of the day or night' as appropriate for the site. For the purpose of determining background sound characteristics the preferred testing time is from 10pm until 4 am. If circumstances indicated that a different time of the day should be sampled the test may be conducted at the alternate time if approved by the Town.

Sound level measurements shall be made on a weekday of a non-holiday week. Weekend measurements may also be taken at selected sites where there are weekend activities that may be affected by WT sound.

Measurements must be taken with the microphone at 1.2 to 1.5 meters above the ground and at least 15 feet from any reflective surface following ANSI 12.9 Part 3 protocol including selected options and other requirements outlined later in this Section.

the application cannot be approved. In all cases the burden to establish the operation as meeting safety and health limits will be on the Applicant.

Next, it covers requirements for the sound propagation model to be supplied with the application.

Finally, if the project is approved, this section covers the study needed to compare the post-build sound levels to the predictions and the baseline study. The level limits in the ordinance apply to the post-build study. In addition, if there have been any complaints about WES sound or low frequency noise emissions or wind turbine noise induced dwelling vibration by any resident of an occupied dwelling that property will be included in the post-build study for evaluation against the rules for sound level limits and compliance.

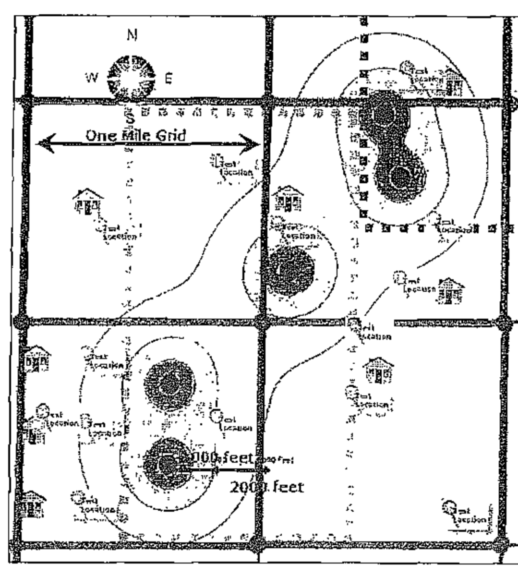
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors should be taken into consideration when designing a sound study. The work will be performed by a qualified independent acoustical consultant for both the pre-construction background and post-construction sound studies as described in the body of the ordinance.

II. Instrumentation

All instruments and other tools used to measure audible, inaudible and low frequency sound shall meet the requirements for ANSI or IEC Type 1 Integrating Averaging Sound Level Meter Standards The principle standard reference for this document is ANSI 12.9/Part 3 with important additional specific requirements for the measuring instrumentation and measurement protocol.

III. Measurement of Pre-Construction Sound Environment (Base-line)

An assessment of the proposed WES project areas existing sound environment is necessary in order to predict the likely impact resulting from a proposed project. The following guidelines must be used in developing a reasonable estimate of an area's existing background sound environment. All testing is to be performed by an independent qualified acoustical consultant approved by the LGA as provided in the body of the ordinance. The WES applicant may file objections detailing any concerns it may have with the LGA's selection. These concerns will be addressed in the study. Objections must be filed prior to the start of the noise study. All measurements are to be conducted with ANSI or IEC Type 1 certified and calibrated test equipment per reference specification at the end of this section. Test results will be reported to the LGA or its appointed representative.



Sites with No Existing Wind Energy Systems (Base-line Sound Study)

Sound level measurements shall be taken as follows:

The results of the model showing the predicted worst case L_{Aeq} and L_{Ceq} sound emissions of the proposed WES project will be overlaid on a map (or separate L_{Aeq} and L_{Ceq} maps) of the project area. An example (right) shows an approximately two (2) mile square section with iso-level contour lines prepared by the

Reporting

1. For each Measurement Point and for each qualified measurement period, provide each of the following measurements:

a. L_{Aeq}, L_{A10}, and L_{A90}, and

b. L_{Ceq} , L_{C10}, and L_{C90}

2. A narrative description of any intermittent sounds registered during each measurement. This may be augmented with video and audio recordings.

3. A narrative description of the steady sounds that form the background soundscape. This may be augmented with video and audio recordings.

4. Wind speed and direction at the microphone (Measurement Point), humidity and temperature at time of measurement will be included in the documentation. Corresponding information from the nearest 10 meter weather reporting station shall also be obtained.

Measurements taken only when wind speeds are less than 2m/s (4.5 mph) at the microphone location will be considered valid for this study. A windscreen of the type recommended by the monitoring instrument's manufacturer must be used for all data collection.

5. Provide a map and/or diagram clearly showing (Using plot plan provided by LGA or Applicant):

- The layout of the project area, including topography, the project boundary lines, and property lines.
- The locations of the Measurement Points.
- The distance between any Measurement Points and the nearest WT(s).
- The location of significant local non-WES sound and vibration sources.
- The distance between all MPs and significant local sound sources. And,
- The location of all sensitive receptors including but not limited to: schools, day-care centers, hospitals, residences, residential neighborhoods, places of worship, and elderly care facilities.

Sites with Existing Wind Energy Systems

Two complete sets of sound level measurements must be taken as defined below:

1. One set of measurements with the wind generator(s) off unless the LGA elects to substitute the sound data collected for the background sound study. Wind speeds must be suitable for background sound tests as specified elsewhere in this ordinance.

2. One set of measurements with the wind generator(s) running with wind speed at hub height sufficient to meet nominal rated power output or higher and less than 2 m/s below at the microphone location. Conditions should reflect the worst case sound emissions from the WES project. This will normally involve tests taken during the evening or night when winds are calm (less than 2m/sec) at the ground surface yet, at hub height, sufficient to power the turbines.

Sound level measurements and meteorological conditions at the microphone shall be taken and documented as discussed above.

Sound level Estimate for Proposed Wind Energy Systems (when adding more WT to existing project)

In order to estimate the sound impact of the proposed WES project on the existing environment an estimate of the sound produced by the proposed WES(s) under worst-case conditions for producing sound emissions must be provided. This study may be conducted by a firm chosen by the WES operator with oversight provided by the LGA.

The qualifications of the firm should be presented along with details of the procedure that will be used, software applications, and any limitations to the software or prediction methods as required elsewhere in this ordinance for models.

Provide the manufacturer's sound power level (L_{Aw}) and (L_{Cw}) characteristics for the proposed WES(s) operating at full load utilizing the methodology in IEC 61400-11 Wind Turbine Noise Standard. Provide one-third octave band sound power level information from 6.3 Hz to 10k Hz. Furnish the data using no frequency weighting. A-weighted data is optional. Provide sound pressure levels predicted for the WES(s) in combination and at full operation and at maximum sound power output for all areas where the predictions indicate L_{Aeq} levels of 30 dBA and above. The same area shall be used for reporting the predicted L_{Ceq} levels. Contour lines shall be in increments of 5 dB.

Present tables with the predicted sound levels for the proposed WES(s) as L_{Aeq} and L_{Ceq} and at all octave band centers (8 Hz to 10k Hz) for distances of 500, 1000, 1500, 2000, 2500 and 5000 feet from the center of the area with the highest density of WES(s). For projects with multiple WES(s), the combined sound level impact for all WES(s) operating at full load must be estimated.

The above tables must include the impact (increased dBA and dBC (L_{eq}) above baseline L_{90} background sound levels) of the WES operations on all residential and other noise sensitive receiving locations within the project boundary. To the extent possible, the tables should include the sites tested (or likely to be tested) in the background study.

Provide a contour map of the expected sound level from the new WES(s), using 5dB L_{Aeq} and L_{Ceq} increments created by the proposed WES(s) extending out to a distance of two (2) miles from the project boundary, or other distance necessary, to show the 25 L_{Aeq} and 50 L_{Ceq} boundaries.

Provide a description of the impact of the proposed sound from the WES project on the existing environment. The results should anticipate the receptor sites that will be most negatively impacted by the WES project and to the extent possible provide data for each MP that are likely to be selected in the background sound study (note the sensitive receptor MPs):

1. Report expected changes to existing sound levels for L_{Aeq} and L_{A90}
2. Report expected changes to existing sound levels for L_{Ceq} and L_{C90}
3. Report the expected changes to existing sound pressure levels for each of the 1/1 or 1/3 octave bands in tabular form from 8 Hz to 10k Hz.
4. Report all assumptions made in arriving at the estimate of impact, any limitations that might cause the sound levels to exceed the values of the estimate, and any conclusions reached regarding the potential effects on people living near the project area. If the effects of coherence, worst case weather, or operating conditions are not reflected in the model a discussion of how these factors could increase the predicted values is required.
5. Include an estimate of the number of hours of operation expected from the proposed WES(s) and under what conditions the WES(s) would be expected to run. Any differences from the information filed with the Application should be addressed.

IV. Post-Construction Measurements

Post Construction Measurements should be conducted by a qualified noise consultant selected by and under the direction of the LGA. The requirements of this Appendix for Sites with Existing Wind Energy Systems shall apply

1. Within twelve months of the date when the project is fully operational, preferably within two weeks of the anniversary date of the pre-construction background sound measurements, repeat the measurements. Post-construction sound level measurements shall be taken both with all WES(s) running and with all WES(s) off except as provided in this ordinance.

2. Report post-construction measurements to the LGA using the same format as used for the background sound study.

VIII. REFERENCE Standards and ANSI S12.9 Part 3 with Required Amendments

ANSI/ASA S12.9-1993/Part 3 (R2008) - American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present.

This standard is the second in a series of parts concerning description and measurement of outdoor environmental sound. The standard describes recommended procedures for measurement of short-term, time-average environmental sound outdoors at one or more locations in a community for environmental assessment or planning for compatible land uses and for other purposes such as demonstrating compliance with a regulation. These measurements are distinguished by the requirement to have an observer present. Sound may be produced by one or more separate, distributed sources of sound such as a highway, factory, or airport. Methods are given to correct the measured levels for the influence of background sound.

Wind Turbine Siting Acoustical Measurements
ANSI S12.9 Part 3 Selected Options and Requirement Amendments

For the purposes of this ordinance specific options provided in ANSI S12.9-Part 3 (2008) shall apply with the additional following requirements to Sections in ANSI S12.9/Part 3:

5.2 background sound: Use definition (1) 'long-term'
5.2 long-term background sound: The L_{90} excludes short term background sounds
5.3 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$
5.6 Sound Measuring Instrument: Type 1 Integrating Meter meeting ANSI S1.43 or IEC 61672-1. The sound level meter shall cover the frequency range from 6.3 Hz to 20k Hz and simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of accurately measuring low-level background sounds down to 20 dBA.
6.5 Windscreen: Required
6.6(a) An anemometer accurate to ± 10% at 2m/s. to full scale accuracy. The anemometer shall be located 1.5 to 2m above the ground and orientated to record maximum wind velocity. The maximum wind velocity, wind direction, temperature and humidity shall be recorded for each ten (10) minute sound measurement period observed within 5 m. of the measuring microphone..
7.1 Long-term background sound
7.2 Data collection Methods: Second method with observed samples to avoid contamination by short term sounds (purpose: to avoid loss of statistical data)
8 Source(s) Data Collection: All requirements in ANSI S12.18 Method #2 precision to the extent possible while still permitting testing of the conditions that lead to complaints. The

meteorological requirements in ANSI S12.18 may not be applicable for some complaints. For sound measurements in response to a complaint, the compliance sound measurements should be made under conditions that replicate the conditions that caused the complaint without exceeding instrument and windscreen limits and tolerances.

8.1(b) Measuring microphone with windscreen shall be located 1.2m to 1.8m (1.5m preferred) above the ground and greater than 8m from large sound reflecting surface.

8.3(a) All meteorological observations required at both (not either) microphone and nearest 10m weather reporting station.

8.3(b) For a 10 minute background sound measurement to be valid the wind velocity shall be less then 2m/s (4.5 mph) measured less than 5m from the microphone. Compliance sound measurements shall be taken when winds shall be less than 4m/s at the microphone.

8.3(c) In addition to the required acoustic calibration checks, the sound measuring instrument internal noise floor, including microphone, must also be checked at the end of each series of ten minute measurements and no less frequently than once per day. Insert the microphone into the acoustic calibrator with the calibrator signal off. Record the observed dBA and dBC reading on the sound level meter to determine an approximation of the instrument self noise. Perform this test before leaving the background measurement location. This calibrator-covered microphone must demonstrate the results of this test are at least 5 dB below the immediately previous ten-minute acoustic test results, for the acoustic background data to be valid. This test is necessary to detect undesired increase in the microphone and sound level meter internal self-noise. As a precaution sound measuring instrumentation should be removed from any air-conditioned space at least an hour before use. Nighttime measurements are often performed very near the meteorological dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the measured background data.

8.4 The remaining sections starting at 8.4 in ANSI S12.9 Part 3 Standard do not apply.

ANSI S12.18-1994 (R2004) American National Standard Procedures for Outdoor Measurement of Sound Pressure Level

This American National Standard describes procedures for the measurement of sound pressure levels in the outdoor environment, considering the effects of the ground, the effects of refraction due to wind and temperature gradients, and the effects due to turbulence. This standard is focused on measurement of sound pressure levels produced by specific sources outdoors. The measured sound pressure levels can be used to calculate sound pressure levels at other distances from the source or to extrapolate to other environmental conditions or to assess compliance with regulation. This standard describes two methods to measure sound pressure levels outdoors. METHOD No. 1: general method; outlines conditions for routine measurements. METHOD No. 2: precision method; describes strict conditions for more accurate measurements. This standard assumes the measurement of A-weighted sound pressure level or time-averaged sound pressure level or octave, 1/3-octave or narrow-band sound pressure level, but does not preclude determination of other sound descriptors.

ANSI S1.43-1997(R2007) American National Standard Specifications for Integrating Averaging Sound Level Meters

This Standard describes instruments for the measurement of frequency-weighted and time-average sound pressure levels. Optionally, sound exposure levels may be measured. This standard is consistent with the relevant requirements of ANSI S1.4-1983(R 1997) American National Standard Specification for Sound Level Meters, but specifies additional characteristics that are necessary to measure the time-average sound pressure level of steady, intermittent, fluctuating, and impulsive sounds.

ANSI S1.11-2004 American National Standard 'Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters'

This standard provides performance requirements for analog, sampled-data, and digital implementations of band-pass filters that comprise a filter set or spectrum analyzer for acoustical measurements. It supersedes ANSI S1.11-1986 (R1998) American National Standard Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters, and is a counterpart to International Standard IEC 61260:1995 Electroacoustics - Octave-Band and Fractional-Octave-Band Filters. Significant changes from ANSI S1.11-1986 have been adopted in order to conform to most of the specifications of IEC 61260:1995. This standard differs from IEC 61260:1995 in three ways: (1) the test methods of IEC 61260 clauses 5 is moved to an informative annex, (2) the term 'band number,' not present in IEC 61260, is used as in ANSI S1.11-1986, (3) references to American National Standards are incorporated, and (4) minor editorial and style differences are incorporated.

ANSI S1.40-2006 American National Standard Specifications and Verification Procedures for Sound Calibrators

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-05

IEC 61400-11

Second edition 2002-12, Amendment 1 2006-0

Wind turbine generator systems –Part 11: Acoustic noise measurement techniques

The purpose of this part of IEC 61400 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. The standard has been prepared with the anticipation that it would be applied by:

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

This standard provides guidance in the measurement, analysis and reporting of complex acoustic emissions from wind turbine generator systems. The standard will benefit those parties involved in the manufacture, installation, planning and permitting, operation, utilization, and regulation of wind turbines. The measurement and analysis techniques recommended in this document should be applied by all parties to insure that continuing development and operation of wind turbines is carried out in an atmosphere of consistent and accurate communication relative to environmental concerns. This standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

End of Measurement Procedure

Report by

Dr Christopher HANNING
BSc, MB, BS, MRCS, LRCP, FRCA, MD

on

Sleep disturbance and wind turbine noise

on behalf of

Stop Swinford Wind Farm Action Group **(SSWFAG)**

June 2009

Contents

1. Introduction

1.1 The author

1.1.1. My name is Dr Christopher Hanning, Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, based at Leicester General Hospital, having retired in September 2007 as Consultant in Sleep Disorders Medicine. In 1969, I obtained a First class Honours BSc in Physiology and, in 1972, qualified in medicine, MB, BS, MRCP, LRCP from St Bartholomew's Hospital Medical School. After initial training in anaesthesia, I became a Fellow of the Royal College of Anaesthetists by examination in 1976 and was awarded a doctorate from the University of Leicester in 1996. I was appointed Senior Lecturer in Anaesthesia and Honorary Consultant Anaesthetist to Leicester General Hospital in 1981. In 1996, I was appointed Consultant Anaesthetist with a special interest in Sleep Medicine to Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester.

1.1.2. My interest in sleep and its disorders began nearly 30 years ago and has grown ever since. I founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the country, until retirement. The University Hospitals of Leicester NHS Trust named the Sleep Laboratory after me as a mark of its esteem. I was a founder member and President of the British Sleep Society and its honorary secretary for four years and have written and lectured extensively on sleep and its disorders and continue an active research programme. My expertise in this field has been accepted by the civil, criminal and family courts. I chair the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sit on Advisory panels for several companies with interests in sleep medicine.

1.1.3. I live in Ashby Magna, Leicestershire which is subject to an application by Broadview Energy for a wind farm at Lower Spinney.

1.2. Brief from SSWFAG

1.2.1. My brief from SSWFAG was to review the potential consequences of wind turbine noise and, in particular, its effect on sleep and health and to make recommendations with regard to the proposed setback distances.

1.3. Scope of report.

1.3.1. This report centres on the effects of industrial wind turbine noise on sleep as this is the particular area of expertise of the author. Other areas of health concern related to low frequency noise emissions and vibro-acoustic disease will be left to others.

1.4. Source material

1.4.1. A full list of the publications reviewed and other source material is given in Section 7 and are cited in the text.

2. Background

2.1. Introduction

2.1.1. There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby. Section 5.1.1 of the draft New Zealand standard on wind farm noise, 2009, states: "Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity." Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2007). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2006), one of the principal researchers in this field. The experiences of the Davis (2008) and Rashleigh (2008) families from Lincolnshire whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually drove them from their homes. Similar stories have been reported from around the world, in anecdotal form but in large numbers.

2.2. Sleep, sleep physiology and the effects of noise

2.2.1. Sleep is a universal phenomenon. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. In mammals, including humans, this is expressed as one or more sleep periods per 24 hours. Sleep was previously thought to be a period of withdrawal from the world designed to allow the body to recuperate and repair itself. However, modern research has shown that sleep is primarily by the brain and for the brain. The major purpose of sleep seems to be the proper laying down and storage of memories, hence the need for adequate sleep in children to facilitate learning and the poor memory and cognitive function in adults with impaired sleep from whatever cause.

2.2.2. Inadequate sleep has been associated not just with fatigue, sleepiness and cognitive impairment but also with an increased risk of obesity, impaired glucose tolerance (risk of diabetes), high blood pressure, heart disease, cancer and depression. Sleepy people have an increased risk of road traffic accidents.

2.2.3 Humans have two types of sleep, slow wave (SWS) and rapid eye movement (REM). SWS is the deep sleep which occurs early in the night while REM or dreaming sleep occurs mostly in the second half of the night. Sleep is arranged in a succession of cycles, each lasting about 90 minutes. We commonly wake between cycles, particularly between the second and third, third and fourth and fourth and fifth cycles. Awakenings are not remembered if they are less than 30 seconds in duration. As we age, awakenings become more likely and longer so we start to remember them.

2.2.4. Noise interferes with sleep in several ways. Firstly, it may be sufficiently loud or annoying to prevent the onset of sleep or the return to sleep following an awakening. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the Government's own Noise Working Group, UK research in this area has been stopped.

2.2.5. Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone may underestimate the effect.

2.2.6. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of "wind turbine syndrome". Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. Arousals occur naturally during sleep and increase with age (Boselli 1998) which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dBA and awakenings with events of 42dBA (Muzet and Miedema 2005), well within the measured noise levels of current "wind farms" and the levels permitted by ETSU-R-97 . Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009 and personal communication) notes that parasomnias developed in some of the children in her study group when exposed to turbine noise.

2.2.7. Arousals are caused by aircraft, railway and traffic noise. In one study of aircraft noise, arousals were four times more likely to result than awakenings (Basner 2008a&b). Freight trains are more likely to cause arousals than passenger trains, presumably because they are slower, generating more low frequency noise and taking longer to pass (Saremi 2008). The noise of wind turbines has been likened to a "passing train that never passes" which may explain why wind turbine noise is prone to cause sleep disruption.

2.2.8. It is often claimed that continual exposure to a noise results in habituation, i.e. one gets used to the noise. There is little research to confirm this assertion and a recent small study (Pirrera et al. 2009) looking at the effects of traffic noise on sleep efficiency suggests that it is not so.

2.2.9. Sleep disturbance and impairment of the ability to return to sleep is not trivial as almost all of us can testify. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, poor concentration and memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease. There is a very large body of literature but please see Meerlo et al., 2008, Harding and Feldman, 2008 and Hart et al., 2008 for recent work on this subject. A more general review can found on Wikipedia: http://en.wikipedia.org/wiki/Sleep_deprivation

3. Wind turbine noise, sleep and health

3.1. Introduction

3.1.1. The evidence above demonstrates that it is entirely plausible that wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. As noted above, the draft New Zealand standard on wind farm noise (2009) acknowledges that sleep disturbance is the major consequence of wind turbine noise.

3.1.2 Unfortunately **all** government and industry sponsored research in this area has used **reported awakenings** from sleep as an index of the effects of turbine noise and dismisses the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously **underestimates** the effects of wind turbine noise on sleep.

3.2. Early research.

3.2.1. Surveys of residents living in the vicinity of industrial wind turbines show high levels of disturbance to sleep and annoyance. A 2005 survey of 200 residents living within 1km of a 6 turbine, 9MW installation in France showed that 27% found the noise disturbing at night (Butre 2005). A similar US survey in 2001 (Kabes 2001) of a "wind farm" in Kewaunee County, Wisconsin reported that 52% of those living within 400-800 metres found the noise to be a problem, 32% of those living within 800-1600 metres and 4% of those within 1600 and 3200 metres. 67% of those living within 250 to 400 metres and 35% of those within 400-800 metres reported being awoken by the sound in the previous year. The principal health problem reported by the 223 respondents was sleep loss. The landscape of Kewaunee County is described as "undulating to gently rolling", not dissimilar to South Leicestershire. All of these studies were of smaller turbines than proposed by Nuon. Pedersen and Waye (2004) reported that "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."

3.2.2. Phipps and others (2007) surveyed 1100 New Zealand residents living up to 3.5 km from a wind farm, 604 responded. 75% of all respondents reported being able to hear the noise. Two separate developments have placed over 100 turbines with capacities from 600kW to 1.65MW in this hilly to mountainous area. It has been suggested that mountainous areas may allow low frequency noise to travel further which may explain the long distance over which the turbines were heard. Van den Berg (2004) found that residents up to 1900 m from a wind farm expressed annoyance with the noise, a finding replicated in his more recent study reported below. Dr Amanda Harry (2007), a UK GP, conducted surveys of a number of residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. A study of 42 respondents showed that 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their life quality had been adversely impacted. This study is open to criticism for its design which invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some subjects are severely affected by wind turbine noise at distances thought by the industry to be safe.

3.3. Project WINDFARMperception

3.3.1. van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have recently published a major questionnaire study of residents living within 2.5km from wind turbines, Project WINDFARMperception. A random selection of 725 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 37% replied which is good for a survey of this type but, nevertheless is a weakness. Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing the turbine type and distance and the calculated ambient noise, derived from an environmental sound map of the Netherlands, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. Noise exposure ranged between 24 and 54dBA. It is worth noting that the industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels. Relevant conclusions include. *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35dBA, 10% were rather or very annoyed at wind turbine sound, 20% at 35-40dBA and 25% at 40-43dBA (the permitted ETSU-R-97 night time level).

3.3.2. Project WINDFARMperception further found that *"Three out of four participants declare that swishing or lashing is a correct description of the sound from wind turbines. Perhaps the character of the sound is the cause of the relatively high degree of annoyance. Another possible cause is that the sound of modern wind turbines on average does not decrease at night, but rather becomes louder, whereas most other sources are less noisy at night. At the highest sound levels in this study (45 decibel or higher) there is also a higher prevalence of sleep disturbance."* The lack of a control group prevents this group from making firmer conclusions about turbine noise and sleep disturbance but it is clear that as ETSU-R-97 permits an exterior night time noise level of 43dB, relying on its calculations will guarantee disturbed sleep for those living nearby.

3.3.3. van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. In addition, they compared their results with studies by

Miedema on the annoyance from road, rail and air related noise. Wind turbine noise was several times more annoying than the other noise sources for equivalent noise levels (**Fig 1**). Similar data is given by Pedersen (2004) **(Fig 2) – see end of text** .

3.3.4 With regard to health it was concluded that: *"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."* The conclusions regarding health are not justified from the data for the reasons given below and must be disregarded.

3.3.5. Project WINDFARMperception is currently the largest study in this field but the study is not without considerable flaws. The study may be criticised for using calculated noise levels and for not having a control group (residents not living near turbines). While several of the contributors have expertise in the investigation of health matters none has specific expertise in the physiology and pathophysiology of sleep. The purpose of the study, as its title suggested, was the public perception of wind turbines and their noise. Health questions were added but were of a very general nature. The small number of respondents suggests that any conclusions as to the apparent lack of an effect on health must be regarded as tentative.

3.3.6. The analysis of reported sleep interruption and wind turbine sound levels is flawed by the use of subjects exposed to calculated external sound levels of <30dBA (p53) as the "controls". It has been noted by several studies that calculated turbine noise is often less than measured noise and that levels as low as 30dBA can cause annoyance (Pedersen 2007). Examination of the odds ratio for different calculated sound levels (Table 7.42) shows that it increases progressively with increasing sound levels starting at 30-35dBA and becomes statistically significant for levels >45dBA. If, as is not impossible, the "control" group had its sleep disturbed by wind turbine noise then the actual effect would be considerably underestimated.

3.3.7. The major objection to the conclusions on health is that the study is grossly under-powered (insufficient subjects were studied for any degree of statistical confidence). Wind turbine syndrome, to the degree reported by Pierpont (2009), does not seem to be common even amongst those exposed to high noise levels. The study was designed to detect chronic disease with the GHQ, which is a fairly crude instrument. Assuming that wind turbine syndrome affects 1% of those exposed to calculated sound levels >45dBA and that 25% of the general population suffer from chronic disease (p47) then at least 30,000 subjects would need to be studied in each group (<45dBA v >30dBA) to be able to prove a difference with 95% certainty. Even if a prevalence of wind turbine syndrome of 5% of those exposed to >45dBA is assumed, then there must be at least 1250 subjects in each group. This study therefore can not conclude that wind turbines do not cause ill health of any degree, it can not even make conclusions about severe ill health.

3.4. Pierpont studies

3.4.1. Pierpont (2009 and personal communication) has recently completed a very detailed, peer-reviewed case-control study of 10 families around the world who have been so affected by wind turbine noise that they have had to leave their homes, nine of them permanently. The turbines ranged from 1.5 to 3MW capacity at distances between 305 to 1500m. The group comprised 21 adults, 7 teenagers and 10 children of whom 23 were interviewed. While this is a highly selected group, the ability to examine symptoms before, during and after exposure to turbine noise gives it a strength rarely found in similar case-control studies. The subjects described the symptoms of wind turbine syndrome outlined above and confirmed that they were not present before the turbines started operation and resolved once exposure ceased.

There was a clear relationship between the symptoms, even in children, and the noise exposure. She reports also that all adult subjects reported *"feeling jittery inside"* or *"internal quivering"*, often accompanied by anxiety, fearfulness, sleep disturbance and irritability. Pierpont offers compelling evidence that these symptoms are related to low frequency sound and suggests very plausible physiological mechanisms to explain the link between turbine exposure and the symptoms.

3.4.2. Of particular concern were the observed effects on children, include toddlers and school and college aged children. Changes in sleep pattern, behaviour and academic performance were noted. 7 of 10 children had a decline in their school performance while exposed to wind turbine noise which recovered after exposure ceased. In total, 20 of 34 study subjects reported problems with concentration or memory.

3.4.3. Pierpont's study mostly addresses the mechanism for the health problems associated with exposure to wind turbine noise rather than the likelihood of an individual developing symptoms. Nevertheless, it convincingly shows that **wind turbine noise does cause the symptoms of wind turbine syndrome**, including sleep disturbance. She concludes by calling for further research, particularly in children, and a 2km setback distance.

3.4.4. A recent paper (Todd et al, 2008) has shown that the vestibular system in the human ear, the part concerned with detection of movement and balance, is exquisitely sensitive to vibration at frequencies of around 100Hz. While this must be regarded as preliminary data, it does offer further evidence in support of Dr Pierpont's findings and theories.

3.5. DTI report

3.5.1. Nuon is likely to refer to a DTI report by the Hayes McKenzie Partnership published in 2006 which investigated low frequency noise at three UK wind farms. Hayes McKenzie have a long term relationship with the wind turbine industry, are noise engineers with no medical or physiological expertise so their suitability to undertake the work must be questioned. They took sound measurements at three of five sites where complaints had been recorded over periods from 1-2 months. Communication with residents other than those who complained was minimal. However, they did confirm that *"some wind farms clearly result in modulation at night which is greater than that assumed with the ETSU-R-97 guidelines"*. Measured *"internal noise levels were insufficient to wake up residents at these three sites. However, once awoken, this noise can result in difficulties in returning to sleep."* The lack of physiological expertise in the investigators in not recognising that noise can disturb sleep without actual recalled awakening is a major methodological flaw rendering the conclusions unreliable, as is the short recording period. It is well recognised also that not every resident affected by a nuisance such as noise will actually register a complaint. Many will not be sufficiently literate or confident so to do and others may wish to avoid drawing attention to the problem to protect property prices. They may assume also that protest is futile, which seems to be the experience of many with wind turbine noise. Recorded complaints are thus the tip of the iceberg.

3.5.2. It will be claimed also that only 5 of 126 wind energy developments at the time of the study had attracted complaints of noise and thus the matter is trivial. This assertion is, to say the least, disingenuous. Many of the developments at that time were of small turbines set in isolated areas of the countryside, well away from habitation. In addition, as noted above, the proportion of those affected by wind turbine noise who actually complain is very small. It must be emphasised that research into wind farm noise and health issues in the UK is virtually non-existent and of poor quality. To suggest that there is "no problem" when faced with the large body of evidence presented here is perverse. The conclusion is also contradicted by Moorhouse's study (vide infra) which showed a complaint rate of 20%.

3.6. Salford study

3.6.1. Nuon is likely to refer also to a report by Moorhouse and others of the University of Salford, commissioned by DEFRA into Aerodynamic Modulation of Wind Turbine Noise published in 2007. A survey was made of the local authorities responsible for wind farms in, or adjacent to, their area. 133 wind farms were identified of which 27 (20%) had attracted complaints. An attempt was made to correlate complaint logs with recorded wind speed and direction. Once again the methodology is fundamentally flawed. Complaints were solicited from local authorities and not from residents. The review was entirely theoretical with no communication with residents. The conclusions were that AM was such a minor problem that no further research was warranted.

3.6.2. The Editor of Noise Bulletin greeted the publication of the report thus:

"'New report eases concerns over wind turbine noise' trumpets the Government press release, then saying aerodynamic modulation is 'not an issue for the UK's wind farm fleet'. This conclusion is not justified based on the report, and by halting further research work without transparently monitoring the wind farms subject to complaints will inflame, not ease concern of objectors ... Only when the public can trust the Government and wind farm developers on noise issues will there be a chance that the public will accept them without a fight ..."
(Pease J. *Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5).

3.6.3. On 2 August 2007, Dick Bowdler, an acoustician and member of the Noise Working Group which commissioned the report, resigned from the NWG. This highly unusual step was taken because, as his letter states:

"I have read the Salford Report and the Government Statement. As a result I feel obliged to resign from the Noise Working Group.
The Salford Report says that the aims of this study are to ascertain the prevalence of AM from UK wind farm sites, to try to gain a better understanding of the likely cause, and to establish whether further research into AM is required. This bears little relation to what we asked for which clearly set out in the minutes of the meeting in August 2006. We all knew then (as was recorded in the original notes of the meeting) that complaints concerning wind farm noise are currently the exception rather than the rule. The whole reason for needing the research was that 'The trend for larger more sophisticated turbines could lead to an increase in noise from AM'.

It was not the intended purpose of the study to establish whether more research was required. We all agreed at the August 2006 meeting that such research was needed. That was precisely the outcome of the meeting. The prime purpose of what eventually became the Salford Report was to identify up to 10 potential sites which could be used to carry out objective noise measurements. The brief for the Salford report, which was never circulated to the NWG, completely ignored the NWG views.
Additionally, I find it entirely unacceptable that we are not to be told the names of the wind farms listed in the Salford report. So the only part of the report of any value to assist future research is inaccessible to those of us who would like to progress matters further.
Looking at the Government Statement it is clear that the views of the NWG (that research is needed into AM to assist the sustainable design of wind farms in the future) have never been transmitted to government and so the Statement is based on misleading information".
(*Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5)

3.6.4. If both a leading commentator in the field and a leading member of the Government's own working group have no faith in the study then its conclusions may safely be dismissed.

3.7. Kamperman comments

3.7.1. George Kamperman, (2008 personal communication) a distinguished US noise engineer, is quoted in Pierpont's book as saying, *"After the first day of digging into the wind turbine noise impact problems in different countries, it became clear the health impact on persons living within about two miles from 'wind farms' all had similar complaints and health problems. I have never seen this type of phenomenon [in] over fifty plus years of consulting on industrial noise problems. The magnitude of the impact is far above anything I have seen before at such relatively low sound levels. I can see the devastating health impact from wind turbine noise but I can only comment on the physical noise exposure. From my viewpoint we desperately need noise exposure level criteria."* Kamperman's recommended setback of at least 1km (Kamperman & James 2008) has changed to at least 2km as a result of Dr Pierpont's evidence (Kamperman 2008 personal communication). He has recently published a more detailed set of recommendations to determine setback distances (Kamperman & James 2008b).

3.8. Conclusions

3.8.1. The quality of the research in this area is low. Most are surveys using self-completed questionnaires. Response rates have generally been quite good for this type of enquiry, which may reflect the public interest and concern that wind turbines generate. Nevertheless, it is inevitable that it is more likely that those who feel they have been affected will respond rather than those who have not. The questionnaires themselves have not always have been well drafted. Most do not have a control group, a separate group not exposed to turbine noise with whom to make comparisons. The studies are all post hoc, initiated after the turbines have been operating and generally in response to complaints. The lack of pre-exposure data weakens the studies but does not invalidate them totally. Many of the authors have been criticised for their presumed lack of expertise in this area. The poor quality of the research is not surprising as government and industry have refused funding and co-operation and individuals conducting research have had to rely on their own resources.

3.8.2. In weighing the evidence, I find that, on the one hand there is a large number of reported cases of sleep disturbance and, in some cases, ill health, as a result of exposure to noise from wind turbines supported by a number of research reports that tend to confirm the validity of the anecdotal reports and provide a reasonable basis for the complaints. On the other, we have badly designed industry and government reports which seek to show that there is no problem. I find the latter unconvincing.

3.8.3. **In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions cause sleep disturbance and ill health.**

4. Preventing sleep disturbance from wind turbine noise.

4.1 Background

4.1.1. Developers of noisy industrial processes, including wind turbines, seek to mitigate the disturbance by siting them in areas of high ambient noise, such as close to major roads. In the case of wind turbines, it is assumed that rising wind speed will not only increase turbine noise but ambient noise also. This is, of course, not the case if you are sheltered from the wind in your bedroom. Motorway noise diminishes at night as the volume of traffic decreases. In addition, it is common for wind speeds to diminish at ground level as night falls while being maintained at turbine hub level, wind shear (Pedersen E and Persson Waye K. 2003, Schneider 2007). In both cases, the turbine noise will be much more audible as ambient noise decreases and explains why complaints of nocturnal noise and disturbed sleep are common. The importance of wind shear has been acknowledged in a recent technical contribution to Acoustics Bulletin (March April 2009) from some members of the NWG calling for all noise levels to be referenced to wind speed at turbine hub height.

4.1.2. Schneider found that night time turbine noise was between 3 and 7dBA greater than predicted and, during periods of atmospheric stability, turbine noise was 18.9 to 22.6dBA above ambient. In addition, as noted above, the characteristics of wind turbine noise are such that it can be heard despite road noise. It should be noted that as the decibel scale is logarithmic, a 6dB increase is equivalent to a **doubling** in sound pressure level and a 12dB change is a **quadrupling**.

4.1.3. van den Berg, in a paper presented at Euronoise 2003, investigated the relationship between calculated noise generated by wind turbines and that actually measured. He confirmed that the turbines were more audible at night principally due to amplitude modulation. To quote his paper: *"As measured immission levels near the wind park Rhede show, the* *discrepancy may be very large: sound levels are up to 15 dB (!) higher than expected at 400 m from the wind park. At a distance of 1500 m actual sound levels are 18 dB higher than expected, 15 dB of this because of the higher sound emission and 3 dB because sound attenuation is less than predicted by the sound propagation model."* An 18dB increase is equivalent to an **8 fold increase** in sound pressure and a 15dB change is a **6 fold increase.** An 18dB increase is a close to a three fold increase in perceived loudness. **Calculated measures of wind turbine noise are woefully inadequate.**

4.2. Mitigation of wind turbine noise

4.2.1. Bowdler (2008) has recently reviewed the causation of the swishing and thumping noises associated with wind turbines. He concludes that, while there are several theories, no definitive mechanism can be established. It follows that industry claims to mitigate turbine noise by changing blade shape and turbine spacing should be treated with scepticism until definitive evidence of their efficacy are presented.

4.2.2. It follows that attempts to reduce wind turbine noise immissions after plant becomes operational are unlikely to be successful. Blade feathering will reduce power output, which will be opposed by the operators. The importance of assuring residents that noise limits are capable of being met before construction was emphasised by Mr Lavender, Inspector at the Thackson's Well Inquiry (APP/E2530/A/08/2073384) who stated: "securing compliance with noise limit controls at wind farms, in the event of a breach, is not as straightforward as with most other forms of noise generating development. This is because noise from turbines is affected primarily by external factors such as topography and wind strength, a characteristic that distinguishes them from many other sources of noise, such as internal combustion engines or amplified music, which can be more directly and immediately influenced by silencing equipment, insulation or operator control." It follows that application of the precautionary principle is essential where there is any possibility of noise disturbance from wind turbines.

4.2.3. Thus, the **only** mitigation for wind turbine noise is to place a sufficient distance between the turbines and places of human habitation. PPS22 advises that ETSU-R-97 *should* (author's italics) be used to estimate noise levels around turbines which taken with measurements of ambient noise can, in theory, predict noise disturbance in adjacent properties. Many expert acousticians have severely criticised ETSU-R-97, not least Mr Dick Bowdler (2007), a member of the Government's Noise Working Group considering ETSU-R-97. Its major flaws include the use of **averaged** noise levels over too long a time period and using a best fit curve, thus ignoring the louder transient noise of AM which cause awakenings and arousals. It ignores also the property of low frequency noise to be audible over greater distances than higher frequency noise. By concentrating on sound pressure alone, it ignores the increased annoyance of particular noises, especially that associated with AM. It is also the only guidance anywhere in the world which permits a **higher** sound level at night than during the day, completely contrary to common sense, noise pollution legislation and WHO guidelines.

4.2.4. Stigwood (2009) has shown that large turbines (hub heights 50-100m) are more likely than smaller turbines (hub height 30m) to cause excessive amplitude modulation, increased likelihood of low frequency noise and greater disturbance inside buildings. Internal noise can modulate over 15-20dB, changes which are easily perceived. This is probably due to different wind speeds and atmospheric conditions at these heights. He concludes that ETSU-R-97, which was developed for smaller turbines is inappropriate for large turbines.

4.2.5. Bullmore (2009) concluded that measuring wind speed at a single, low height, as required by ETSU-R-97, does not permit an accurate calculation of turbine and ambient noise.

4.2.6. Despite, or because of, ETSU-R-97, complaints of noise disturbance from industrial wind turbines continue and it is clear that ETSU-R-97 can not be relied upon to prevent sleep disturbance in those living near wind turbines.

To quote Mr Peter Hadden in evidence to the House of Lords Economic Affairs Committee:

"There is material evidence available to show that ETSU R 97 has failed to provide a reasonable level of protection to family homes from unbearable noise pollution where wind turbines are located too close to homes. Symptoms include sleep disturbances and deprivation, sometimes so severe that families are forced to evacuate their homes in order to stabilise well-being and to resume normal family life. This is a worldwide phenomenon where wind turbines are located too close to homes."

4.2.7. Planners should note also that the application of ETSU-R-97 is advisory in PPS22, not mandatory (*should* not *must*). It is also subordinate to the precautionary principle set out in PPS 23 (see below). Rather than rely on a provenly inadequate set of theoretical calculations to determine setback distance it is logical to look at the real world and the relationship between setback and noise complaints from existing sites. Human senses and opinion are used to judge visual impact. It is therefore consistent and logical to rely on human senses and opinion in respect of noise impact. Many of these sites causing problems have been in place for several years. The application by Nuon is for larger turbines than have been previously erected in the UK and thus allowance must be made for their additional noise in determining setback.

4.2.8. While it may be possible to produce a reasonable acoustically based theoretical approach to calculating set back distances (Kamperman and James 2008b), it makes more sense to rely on recommendations from observations of the effects on real people at established wind farms.

4.3. Swinford

4.3.1. The prevailing wind in South Leicestershire is from the south west and the village of Swinford is thus up wind of the proposed turbines. However, for about 20% of the year, the wind is from the north east. Under these conditions, the background noise in the village diminishes markedly as the M1/A14 and Catthorpe interchange is now down wind. Stable wind conditions with increased wind shear is equally likely to occur in any wind direction and occur to a level greater than that allowed for in ETSU-R-97.

4.3.2. Under the conditions of a north easterly wind and stable wind conditions, the residents of the village of Swinford which is only 800-1000 meters from the proposed turbines will be at much greater risk of sleep disturbance from lower than average background noise levels and greater than predicted turbine noise levels.

4.4. Conclusions

4.4.1. **Table 1** (see end of text) shows recommendations for setback distance by a number of authorities. References can be found in the Bibliography. In general, noise engineers recommend lesser setback distances than physicians. The former rely more on measured and/or calculated sound pressures and the latter on clinical reports. It is logical to prefer the actual reports of the humans subjected to the noise rather than abstract calculations, even if the latter accurately measure ambient noise and allow for the low frequency components of wind turbine noise. **Calculations can not measure annoyance and sleep disturbance, only humans can do so.**

4.4.2. A setback distance of at least 1.5km is necessary to ensure, with a reasonable degree of confidence, that the wind turbine noise will not disturb the sleep of those living in proximity to the proposed Swinford development.

5. Planning considerations

5.1. PPS22

5.1.1. PPS22 was promulgated subsequent to ETSU-R-97 and should therefore take precedence. Section 41 states: *"Development proposals should demonstrate any environmental, economic and social benefits as well as how any environmental and social impacts have been minimised through careful consideration of location, scale, design and other measures."* and *"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."*

5.1.2. Proposals that seek to place turbines within 1.5km of habitation have not sought to minimise environmental and social impact by wind turbine noise and its effects on sleep and health. They are therefore in contravention of PPS22.

5.1.3. The Companion Guide to PPS22 states *"RE 3 describes Factors to be considered in Planning for Wind Farms. These include: residential amenity (on noise and visual grounds); safe separation distances;"* and *"Well-specified and well-designed wind farms should be located so that increases in ambient noise levels around noise-sensitive developments are kept to acceptable levels with relation to existing background noise."*

5.1.4. Proposals that site wind turbines within 1.5km of habitation will not keep wind turbine noise to an acceptable level and are therefore in contravention of PPS22.

5.2. PPS7

5.2.1. PPS7 states:

5.2.2. *"ensuring people have decent places to live by improving the quality and sustainability of local environments and neighbourhoods"*

5.2.3. *"All development in rural areas should be well designed and inclusive, in keeping and scale with its location, and sensitive to the character of the countryside and local distinctiveness"*

5.2.4. *"have regard to the amenity of any nearby residents or other rural businesses that may be adversely affected by new types of on-farm development"*

5.2.5. Section 15 states: *"Planning authorities should continue to ensure that the quality and character of the wider countryside is protected and, where possible, enhanced."*

5.2.6. Proposals which site wind turbines within 1.5km of residential dwellings can not be said to enhance the quality of the countryside nor have regard to the amenity of local residents and must be rejected.

5.3. PPS23

5.3.1. PPS23 states:

5.3.2. *"the precautionary principle should be invoked when:*

- *there is good reason to believe that harmful effects may occur to human, animal or plant health, or to the environment*
- *the level of scientific uncertainty about the consequences or likelihood of the risk is such that best available scientific advice cannot assess the risk with sufficient confidence to inform decision-making."*

5.3.3. Application of ETSU R 97 is subordinate to the commitment to the Precautionary Principle outlined in PPS23. The objections to ETSU R 97 are so fundamental and the concerns regarding its validity so great, as is the evidence of human harm, that the precautionary principle must be invoked and consequently PPS 23 and EV/23 applied and permission refused on that account.

5.4 East Midlands Regional Spatial Strategy (RSS8)

5.4.1. Policy 41 states: *"In establishing criteria for onshore wind energy Development Plans and future Local Development Frameworks, should give particular consideration to: the effect on the built environment (including noise intrusion)."*

5.4.2. Proposals that site wind turbines within 1.5km of residential dwellings do not give sufficient consideration to the noise effects on the built environment and are therefore in contravention of RSS8.

5.5. Harborough District Local Plan

5.5.1. Harborough District Local Plan states that:

5.5.2. *"the district council will grant planning permission for the development of renewable energy schemes provided that they do not have an unacceptable impact on the landscape, features of historic and archaeological interest, nearby land use, residential amenity……."*

5.5.3. *"..proposals should not adversely affect the established character of the surrounding area in terms of scale, space around buildings, density, design, colour and texture of materials"*

5.5.4. *"...new development should not adversely affect the amenities of neighbouring users..."*

5.5.5. Policy EV/5 states: *"The district council will refuse planning permission for development proposals in the countryside unless the following criteria are met:*

- *The development does not adversely affect the character and appearance of the countryside*
- *The development does not adversely affect the amenities of the residents of the area*
- *Any new buildings are sited in a position that minimises their impact on the landscape and on important views into and out of villages"*

5.5.6. Clearly, any development which places wind turbines within 1.5km of residential dwellings will adversely affect the amenity of the residents and must be rejected.

5.5.7. Policy EV/23 states: *"the District Council will impose conditions on planning permissions to ensure that the development does not have an adverse effect on the character of its surroundings or harm the amenities of nearby users, through noise...If the District Council is not satisfied that these adverse effects would be overcome by the imposition of conditions, planning permission will not be granted"*

5.5.8. The evidence presented in this paper provides incontrovertible proof that wind turbines emit levels of noise harmful to human health and wellbeing. ETSU R 97 does not provide sufficient protection for residents as has been amply demonstrated by several leading researchers.

5.6 Leicestershire, Leicester and Rutland Structure Plan 1996-2016 Resource Management Policy 1

5.6.1. LLRSP 1996-2016 states: *"All new development will minimise or avoid air, noise, water, land and light pollution"*

5.6.2. Developments within 1.5km of residential dwellings engender several types of pollution: noise, light (the likelihood of aviation lights) and shadow flicker, and will certainly not be minimised.

6. Overall Conclusions

7.1. The only mitigation of sleep disturbance from industrial wind turbine noise is a setback of at least 1.5km and probably greater. This estimate is based on data from present installations, many of which have a much smaller rated capacity than those proposed by Nuon. Most of the village of Swinford as well as outlying properties are within 1-1.5km of the proposed site and there is therefore a very high risk that a large proportion of residents would be adversely affected. **The application must be rejected.**

CD Hanning

14th June 2009

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Figure 1. Sound level and annoyance for different noise sources (van den Berg 2008)

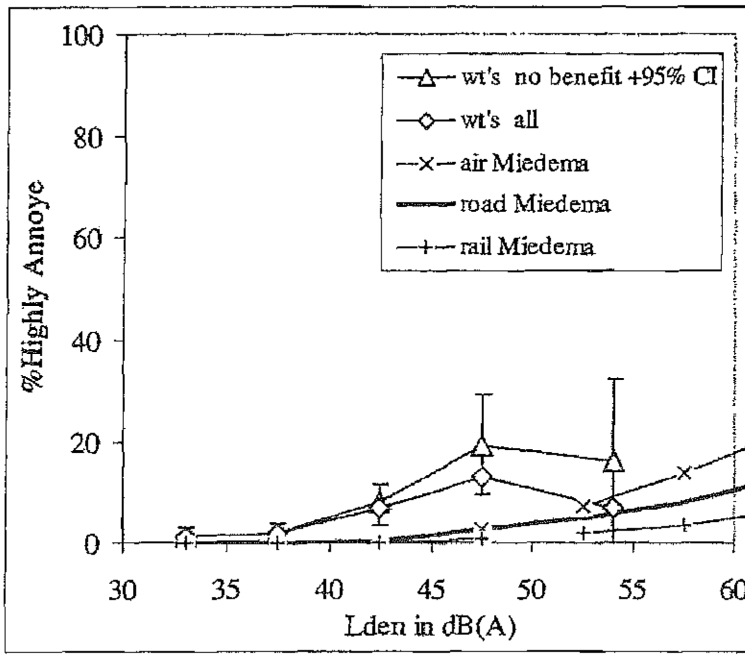
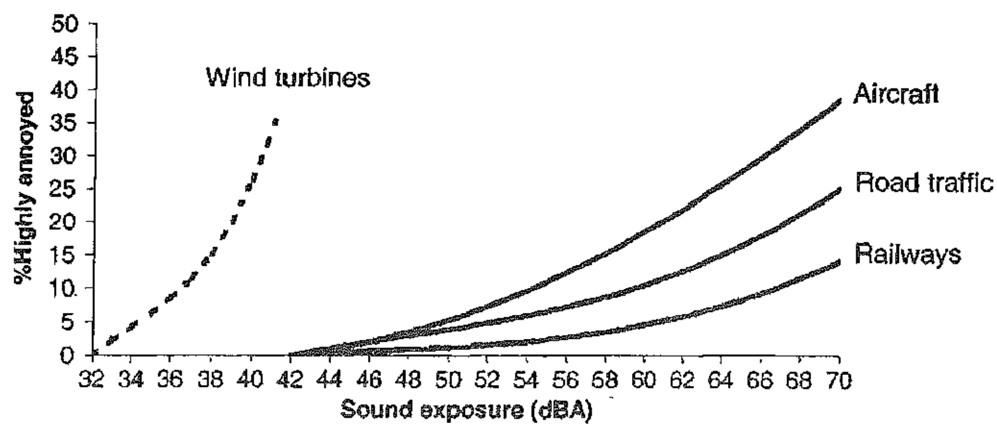


Figure 8.1: relation between sound level Lden and percentage highly annoyed residents exposed to that sound, for three transportation noise sources and for wind turbines; the relation is given for all respondents and for those that have no economical benefit from a wind turbine.

Bars denote 95% confidence interval for non-benefitters.

Figure 2. Sound level and annoyance for different noise sources (Pedersen E and Persson Waye, 2004)



Sound exposure is for wind turbines calculated A-weighted L_{eq} for a hypothetical time period and for transportation DNL.

Table 1. Recommendations for setback of residential properties from industrial wind turbines

Note 1. The 2km limit from edges of towns and villages seems to have been set more for visual than noise reasons

Authority	Year	Notes	Recommendation	
			Miles	Kilometres
Frey & Hadden	2007	Scientists. Turbines >2MW	>1.24	>2
Frey & Hadden	2007	Scientists. Turbines <2MW	1.24	2
Harry	2007	UK Physician	1.5	2.4
Pierpont	2008	US Physician	1.5	2.4
Welsh Affairs Select Committee	1994	Recommendation for smaller turbines	0.93	1.5
Scottish Executive	2007	See note 1.	1.24	2
Adams	2008	US Lawyer	1.55	2.5
Bowdler	2007	UK Noise engineer	1.24	2
French National Academy of Medicine	2006	French physicians	0.93	1.5
The Noise Association	2006	UK scientists	1	1.6
Kamperman & James	2008	US Noise engineers	>.62	>1
Kamperman	2008	US Noise engineer	>1.24	>2
Bennett	2008	NZ Scientist	>0.93	>1.5
Acoustic Ecology Institute	2009	US Noise engineers	0.93	1.5

Wind Turbines, Noise and Health

February 2007

By Dr Amanda Harry M.B.Ch.B. P.G.Dip.E.N.T.

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Mr John Stewart Chair of the UK noise association

THE EFFECT OF WIND TURBINES ON HEALTH.

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).

Since that meeting I have spoken to and / or corresponded with 39 people living between 300meters and 2 km from the nearest turbine of a wind farm all of whom were suffering from the consequences of the noise coming from the turbines. This disturbance is by no means always there and is worse in certain wind directions. The cases mentioned below are from several wind farms in the UK with a variety of turbine sizes from the smaller, older turbines to the taller more modern turbines. However I have had correspondence from people living near wind farms in New Zealand and Australia and have evidence from other sources, (newspapers, journals and papers) of people being similarly affected in France, Germany, Netherlands and the USA.
What this shows is that there is number of people suffering from the consequences of noise from the wind turbines. I'm sure that the cases mentioned here are probably the "tip of the iceberg" and further independent investigation is warranted. The cases are kept anonymous in order to protect the individuals concerned. 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.

METHOD

All people involved in this survey were contacted either by phone or in writing. Questionnaires were completed for all cases. Questionnaires were sent to people already known to be suffering from problems which they felt was due to their proximity to wind turbines.
The identity of the people questioned has been with held in order to maintain confidentiality. The respondents were from a number of sites in the UK- Wales, Cornwall and the north of England

Example of questionnaire.

1) Name- (preferred but optional)

2) Age 18-30 30-45
45-60 >60

3) Occupation

4) Address and /or postcode

5) Which wind farm is near your property?

6) How far away from your property is the nearest turbine?

7) How long have you been living at this property?

8) Do you feel that your health has in any way been affected since the erection of these turbines?

9) If yes please answer the following:-
Do you feel that since living near a wind turbine/turbines you have experienced excess of the following symptoms (i.e. more than you did prior to living near these structures)?

Headaches	yes	no
Palpitations	yes	no
Excessive tiredness	yes	no
Stress	yes	no
Anxiety	yes	no
Tinnitus (ringing in ears)	yes	no
Hearing problems	yes	no
Sleep disturbance	yes	no
Migraines	yes	no
Depression	yes	no
Other- please specify		

If you have answered yes to any or the above questions, have you approached your doctor regarding these symptoms? If yes please state any tests and/or treatment initiated.

10) Do you feel that your quality of life has in any way altered since living near the wind turbines? Yes no

If yes could you please explain in what way you feel your life has been altered.

RESULTS

	1	2	3	4
Age	45-60	45-60	45-60	45-60
Occupation	Cleaner/ housewife	Retired Ill health	Head chef	farmer
Distance from turbine	400m	300m	350m	400m
Time at property	36 years	3 years	7years	4years
Health altered	Yes	Yes	yes	yes
Headaches	Yes	Yes	yes	yes
Palpitations	No	no	no	no
Excessive tiredness	Yes	No	yes	yes
Stress	Yes	Yes	yes	yes
Anxiety	Yes	Yes	yes	yes
Tinnitus	No	No	no	no
Hearing problems	No	No	no	yes
Sleep disturbances	Yes	Yes	yes	yes
Migraines	Yes	Yes	no	yes
Other				
Approached doctor	No	No	no	no
Altered quality of life	Yes	Yes	yes	yes

	5	6	7	8
Age	45-60	>60	18-30	18-30
Occupation	Housewife	Retired	Electrician	carer
Distance from turbine	300m	300m	300-500m	300-500m
Time at property	2.5 years	2.5 years	6 months	6 months
Health altered	Yes	Yes	Yes	yes
Headaches	Yes	Yes	Yes	yes
Palpitations	No	No	No	no
Excessive tiredness	No	Yes	Yes	yes
Stress	No	No	No	no
Anxiety	No	No	No	no
Tinnitus	No	No	No	no
Hearing problems	No	No	No	no
Sleep disturbance	No	No	Yes	yes
Migraines	No	no	No	no
Depression	No	no	No	no
Other		Thumping in ears		
Approached doctor	No	Yes-Rx with pain Killers-ongoing assessment	No- didn't associate symptoms with the turbines	
Altered quality of life	Yes	yes	Yes	yes

	9	10	11	12
Age	>60	30-45	30-45	30-45
occupation	Retired	candle maker	Retired-nervous Breakdown	Retired-ill health
Distance from turbine	300m	¼ mile	300m	300m
Time at property	4years	10 years	3 years	3years
Health altered	Yes	no	Yes	yes
Headaches	No	no	Yes	yes
Palpitations	No	no	No	no
Excessive tiredness	No	no	Yes	no
Stress	No	no	Yes	yes
Anxiety	No	no	Yes	yes
Tinnitus	Yes	no	No	no
Hearing problems	No	no	No	no
Sleep disturbance	No	no	Yes	yes
Migraines	Yes	no	Yes	no
Depression	No	no	Yes	yes
Other		See comments at end	Stomach upset	
Approached doctor	No	no	Yes-seen psychiatrist-Ongoing review	no
Quality of life affected	Yes	yes	Yes	yes

	13	14
Age	30-45	>60
Occupation	Veterinary nurse and HGV driver	Retired from farming and Teaching
Post code	TR8	SA38
Wind farm	Bears Down	Blean Bowi
Distance from turbine	Too close	1mile
Time at property	19 months	27years
Health altered	Yes	Yes
Headaches	Yes	Yes
Palpitations	No	Yes
Excessive tiredness	Yes	Yes
Stress	No	Yes
Anxiety	No	Yes
Tinnitus	No	Yes
Hearing problems	No	No
Sleep disturbance	Yes	Yes
Migraines	No	No
Depression	No	Yes
Other	No	Emotional turmoil
Approached doctor	Yes- taking sleepers and Headache tablets	Yes-had heart check up
Quality of life affected	Yes	Yes

	15	16	17	18
Age	45-60	>60	>60	45-60
Occupation	Teacher	Retired	Retired	Charity manager
Distance from turbine	700m	650m	650	½ mile
Time at property	26 years	30+	30+years	Bear Down
Health altered	Yes	Yes	No	No
Headaches	Yes	No	no	No
Palpitations	No	No	No	No
Excessive tiredness	Yes	Yes	No	No
Stress	No	Yes	No	No
Anxiety	Yes	No	No	No
Tinnitus	No	No	No	No
Hearing problems	No	Yes	No	No
Sleep disturbance	Yes	Yes	No	No
Migraines	No	No	No	No
Depression	No	Yes	No	No
Other	No	No	No	No
Approached doctor	No	No	No	No
Quality of life altered	Yes	Yes	Yes	No

	19	20	21	22
Age	>60	>60	>60	>60
Occupation	Retired		Retired	Retired
Distance from turbine			700m	700m
Time at property	20years	20 years	25years	25 years
Adverse health affects	Yes	Yes	Yes	Yes
Headaches			Yes	Yes
Palpitations				
Excessive tiredness	Yes	Yes	Yes	Yes
Stress			Yes	Yes
Anxiety			Yes	Yes
Tinnitus				Yes
Hearing problems				Yes
Sleep disturbance		Yes	Yes	Yes
Migraines				
Depression	Yes		Yes	Yes
Other				
Approached doctor			Yes	Yes- doctor referred me to the hospital. After tests the consultant could find nothing wrong with my ears.
Quality if life affected	Yes	Yes	Yes	Yes

	23	24	25	26
Age	45-60	45-60	>60	57
Occupation	Farmer	Farmer	Retired	Retired police officer
Distance from turbines	430m	430m	1000m	1000m
Time at property	5 ½ years	5 ½	30years	30years
Adverse health affects	No	Yes	Yes	Yes
Headaches			Yes	Yes
Palpitations				
Excessive tiredness			Yes	Yes
Stress			Yes	Yes
Anxiety				Yes
Tinnitus		Yes		
Hearing problems			Yes	
Sleep disturbance				Yes
Migraines			Yes	
Depression				Yes
Other				
Approached doctor		Yes- been under a specialist in Furness General hospital for 1 ½ years	Yes	No
Quality of life affected	Yes	Yes	Yes	Yes

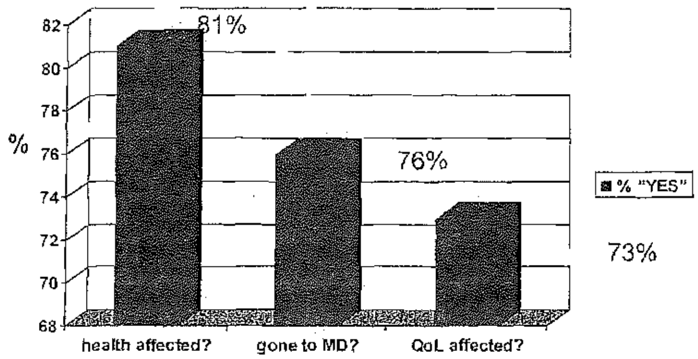
	27	28	29	30
Age	>60	>60	56	79
Occupation	Farmer/ sheep breeder		Pedigree sheep breeder	War veteran
Distance from turbine	½ mile	700m	1/3mile	
Time at property	9 years	33 years	9 years	33 years
Adverse health affect	Yes	Yes	Yes	Yes
Headaches	Yes		Yes	Yes
Palpitations			Yes	
Excessive tiredness	Yes		Yes	Yes
Stress	Yes		Yes	Yes
Anxiety			Yes	Yes
Tinnitus				Yes
Hearing problems				Yes
Sleep disturbance	Yes	Yes	Yes	
Migraines	Yes		Yes	Yes
Depression				
Other			Concentration	
Approached doctor	Yes	No	Yes- have had a 24 hour e.c.g. for investigations of palpitations. Brain haemorrhage 2 years ago.	Yes
Quality of life affected	Yes		Yes	Yes

	31	32	33	34
Age	81	45-60	>60	30-45
Occupation	Retired carpenter	Systems analyst/programmer	Business owner	Retired State registered nurse
Distance from turbine		¾ mile	Less than 1 mile	300m
Time at property	33 years	16 years	16 years	7 years
Health adversely affected	Yes	No	Yes	Yes
Headaches	Yes		No	Yes
Palpitations			No	
Excessive tiredness	Yes	Yes	Yes	Yes
Stress	Yes		Yes	Yes
Anxiety	Yes		No	
Tinnitus	Yes		No	
Hearing problems	Yes		Yes	
Sleep disturbance			Yes	Yes
Migraines	Yes		no	
Depression			No	
Other				
Approached doctor	Yes	Yes	No	No
Quality of life affected	Yes		Yes	Yes

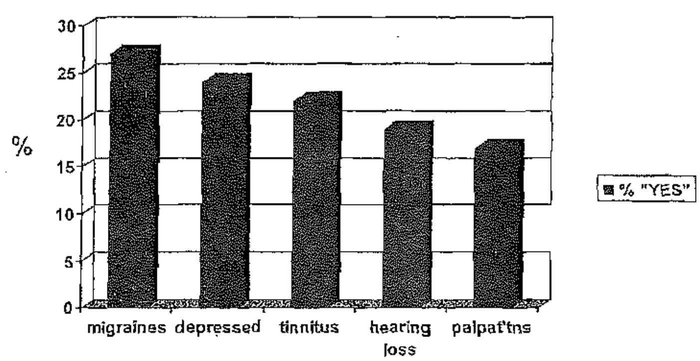
	35	36	37	38
Age	45-60	45-60	45-60	62
Occupation	Retired due to Nervous breakdown	Semi Retired farmer	Semi retired farmer	Retired
Distance from turbine	300m	800m	800m	
Time at property	7 years	11 years	11 years	25 years
Health adversely affected	yes	Yes definitely	Yes	
Headaches	yes	Yes	Yes	
Palpitations		Yes	Yes	
Excessive tiredness		Yes	Yes	Yes
Stress	yes	Yes yes	Yes	
Anxiety	yes	Yes yes yes	Yes	
Tinnitus		Yes	Yes	
Hearing problems		May be		
Sleep disturbance	yes	Yes yes yes	Yes	Yes
Migraines		No	No	
Depression		No	no	
Other	nausea			
Approached doctor	yes	Yes put on antidepressants and anti-hypertensives	Yes	
Quality of life affected	Yes	Absolutely yes	Yes	Yes

	39	40	41	42
Age			45-60	>60
Occupation	Retired phlebotomist	Running own business	Database administrator	Retired farmer
Distance from turbine		600m	3/4mile	1 mile
Time at property	20 years	24 years	7 years	26 years
Adverse affect on health	Yes	Yes	Yes	Yes
Headaches		Yes		Yes
Palpitations				Yes
Excessive tiredness	Yes	Yes		Yes
Stress				Yes
Anxiety		Yes	Yes	Yes
Tinnitus				
Hearing problems				
Sleep disturbance	Yes	Yes		Yes
Migraines				
Depression				Yes
Other	Lack of concentration And irritability		Nausea	
Approached doctor	No	No		Yes
Quality of life affected	Yes	Yes	Yes	Yes

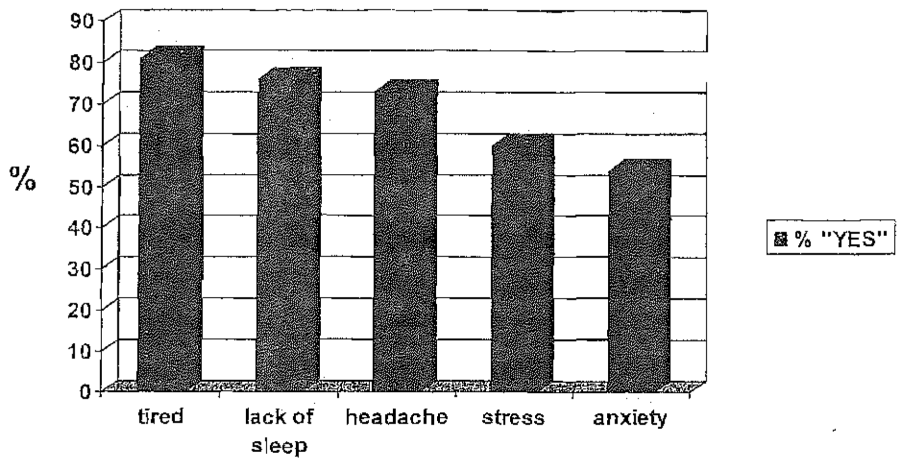
- *Has your health in any way been affected since the erection of these turbines?*
- *As a result, have you gone to see your doctor?*
- *Do you feel that your Quality of Life has in any way been altered since living near the wind turbines?*



Top 5 Self-reported Health Symptoms



Next 5 Self-reported Health Symptoms



ADDITIONAL COMMENTS MADE BY RESPONDANTS

1) 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.

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

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

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

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

6) I also find that the sound we get from the farm affects my metal heart valve.

7) I couldn't say whether or not the storbing effect wakes me up but it is impossible to go back to sleep with it there.

8) 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.

9) 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.

10) 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.

11) 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........

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

13) I dare not sleep at home.

14)
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.

15) Certain wind directions mean excessive noise, like a thrashing machine constantly pounding, making it unpleasant to be in the garden or to have windows open. With strong wind conditions, double glazed windows vibrate and cause an intrusive, almost sub audible interference in some rooms.

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

17) 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.

18) Our quality of life we had before the wind farm came has gone. We no longer control the way we live our lives e.g. if we can work or sit in the garden, or at times, even where we can sit in our own home or get a full nights sleep.

19) 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 (hypertension and stress). Prior to 1999 I always enjoyed excellent health and rarely visited the doctor's 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.

20) Not being able to choose when I work or sit in my own garden. Not getting full nights sleep. Waking with headaches when the noise is bad and feeling sick. Ears feel like I experience when travelling by plane- feel as if they are swollen inside. I cannot work more than 2-3 hours in the garden when the wind direction if from the east. We cannot see the wind farm from our property but at times the noise is horrendous.

21) My quality of life has been affected by the shadow flicker and the noise

22) I am bothered by the shadow flicker, and the noise while working behind the building.

23) I feel generally off colour

24) As we leave the house, the turbines are always there, menacing, always drawing your attention, depressing, in a beautiful area. Normally I sleep with the bedroom windows closed, if in summer we have a heat wave and the windows are open, I find I am wheezing in time with the turbine noise, it seems to come inside my body. This is an old stone gatehouse south of the site.

25) Quality of life has almost disappeared. No longer able to relax in the garden (when wind speed/ direction cause noise). Glinting and reflection also cause disturbance. Visual dominance is oppressive- extremely angry.

26) Constant sleep disturbance. Unable to work within certain areas, for noise levels, when wind is in certain directions, very stressful.

27) Disturbed sleeping. View blades whishing in the wind. Drawn to blades going round. Little concentration. Ugly to look at. Dominant. Not able to work in yard for long periods of time.

28) 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.

29) constant noise

30) Constant noise when turbine is facing us and away from us. Sleepless nights which make me irritable. Stress due to husbands anxiety about the turbines.

31) Noise from turbines effects my sleep patterns, I sleep less. I get nausea when the turbines face our home and causes a drumming at low noise frequency. I worry about the turbine blades coming off and killing me

32) Alienation from mainstream community that have the erroneous impression that wind power is a good alternative. Forced to sell property at a reduced rate- that was meant to be our retirement home. Health improved since moving from the property

33) As soon as the wind farm was operating I experienced horrendous continuous noise when the wind was from the east. This was both inside and outside my home. There were many times I had to leave the garden because of the noise. It was like a Chinese water torture, it was a constant pulsating noise. It was almost a feeling of compression as much as noise. I had to move bedrooms at times in order to escape the noise. It imprints on you, if you have had it all day in the garden, it stays with you,

once it's in your head it's hard to get rid of. It's weird. It's a feeling as much as a noise. It's torture.

34) It's an irritating and tiring noise, especially when you have not had any sleep because of it.

35) Even if you shut the window, the noise is still there, but not as much. The problem is, once you get the noise in your head, it's always there, it does annoy you and it is difficult to disregard.

36) 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.

37) Once the noise gets into your head, it also seems to beat at the same frequency as my heart and I find it annoying and am unable to get any sleep- this can go on for nights on end. It's not always the level of the noise, it's the intermittent nature. You think "Oh it's stopped" then it starts up again.

38) If the wind is from the East or the South the noise is horrendous- you can't get away from it. It's inside and outside the house. It's worse at night- I have to bed hop. It's a whooshing, drumming, constant drumming noise. It's annoying. It's frustrating. It wears you down. You can't sleep at night or concentrate during the day. Once it gets inside your head you can't get rid of it. You get up in the morning, tired, agitated and depressed and it makes you short- tempered.

39) Our lives are hell, they have been ruined and it's all due to those turbines.

40) The noise from the wind farm is different and I can't explain why, it just is. All you ever want to do is to get out of the way of it, by whatever means you can.

CONCLUSIONS

I think it is clearly evident from these cases that 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.
A discussion follows which clearly explains why the characteristic noise from these turbines can be producing the symptoms that are being described above. 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. In addition to this 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.

DISCUSSION

As shown in the case studies, people living near wind farms in the United Kingdom have been complaining of health problems since the construction of the wind farms near their homes. Inquiries reveal that some wind farms located close to peoples residences in Europe, Australia and North America have reported similar problems

The range of symptoms mentioned by complainants includes headaches, sleep disturbance, anxiety, depression, stress, vertigo and tinnitus. People complain of the noise, vibration and shadow flicker (caused by rotation of the blades and the reflection of the sun).

The following seeks to explain why these symptoms and problems could be caused by the wind turbines.

The evidence supplied has been made by a prolonged study of research available worldwide. Some acousticians have expressed the opinion that the level of low frequency noise (in dB (A)) emitted by a wind turbine will not produce health problems. However during my extensive search of the published literature, I have been unable to find any medical evidence to support this opinion.

Although the papers researched are generally not specific to wind turbines they are specific to the type and intensity of noise produced by wind turbines. The noise produced by wind turbines is quite complex therefore our response is likely to be complex also. In addition wind turbines produce a repetitive visual stimulus which goes to reinforce annoyance.

SOUND AND NOISE

Recently the European Union Noise Committee stated that noise is the biggest pollutant and the fastest growing pollutant in Europe.

Noise can be defined as unwanted sound and is commonly associated with annoyance reactions. It is commonly perceived as an environmental stressor and nuisance. Environmental noise is ubiquitous and annoyance is one of the most widely studied adverse reactions to noise. Noise interferes with task performance; cognitive performance modifies social behaviour and causes stress and irritation.

According to the World Health Organisation (WHO), health should be regarded as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity"- WHO 2001. Under this broad definition, noise induced annoyance is an adverse health effect. As with any psychological reaction, annoyance has a wide range of individual variability, which is influenced by multiple personal and situational factors.

WHO also defines noise annoyance as "a feeling of resentment displeasure, discomfort, dissatisfaction or offence which occurs when noise interferes with someone's thoughts, feelings or daily activities- (WHO paper on Environmental noise- Passchier and Verneer 1993.

Noise annoyance is always assessed at the level of populations, using questionnaires. There is consistent evidence for annoyance in populations, exposed for more than one year to sound levels of 37dBA and severe annoyance at 42dBA.

There is no doubt that annoyance from noise adversely affects human wellbeing.

The level of annoyance can only be described by listeners themselves. These descriptions are often fuzzy and not quantified most of the time. In addition to this different people have different subjective responses on the grade of annoyance. There are many theories regarding noise nuisance and many factors are thought to have an influence e.g. the types of noise source, noise energy, frequency, age , previous noise exposure, types of building structures and weather conditions. Subjective annoyance relates not only to the sound level and frequency but also to the physiological and mental factors of the sound recipients.

Field studies performed among people living in the vicinity of wind turbines showed that there is a correlation between sound pressure levels and annoyance but that annoyance is also influenced by other factors such as attitude to wind turbines an the landscape. However noise annoyance from wind turbines was found at lower sound pressure levels than in studies of annoyance from road traffic noise.
This is because the absolute noise level is less important than the character of the noise produced.

Non-auditory effects of noise, can be defined as all those effects on health and well being which are caused by noise exposure with the exclusion of effects on the hearing organ. Non auditory effects include stress, related physiological and behavioural effects and safety concerns. There have been studies showing that aircraft noise can decrease cognitive function resulting in decreased scholastic achievement.

It is obvious that the health issues relating to wind turbines are caused by these non-auditory effects as the sound pressure levels are not high enough to cause an auditory effect (e.g. hearing impairment resulting from excessive noise exposure).

How does noise affect health?

It is generally considered that noise can be an intrusion into daily activities and tasks, causing annoyance. In certain circumstances in certain susceptible individuals this annoyance may lead to a stress response which in turn may lead to symptoms and subsequently illness.
The response to noise probably depends upon the characteristics of the sound, including intensity, frequency, and complexity of sound, duration and meaning of the noise i.e. whether the noise is perceived as threatening or not.

Alternatively, noise may affect health directly and not through annoyance. E.g. studies show elevated cortisol levels in individuals subjected to; vibroacoustic disease caused by excessive exposure to low frequency noise resulting in abnormal proliferation of extra cellular matrices.

Any severe extreme imposed on the sonic environment has a profoundly destabilizing effect on the individual.
This is evident in both the areas of high intensity acoustic energy and also its complete absence.
Anechoic chambers, which create an environment void of sound, have the ability to produce similar feelings of disorientation and disturbance that are evident with high intensity sound. The silence envelops the individual in a suffocating manner causing both psychological trauma and also physiological disturbance in the form of balance problems and other related body functions. It is clearly apparent that the human organism is in an extremely delicate state of equilibrium with the sonic environment and any profound disturbance of this system will have profound ramifications to the individual

The auditory system is an extremely complex system .Because of the complexity of the auditory and cerebral systems it becomes easy to understand why the issues surrounding noise annoyance/ disturbance and associated health effects is not a simple one.

Studies in USA have shown a relationship between anxiety and vestibular disorders such as dizziness and migraines vertigo. Anatomical and electrophysiological evidence suggests that serotonin modulates processing in the vestibular nuclei in the brain. Therefore a disturbance in the serotonin balance which occurs in anxiety and depression syndromes can cause vestibular problems.

Low frequency noise is also produced from wind turbines. Low frequency sound is predominately the result off the displacement of air by a blade and of turbulence at the blade surface. The low frequencies contribute to the overall audible noise but also produce a seismic characteristic which is one of the common complaints from neighbours when they say that not only can they hear the noise but they can also feel it.

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).

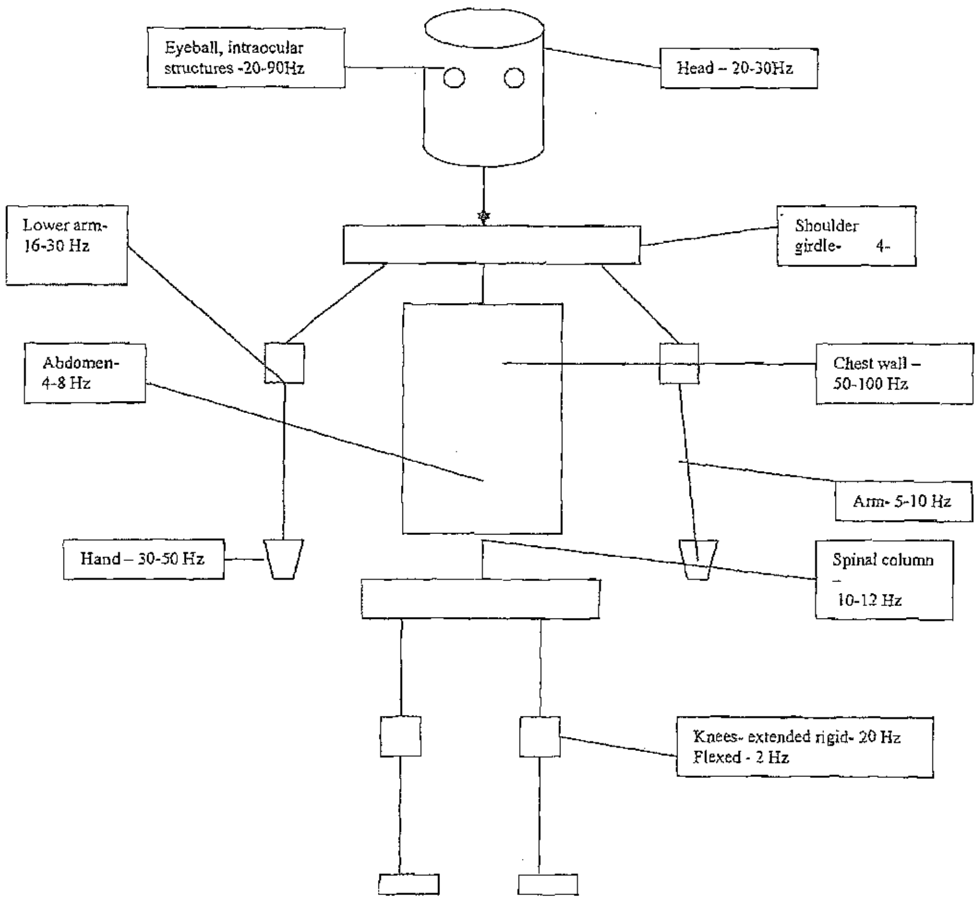
A research paper by G Rasmussen looked at body vibration exposure at frequencies of 1-20 Hz. Part of a table shows:-

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

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

Fig. 1

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



An important contribution to the low frequency part of the sound spectrum may be the result of the sudden variation in air flow the blade encounters when it passes the tower: the angle of attack of the incoming air suddenly deviates from the angle that is optimised for the mean flow. This effect has not been considered important as the blade frequency is of the order of 1Hz where humans' hearing is relatively insensitive. However low frequency modulates well audible, higher frequency sounds and thus creates periodic sound. This effect is stronger at night because in the stable atmosphere there is a greater difference between rotor average and near tower wind speed. In addition to this multiple turbines can interact with each other to further multiply the effect. The effect will be greater for the larger more modern wind turbines.

As wind is variable and not consistent, the nature of the noise produced is also impulsive and unpredictable.

Low frequency noise issues have been researched extensively in Portugal and have been found to cause a complex disease known as vibroacoustic disease. Although this research has been mainly concerned with high levels of low frequency noise, it is felt that over years lower levels of low frequency noise may cause similar problems. It appears that the low frequency noise compromises the mechanotransduction signalling of cells which lead to structural changes of tissues and cells. This damage sustained is dose dependent and it is only in the latter stages that routine medical investigations will become positive. The syndrome can be broken down into various stages:-

Stage 1 - MILD *(1-4 years)* Slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis
Stage 2 - MODERATE *(4-10 years)* Chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, and parasitic), inflammation of stomach lining, pain and blood in urine, conjunctivitis, allergies.
Stage 3 - SEVERE *(> 10 years)* psychiatric disturbances, haemorrhages (nasal, digestive, conjunctive mucosa) varicose veins, haemorrhoids, duodenal ulcers, spastic colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, neurological disturbances.)

Low frequency noise exposure has also been shown in many studies to interfere with performance and cognitive function in the workplace. The effects are greatest in noise sensitive particularly low frequency noise sensitive individuals. In this group of people salivary cortisol levels are elevated during exposure.

For many years research has been carried out using noise as a non lethal weapon. Recently the Israeli army used such a weapon for crowd dispersal. Witnesses describe d a minute-long blast of sound emanating from a white Israeli military vehicle. Within seconds, protestors began falling to their knees, unable to maintain their balance. The technology is believed to be similar to the LRAD — Long-Range Acoustic Device — used by U.S. forces in Iraq as a means of crowd control.

Professor Pratt a professor of neurobiology specializing in human auditory responses at Israel's Technion Institute explains that by stimulating the inner ear, which houses the auditory and vestibular systems, with high intensity acoustic signals that are below the audible frequencies- below 20 Hz, the vestibular organ can be stimulated and create a discrepancy between inputs from the visual system and somatosensory system and the vestibular organ will erroneously report acceleration (because of the low- frequency inaudible sound). It doesn't have to be a loud sound This will create a sensation similar to motion sickness. Such cases have been reported in relation to air conditioning systems.

Work by Fritz van den Berg shows why the characteristics of the noise produced by wind turbines increases and alters at night . He showed that the noise at night can be 15-18dBs higher at night time than during the day because of atmospheric changes (ref. Fritz van den Berg).
Therefore when we are resting in bed at night, the noise from the wind turbines can be at their loudest and most disturbing.

Those people who are disturbed by the noise are often particularly aware of the problems at night. – this statement can be partially explained by lower background noise levels at night, and also the fact that atmospheric stability increases at night giving a greater differential between rotor averaged and near tower wind speed . This explains why the characteristic of the noise emitted from turbines takes on a "beating" character early evening and night-in agreement with the blade passing frequency.

Noise induced sleep disturbance is well known to have adverse health effects and has been studied extensively although not with particular reference to wind turbines. Due to the indisputable restorative function of sleep, noise induced sleep disturbances are regarded as the most deleterious effects of noise.

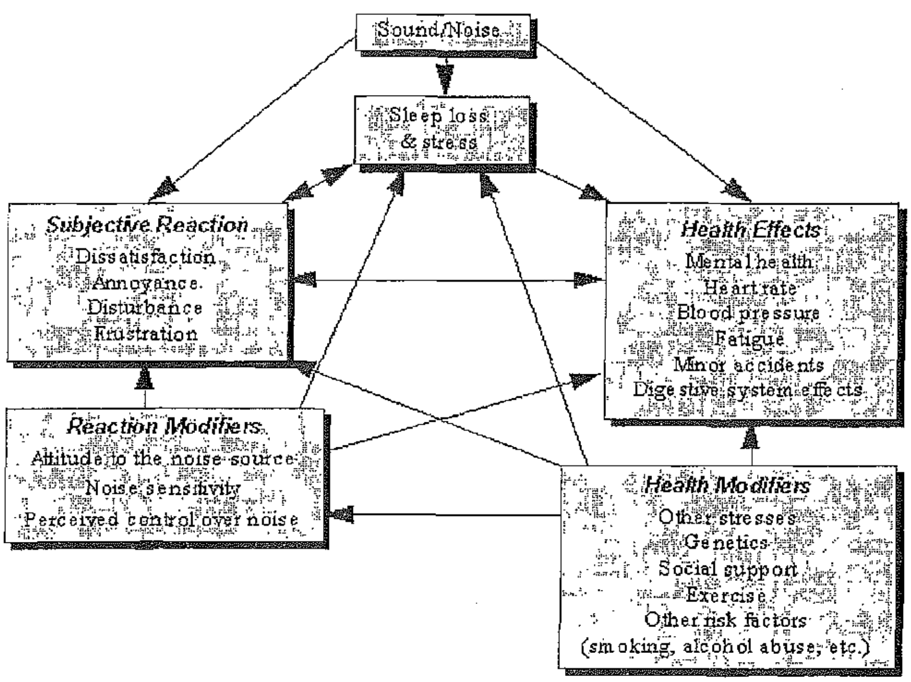
Nocturnal noise disturbance has been shown to disrupt nocturnal cortisol secretion. Nocturnal noise excites areas of the brain such as the amygdyla (functions as the fear centre) and cortical areas (arousal, annoyance and awakening). Noise –even levels below awakening threshold – can induce cortisol secretion. Repeated night time disturbance will result in an accumulation of cortisol levels in the blood. In the long term this can result in long term stress activation.

Several epidemiological studies in patients with primary insomnia found to be at a higher risk of developing major depression in the following years.
It has also been shown that women with increased morning cortisol levels show a higher risk of a major depressive episode within the next 12 months.

Psycho physiological reactions such as effects on heart rate and respiration rate have been observed during exposure to noise whilst subjects sleep. These have been found to be induced by road traffic noise with levels exceeding 40 dB LA max (both in lab and in field studies). Hardly any habituation occurs during or between nights. Children have higher psycho physiological reactivity than adults. In addition for these types of reactions, the difference between the background noise levels and the maximum sound pressure level is of more importance than the absolute sound level. (Vernet 1983).

The potential adverse health effects are usually classified according to the type of noise. Sudden or impulsive noise appears to create more disturbance than non impulsive noise (Job 1996). Intermittent noise has a greater effect than louder more continuous noise (Westman and Walters 1981). Predictability and controllability are clearly influencing factors in an individual's response to noise and this has been born out by surveys conducted by Eja Pederson in a paper presented in Berlin in Oct 2005.

It has been shown in several studies that depressed people and the elderly have a diminished variability in circadian cortisol levels and a raised morning cortisol in common. (Kern et al in 1996, Van Cauter et al 1998, Deushle et al 1998). It would therefore be likely that the elderly and patients already suffering depression might be more susceptible to noise induced arousals.



However we as humans experience our environment through multi sensory channels e.g. acoustic, visual, proprioceptive, vibrational and psychological and emotional issues.

Therefore all these factors have to be considered when we try to explain why people might be disturbed by wind turbines. When discussing noise with people who are disturbed by turbines, frequent complaints are of vibration leading to an intrusional and invading noise that they feel they cannot get away from. People say that they can "feel the noise".

I would suggest that several factors are therefore concerned in this annoyance. The "periodic noise" as described previously and the low frequency component. I think that the presence of these two together has an additive effect compounding both. The periodic noise draws the attention to the vibrational component and therefore becomes more annoying than if either were present individually.

In addition to this there is the visual stimulation of the turbine blades rotating- this is particularly disturbing in certain light conditions where strobing occurs, but provide a constant reminder of the presence of the turbines by their movement.

Psychological and social issues must also be considered. E.g. pre-existing psychological problems and also perceptions of having a wind turbine built close to their homes. Most people live in the countryside because they appreciate the quiet and the visual amenity. Therefore reluctance to having a wind farm nearby will exacerbate any problems.

SUMMARY

There are many people living near wind turbines who are suffering from problems with their health.

The noise produced from wind turbines is an extremely complex one and I feel that it is the complexity of the noise and vibration which causes the disturbance.

From my discussions with people suffering from ill health who live near wind farms, it seems that the symptoms suffered can occur up to a mile from the wind farm. Until further independent medical and epidemiological research has been carried out I would suggest that no wind turbines should be sited closer than 1.5 miles away from the nearest wind turbine.

The current UK guidance for establishing a safe distance between turbines and dwellings is the ETSU-R-97. This document was produced when turbines were approximately 20% the size of the currently proposed turbines. The guidelines pay scant reference to low frequency noise and the complexity of the noise profile produced by the turbines.
The continued use of ETSU-R-97 has been publically condemned by Professor FFowcs- Williams and G.P.Van den Berg.

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Appendix 1

Something in the Wind

THE SUNDAY TIMES - JANUARY 20, 2002

To some people they are "grotesque"blights on the countryside; to others,graceful machines that offer a welcome alternative to nuclear power and a way of tackling global warming. There are now more than 60 wind farms in Britain – the windiest nation in Europe –with 853 turbines producing enough power to run 500,000 homes a year. The numbers are set to rise as the government cranks up its drive to generate 10% of Britain's electricity from green energy sources by 2010.
Last week Powergen announced that it is considering building one of the biggest wind farms in the world in the Thames Estuary, sinking several hundred turbines into a sand bank in a project worth £500m. It comes in the wake of plans announced in December for a huge onshore wind farm on the Hebridean island of Lewis.
If the project gets planning permission, 300 turbines will be built, eventually meeting 1% of Britain's electricity needs. An increasing number of homeowners therefore have to get used to the prospect of living near the whirling blades. Margaret Gough, for one, cannot stand the sight of the towers that straddle the grassy slopes near her mid-Wales home. When she and her late husband retired to a village outside Aberystwyth 15 years ago, they chose a bungalow which had stunning views – until the Mynydd Gorddu wind farm opened several years later. "The reason we bought this property was for the scenery," says Gough. "It was such a beautiful skyline: if I stood in the garden and looked around all I could see was tree- covered hillsides. Now when I look out I can see about eight or nine wind turbines."

I stand under the turbine in Swaffham in Norfolk [the world's most efficient turbine andat 67m, thought to be Europe's tallest] and you
don't know it's turning." Surveys have found that although up to 96%
of people say they approve of wind farms, about a quarter would not like to live close to one. Householders' main objections are that wind turbines are "ugly" and they may bring down the value of their properties. Michael Williams, manager of estate agent Shearer & Morris in Aberystwyth, says that unless homes are very close to wind turbines property prices are unaffected. "I've sold quite a few properties within a mile of wind farms without any bother," he says. Nevertheless, some homeowners are fighting back. Martin Wright, Chairman of the Cefn Croes Campaign, is trying to halt the construction of the biggest wind farm in Britain. Under the £35m project – already approved by Brian Wilson, the energy minister – 39 turbines, each 100m high, will be cited at Cefn Croes, near Devil's Bridge in Ceredigion, mid-Wales. Wright says he objects to wind farms because he fears that vast swathes of rural Britain will be lost to the machines. "Mid-Wales is full of them," he laments. "The reason I oppose them isn't because I don't want them in my back yard – there's a wind farm on the mountain above my house and I can't say it disrupts my life -- it's to do with the wider issue of the value of our landscape.

"Wind power is a good idea, but the only way it is going to have any impact on our energy needs is to cover the whole country with turbines. So unless we are going to go down that path, why bother?
"We are going to ruin some of the lovely wildernesses that have been protected since the war: you can't build bungalows, but you can put up a 100m high turbine. That doesn't seem right."

Archaeologist **Dr Stephen Briggs**, also from Wales, claims he moved because infrasound, sound with a frequency below an audible level, from a wind farm made his wife ill. Problems started not long after the Llangwyryfon wind farm, 12 miles from Aberystwyth, opened 10 years ago. The Briggs' house was 350m from three of the 20-plus turbines and 650m from six of the machines. "Our initial intention was to stay put, even though we were disturbed by the changes and damage," says Briggs. "We had been assured the turbines would make no noise, but we were so close we could hear the wind whistling through them. "We also discovered that not only did they broadcast audible sound, they produced infrasound. It started to make my wife sick." Finally, six years ago, the Briggs decided to sell their house and move to a new home five miles away.

Dr Peter Musgrove, head of development at National Wind Power, which used to own Llangwyryfon, says; "The issue of the infrasound has been looked into in considerable detail and no evidence has been found that it is emitted by the turbines." Not everybody objects to turbines, however. John Theobald and his wife Sue are more than happy to live in the lee of a wind farm. Their bungalow overlooks Delabole in Cornwall, the oldest commercial wind farm in Britain, which attracts thousands of visitors a year. From their windows, they have a clear view of all 10 turbines.
"My wife and I are inveterate supporters of renewable energy anyway, but I love them," says Theobald, who runs a woodturning business and a bed-and-breakfast. "They change colour depending on the weather: some days they look thunderously grey and broody; other days, when the sun goes down, they turn pink and purple. "Having said that, I don't think anyone would like to live right underneath the tower." "We live about four or five fields away and only occasionally hear the noise from theturbines if the wind is in the East."
In fact, the noise is diminishing all the time as technology advances.
"Noise is no longer an issue," asserts Peter Edwards, owner of Delabole farm.

Blowing hot and cold: Martin Wright, above, from mid-Wales, fears turbine blight
The Theobalds: see no problems with turbines
Source: *The Sunday Times*, 20 January 2002

Appendix 2

Flurry of complaints after wind change

Jul 25. 2005

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

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

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

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

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

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

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

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

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

There's growing opposition from the public to windfarms.

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

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

Appendix 3

FEATURE: And the beat goes on . . .and on and on

18.02.2006
KATHY WEBB

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Meridian is dismissive of complaints about noise from Te Apiti.

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

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

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

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

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

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

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

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

J ohn Napier lives on the Woodville side of the Te Apiti turbines, about 2km from the nearest one.

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

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

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

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

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

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

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

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

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

He predicts disaster for the residents of Makara and Karori.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

* It detracts from those people who have genuine low-frequency noise problems, often from industrial exhaust fans, compressors and similar.

* It undermines the credibility of the complainants, who may be harming their own cause in their apparent 'grasping at straws' approach."

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

Dr Leventhall says:

* High levels of low-frequency noise are needed before people can perceive it, and the levels must

increase as frequency reduces.

* The ear is the most sensitive receptor in the body, so if you cannot hear it you cannot feel it.

* When there are problems with predominantly low-frequency noise, that is because assessment methods do not cater for it. That leads to the noises being dismissed as not being a nuisance, which in turn leaves unhappy complainants in a distressed state.

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

Appendix 4

Guantanamo Serenade

Jon Ronson knew from his investigation into US military intelligence that top brass had adopted some strange practices. Jamal al-Harith, the Briton released from Guantánamo in the spring, confirmed it: here, in our second extract from Ronson's revealing new book, he describes the discordant sounds and apparently random music played to him during all-day interrogation sessions, and four psychological warfare experts give their reaction

Saturday November 6, 2004
The Guardian

The more I've delved into the US military's psychological warfare, the more examples of New Age-style, First Earth Battalion tactics I've been noticing in the war on terror. I learned of one fact in particular that struck me as entirely incongruous, something at once banal and extraordinary. It happened to a Mancunian called Jamal al-Harith in a place called the Brown Block. Jamal doesn't know what to make of it either, so he mentioned it to me only as an afterthought when I met him in the coffee bar of the Malmaison Hotel, near Manchester Piccadilly station, one June morning this year.

Jamal is a website designer. He lives with his sisters in south Manchester. He is 37, divorced, with three children. He said he assumed MI5 had followed him here to the hotel, but he's stopped worrying about it. He said that he keeps seeing the same man watching him from across the street, leaning against a car, and that whenever the man thinks he's been spotted, he looks briefly panicked and immediately bends down to fiddle casually with his tyre.

Jamal laughed when he told me this. He was born Ronald Fiddler into a family of second-generation Jamaican immigrants. When he was 23, he learned about Islam and converted, changing his name to Jamal al-Harith: he liked the sound of it. He says al-Harith basically means "seed planter".

In October 2001, Jamal visited Pakistan as a tourist, he says. He was in Quetta on the Afghanistan border, four days into his trip, when the American bombing campaign began. He quickly decided to leave for Turkey and paid a local truck driver to take him there. The driver said the route would take them through Iran, but somehow they ended up in Afghanistan, where they were stopped by a gang of Taliban supporters. They asked to see Jamal's passport, and he was promptly arrested and thrown in jail on suspicion of being a British spy.

Afghanistan fell to the coalition. The Red Cross visited Jamal in prison. They suggested he cross the border into Pakistan and make his own way back home to Manchester, but Jamal had no money, so instead he asked to be put in contact with the British embassy in Kabul.

Nine days later - while he waited in Kandahar for the embassy to transport him home - the Americans picked him up.

"The Americans," Jamal said, "kidnapped me." When he said "kidnapped", he looked surprised at himself for using such a dramatic word.

The Americans in Kandahar told Jamal he needed to be sent to Cuba for two months for administrative processing, and so on, and the next thing he knew he was on a plane, shackled, his arms chained to his legs and then chained to a hook on the floor, his face covered in earmuffs and goggles and a surgical mask, bound for Guantánamo Bay.

In the weeks after Jamal's release, two years later, he gave a few interviews, during which he spoke of the shackles and the solitary confinement and the beatings - the things the outside world had already imagined about life inside that mysterious compound. He said they beat his feet with batons, pepper-sprayed him and kept him inside a cage that was open to the elements, with no privacy or protection from the rats and scorpions that crawled around the base. But these were not sensational revelations.

He spoke to ITV's Martin Bashir, who asked him (off-camera), "Did you see my Michael Jackson documentary?"

Jamal replied, "I've, uh, been in Guantánamo Bay for two years."

When I met Jamal, he began to tell me about the more bewildering abuses. Prostitutes were flown in from the US - he doesn't know whether they were there to smear their menstrual blood on the faces of the more devout detainees. Or perhaps they were brought in to have sex with the soldiers, and some psychological operations (PsyOps) boffin - a resident cultural analyst - devised this other job for them as an afterthought, exploiting the resources at the army's disposal.

"One or two of the British guys," Jamal told me, "said to the guards, 'Can we have the women?' But the guards said, 'No, no, no. The prostitutes are for the detainees who don't actually want them.' They explained it to us: 'If you want it, it's not going to work on you.' "

"So what were the prostitutes doing to the detainees?" I asked.

"Just messing about with their genitals," said Jamal. "Stripping off in front of them. Rubbing their breasts in their faces. Not all the guys would speak. They'd come back from the Brown Block [the interrogation block] and be quiet for days and cry to themselves, so you know something went on, but you don't know what. But for the guys who did speak, that's what we heard." I asked Jamal if he thought that the Americans at Guantánamo were dipping their toes into the waters of exotic interrogation techniques.

"They were doing a lot more than dipping," he replied. And that's when he told me about what happened to him inside the Brown Block.

Jamal said that, being new to torture, he didn't know whether the techniques tested on him were unique to Guantánamo, or as old as torture itself, but they seemed pretty weird to him. His description of life inside the Brown Block made Guantánamo Bay sound like an experimental interrogation lab, teeming not only with intelligence agents, but also with ideas. It was as if, for the first time in the soldiers' careers, they had prisoners and a ready-made facility at their disposal, and they couldn't resist putting all their concepts - which had until then languished, sometimes for decades, in the unsatisfactory realm of the theoretical - into practice.

First there were the noises.

"I would describe them as industrial noises," said Jamal. "Screeches and bangs. These would be played across the Brown Block into all the interrogation rooms. You can't describe it. Screeches, bangs, compressed gas. All sorts of things. Jumbled noises."

"Like a fax machine cranking up into use?" I asked.

"No," said Jamal. "Not computer-generated. Industrial. Strange noises. And mixed in with it would be something like an electronic piano. Not as in music, because there was no rhythm to it."

"Like a synthesiser?"

"Yes, a synthesiser mixed in with industrial noises. All a jumble and a mishmash."

"Did you ever ask them, 'Why are you blasting these strange noises at us?' " I said.

"In Cuba you learn to accept," said Jamal.

The industrial noises were blasted across the block. But the strangest thing of all happened inside Jamal's own interrogation room. The room was furnished with a CCTV camera and a two-way mirror. Jamal would be brought in for 15-hour sessions, during which time they got nothing out of him because, he said, there was nothing to get. He said his past was so clean - not even a parking ticket - that at one point someone wandered over to him and whispered, "Are you an MI5 asset?"

"An MI5 asset!" said Jamal. He whistled. "Asset!" he repeated. "That was the word he used!"

The interrogators were getting more and more cross with Jamal's apparent steely refusal to crack. Also, Jamal used his time inside the Brown Block to do stretching exercises, keeping himself sane. Jamal's exercise regime made the interrogators more angry, but instead of beating him, or threatening him, they did something very odd.

A military intelligence officer brought a ghetto blaster into his room. He put it on the floor in the corner. He said, "Here's a great girl band doing Fleetwood Mac songs."

He didn't blast the CD at Jamal. This wasn't sleep-deprivation, and it wasn't an attempt to induce the Bucha Effect[1]. Instead, the agent simply put it on at normal volume.

"He put it on," said Jamal, "and he left."

"An all-girl Fleetwood Mac covers band?" I said.

"Yeah," said Jamal.

This sounded to me like the tip of a very strange iceberg.

"And what happened next?" I asked.

"When the CD was finished, he came back into the room and said, 'You might like this.' And he put on Kris Kristofferson's greatest hits. Normal volume. And he left the room again. And then, when that was finished, he came back and said, 'Here's a Matchbox Twenty CD.' "

"Was he doing it for entertainment purposes?" I asked.

"It's interrogation," said Jamal. "I don't think they were trying to entertain me."

"Matchbox Twenty?" I said.

I didn't know much about Matchbox Twenty. My research reveals them to be a four-piece country rock band from Florida, who do not sound particularly abrasive (like Metallica and Burn Motherfucker Burn!) nor irritatingly repetitive (like Barney The Purple Dinosaur and Ya! Ya! Das Is A Mountain). They sound a bit like REM. The only other occasion when I had heard of Matchbox Twenty was when Adam Piore from Newsweek told me that they, too (like Metallica and Barney), had been blasted into the shipping containers where detainees were held at al-Qa'im in Iraq. I mentioned this to Jamal and he looked astonished.

"Matchbox Twenty?" he said.

"Their album More Than You Think You Are," I said.

There was a silence.

"I thought they were just playing me a CD," said Jamal. "Just playing me a CD. See if I like music or not. Now I've heard this, I'm thinking there must have been something else going on. Now I'm thinking, why did they play that same CD to me as well? They're playing this CD in Iraq and they're playing the same CD in Cuba. It means to me there is a programme. They're not playing music because they think people like or dislike Matchbox Twenty more than other music. Or Kris Kristofferson more than other music. There is a reason. There's something else going on. Obviously I don't know what it is. But there must be some other intent."

"There must be," I said.

Jamal paused for a moment and then he said, "You don't know how deep the rabbit hole goes, do you? But you know it is deep. You know it is deep."

Subsequently, I talked to Joseph Curtis (not his real name), who worked on the night shift at the Abu Ghraib prison, in charge of the computer network. I asked if he knew anything about the music. He said, sure, they blasted loud music at the detainees all the time. "What about quieter music?" I said, and told him Jamal's story about the ghetto blaster and the Fleetwood Mac all-girl covers band and Matchbox Twenty.

Joseph laughed. He shook his head in wonderment. "They were probably fucking with his head," he said.

"You mean they did it just because it seemed so weird?" I asked. "The incongruity was the point of it?"

"Yeah," he said.

"But that doesn't make sense," I said. "I can imagine that might work on a devout Muslim from an Arab country, but Jamal is British. He was raised in Manchester. He knows all about ghetto blasters and Fleetwood Mac and country and western music."

"Hm," said Joseph.

"Do you think ...?" I said.

Joseph finished my sentence for me.

"Subliminal messages?" he said.

"Or something like that," I said. "Something underneath the music."

"You know," said Joseph, "on a surface level that would be ridiculous. But Guantánamo and Abu Ghraib were anything but surface."

Jamal seemed fine when I met him in Manchester. I asked if he felt at all unusual after listening to Matchbox Twenty and he said no. But one shouldn't read too much into this. There is a very strong chance, given the history of the goat staring and the wall walking and so on that US military intelligence honchos went in for, that they blasted Jamal with silent sounds and it just didn't work.

In late June 2004 I sent an email to Jim Channon and everyone else I'd met during my two-and-a-half-year journey who might have some inside knowledge about the current use of the kinds of psychological interrogation techniques that had first been suggested in Jim's First Earth Battalion manual. I wrote:

Dear ---

I hope you are well.

I was talking with one of the British Guantánamo detainees (innocent - he was released) and he told me a very strange story. He said at one point during the interrogations the MI [military intelligence] officers left him in a room - for hours and hours - with a ghetto blaster. They played him a series of CDs - Fleetwood Mac, Kris Kristofferson, etc. They didn't blast them at him. They just played them at normal volume. Now, as this man is western, I'm sure they weren't trying to freak him out by introducing him to western music. Which leads me to think ... Frequencies? Subliminal messages?

What's your view on this? Do you know any time when frequencies or subliminal sounds have been used by the US military for sure?

With best wishes,

Jon Ronson

I received four replies straight away.

Commander Sid Heal (the Los Angeles Sheriff's Department non-lethals expert who told me about the Bucha Effect): "Most interesting, but I haven't a clue. I know that subliminal messages can be incorporated and that they have a powerful influence. There are laws prohibiting it in the US, but I'm not aware of any uses like you describe. I would imagine, however, that it would be classified and no one without a 'need to know' would be aware anyway. If it were frequencies, it would probably need to be in the audible range or they wouldn't need to mask them with other sounds."

Skip Atwater (General Stubblebine's former psychic spying headhunter): "You can bet this activity was purposeful. If you can get anybody to talk to you about this, it would be interesting to know the 'success rate' of this technique."

Jim Channon: "Strikes me the story you tell is just plain kindness (which still exists)."

I couldn't decide if Jim was being delightfully naive, infuriatingly naive, or sophisticatedly evasive.

Then Colonel John Alexander responded to my email. He remains the US army's leading pioneer of non-lethal technologies, a role he created for himself in part inspired by Jim's First Earth Battalion manual.

Colonel Alexander: "Re your assertion he was innocent. If so, how did he get captured in Afghanistan? Don't think there were many British tourists who happened to be travelling there when our forces arrived. Or maybe he was a cultural anthropologist studying the progressive social order of the Taliban as part of his doctoral dissertation and was mistakenly detained from his education. Perhaps if you believe this man's story you'd also be interested in buying a bridge from me? As for the music, I have no idea what that might be about. Guess hard rockers might take that as cruel and unusual punishment and want to report it to Amnesty International as proof of torture."

Jokes about the use of music in interrogation didn't seem that funny any more - not to me, and I doubt they did to him, either. I emailed him back: "Is there anything you can tell me about the use of subliminal sounds and frequencies in the military's arsenal? If anyone alive today is equipped to answer that question, surely you are."

Colonel Alexander's response arrived instantly. He said my assertion that the US army would ever entertain the possibility of using subliminal sounds or frequencies "just doesn't make sense".

Which was strange. I dug out an interview I'd conducted with the colonel the previous summer. I hadn't been that interested in acoustic weapons at that point, but the conversation had, I now remembered, briefly touched on them.

"Has the army ever blasted anyone with subliminal sounds?" I had asked him.

"I have no idea," he said.

"What's a 'psycho-correction' device?" I asked him.

"I have no idea," he said. "It has no basis in reality."

"What are silent sounds?" I asked.

"I have no idea," he said. "It sounds like an oxymoron to me." The colonel gave me a hard look, which seemed to suggest that I was masquerading as a journalist and was, in fact, a dangerous and irrational conspiracy nut.

"I'm confused," I said. "I don't know much about this subject, but I'm sure I've seen your name linked with something called a 'psycho-correction device'."

Yes, he said, he had sat in on meetings where this sort of thing was discussed, but there was no evidence that machines like this would ever work. "How would you do that [blast someone with silent sounds] without it affecting us? Anybody who's out there would hear it."

How could you blast someone with silent sounds "without it affecting us"? This struck me at the time as an unassailable argument, one that cut through all the paranoid theories circulating on the internet about mind-control machines putting voices into people's heads. Of course it couldn't work.

The thing is, I now realised, if silent sounds had been used against Jamal inside an interrogation room at Guantánamo Bay, there was a clue in Jamal's account, a clue that suggested that military intelligence had craftily solved the vexing problem highlighted by Colonel Alexander.

"He put the CD in," Jamal had said, "and he left the room."

Next, I dug out the recently leaked military report entitled Non-Lethal Weapons: Terms And References. There were a total of 21 acoustic weapons listed, in various stages of development, including the Infrasound ("Very low-frequency sound which can travel long distances and easily penetrate most buildings and vehicles ... biophysical effects: nausea, loss of bowels, disorientation, vomiting, potential internal organ damage or death may occur. Superior to ultrasound ...").

And then, the last entry but one - the Psycho-Correction Device, which "involves influencing subjects visually or aurally with embedded subliminal messages".

I turned to the front page. And there it was. The co-author of this document was Colonel John Alexander.

[1] In the 1950s, helicopters started falling out of the sky, crashing for no apparent reason, and the pilots who survived couldn't explain it. They had been flying as normal and then suddenly they felt nauseous, dizzy and debilitated; they lost control of their helicopters. A Dr Bucha was called in to solve the mystery. What he found was that the rotor blades were strobing the sunlight, and when it reached an approximation of human brainwave frequency, it interfered with the brain's ability to send correct information to the rest of the body.

· This is an edited extract from The Men Who Stare At Goats, by Jon Ronson, published by Picador on November 19 at £16.99. To order a copy for £16.14, with free UK p&p, call 0870 836 0875. Jon Ronson's three-part television series, The Crazy Rulers Of The World, starts on Channel 4 tomorrow. · Jamal al-Harith is one of four Britons released from Guantánamo in March, after more than two years' imprisonment, who claim they were repeatedly tortured at the camp and, it was announced last week, are suing Donald Rumsfeld and other US military leaders for £6m compensation each.

Appendix 5

Western Morning News

SHATTERED DREAM OF QUIET LIFE

09:00 - 06 January 2004

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.

National Wind Power, which owns the Bears Down site, has paid for double-glazing of the caravan to try to curb the noise effect, but this has had little impact.

Kathy and Colin, like their neighbours, complain of headaches, anxiety, sleeplessness and nausea - 97 per cent questioned by Plymouth GP Amanda Harry complained of one symptom or another.

One neighbour, who asked not to be named, describes the effect of the noise as being like "Chinese water torture".

His home is further back from the wind farm, and better insulated against external noise, but he said: "We get a beating sound, it's like a bus engine sitting parked, and we do get headaches. I understand the need for renewable energy, but the problem is that they do not contribute much. To get the things going they have to use electricity anyway."

To add to his sense of injury, he estimates that the wind farm has devalued his property by 25 per cent. Colin's health has got worse since moving to what he dreamed would be the perfect home for the rest of his days. At first he had no opinion of the turbines' appearance, but now he describes them as being "like ogres looking at you".

So what do the couple want, and how do they see a way out of their nightmare?

Kathy wants the turbines stopped at night so that they can sleep, and "some form of compensation" for their misery and troubles.

Colin explains: "We can't afford anywhere else, so what's it going to be like for the rest of our lives? We came here thinking we'd get peace and quiet for the rest of our lives. And it's beautiful - Cornwall has everything.

"But then this happens - you'd need to be in a Chieftain tank with earphones not to hear those things."

Kathy adds: "We came here to live simply, and we both had to retire early because of ill-health. Colin just needed a very quiet environment, and we'd been here before and had three years of peace and quiet and it was gorgeous.

"But this is systematically ruining our lives - and I just feel that people are not aware of the damage these things are doing to health."

The issue is set to come to the fore with a legal test case in Cumbria where people living between 600-800 metres from the 60-metre turbines in the village of Askham complained of headaches and nausea. Barrister John Campbell is representing three couples at Kendal Magistrates Court in a fight to get wind turbines near their homes declared a statutory nuisance under the Environmental Health Act.

He said: "There are a number of complaints of sleep disturbance, headaches, and migraines that are driving people mad. They say it's a pervasive thump, thump noise from the blades."
He said that if they won the test case, which is expected to take several days, the turbines would either have to be stopped or removed.
Meanwhile, one couple living in a residential caravan near the Bears Down site have saved up £1,000 to go to Malta for a month because they say they cannot cope with life next to the turbines in winter when the winds are high.
In desperation last year, they booked into B &Bs in Newquay at Christmas.
Kathy and Colin Bird took early retirement through ill health from their jobs in Coventry as they sought a quiet life in Cornwall. Then they moved into their caravan in 2000, before the wind farm was built. But Mrs Bird now says: "It's just a throb when the wind is up - it's like the sound of a car going by with the stereo blaring, but it doesn't pass."
Matthew Spencer, chief executive of the South West Renewable Energy Agency (Regen) yesterday disputed whether the noise from turbines was the cause of their health complaints.
He said: "People may perceive that is their problem, but the turbines are not very noisy. Nothing has been proved about the health effects, but I would take these initial findings with a pinch of salt. These are arguments that people who are opposed to wind farms use."
He pointed out that travelling at 40mph would create a noise of 55 decibels at 100 metres while a wind turbine produced a noise of 35 decibels at 350 metres.
He said there was no evidence that the new generation of larger turbines planned for the South West would be a problem. "They are becoming less noisy as they are being developed," he said.
He added that the guidelines for the turbines were that they should not be within 400 metres of people's homes, and that noise had not proved a problem in the eyes of planners.
National Wind Power, which owns and operates the Bears Down wind farm, yesterday failed to respond to a series of questions put by the Western Morning News.

Appendix 6

Western Morning News
WIND TURBINES HAVE EATEN INTO MY VERY SOUL
09:00 - 09 January 2004
Mark Taplin has lived in the shadow of wind turbines for more than a decade. As part of our on-going debate on the issue, he describes how the experience has affected his life
Opposed: Mark Taplin says turbines have ruined his way of life MY world has been overshadowed by the spectre of wind turbines for 12 years, and I have lived with the reality for the past eight years of generating machines spinning their blades 75 metres above my house, the closest a mere 440 metres away. They have imposed themselves on my life and eaten into my soul - small wonder that I feel compelled to contribute to the deluge of column inches that this latest debate has generated. I live in a modest cottage which nestles in a small secluded Cornish valley, surrounded by a few acres that I can call my own.
I came here to pursue my ambition of an Arcadian existence, growing my own fruit and vegetables and indulging in a bit of self taught husbandry.
I was eager to leave behind the smug and affluent rural neighbourhood where I had grown up, and endured the tiresome label of leading "the good life".
I was accustomed to a degree of hardship and was prepared for the vicissitudes of the Westcountry climate. I was not expecting a rural idyll "preserved in aspic". I had a grasp of the commercial imperatives that exerted control over the countryside as the end of the century approached. However, what I was not prepared for was the impact on my life of my nearest neighbours - the wind turbines at Four Burrows.
I am not the first, nor will I be the last, to find the terms "windmill" and "windfarm" misplaced. Wind turbines do not mill grain, nor do they harvest the product of their own endeavours.
Arguably they save some forms of pollution, but are responsible in turn for some negative by-products, from the concrete in their foundations to the tips of their blades, offending many by their very sight and sound. I have always considered myself as one who was aware of environmental issues, and I try to live in harmony with the countryside. But, sadly, the intrusive neighbours on my doorstep have introduced a massive note of discord into my peaceful existence.
Why? Because whatever the individual thinks of them aesthetically, I cannot avoid the noise. I hear them nearly all the time. It is not easy to equate it to other noise sources, and I find the attempts at comparisons trite. The dilemma for one such as me is that the industry has always argued that as the wind picks up speed and the

power output and noise level produced increases, the natural background noise created by the wind will mask any turbine noise. Where this argument falls down, however, is when you find yourself in a comparatively sheltered position on lower ground than the turbines and not buffeted by the wind. Then you hear a great deal more than if you stand up close with the wind rushing past your ears. When small but violent changes in wind direction shear past the turbines, the chomp and swoosh of the blades passing the towers creates a noise, albeit mercifully brief, that beggars belief. It is as if a ghostly steam engine were pumping an abandoned mine working.

But this surprising and unacknowledged phenomenon does thankfully pass as the wind abates, whereas the bane of my life - the "tonal" (mechanical whine or resonance) noise - does not. It is ever present when a turbine is generating at more than mere tickover,
despite the manufacturer's claims.

So, how can I hear tonal noise? It has been so distinct at times that I foolishly assumed everyone would own up and do something about it. Sadly, that is where the technicalities come in, and it boils down to mathematics. The wind industry is better supported than local council environmental health departments, and they were well ahead of the game when they formulated the criteria for establishing tones. It is a loaded issue and not what you might call a level playing field. Whatever I hear, they will claim that it does not qualify as a tone - which means that I am stuck with it. Once you hear tonal noise it follows you around, not in your imagination but because the human ear has a natural habit of homing in on an annoying sound.

But, going back to the beginning, what turned me into an "anti" soon after I found myself thrown on to the learning curve in 1992? Was it the way that the whole thrust of renewable energy development was being hijacked by the wind lobby, the cavalier attitude of a new breed of opportunistic developers, the obscenely generous price support structure offered at that time under the Non Fossil Fuel Obligation and the greedy scramble for another subsidy? Was it the arrogance of politicians who jumped on the green bandwagon, the pressure group zealots who adopted the moral high ground in the name of saving the planet and the naive level of argument from the "better than nuclear, nicer than pylons" brigade? Was it the exasperating lesson of having to teach myself all about parliamentary statements, planning procedures and the technicalities of noise attenuation, which only served to disenchant me, when all the while I would much rather have been getting on quietly with my life? Or was it just a selfish determination to defend my precious green and pleasant Shangri La from industrial machines which threatened to invade my privacy?

I resent the same old stale public relations lecture from the vested interest lobby who do not appear to know how or when to apologise.

I do not warm to those who disregard for the sensibilities of others who can be passionate about preserving a particular landscape that is special to them. I cannot accept that wind turbine generators are benign.

I have contributed to the debate with this account not to seek sympathy, but as a reminder to those of a different persuasion that the route down which wind power development has been driven in recent years can cause very real harm. Noise apart, it has turned me, a potential supporter, against my turbine neighbours and what they stand for.

Appendix 7

Meridian pays family to move

02 August 2005

By LEE MATTHEWS

Meridian Energy has paid an undisclosed sum of money to shift a family from their farm where Te Apiti's wind turbines are located, because noise and vibration made it too difficult to live in their house.

Company spokesman Alan Seay would not say how much the compensation is, as it is a confidential agreement between Meridian and the Bolton family. He understands they will move off their farm and build elsewhere.

He also said the payout is not a surprise, as it had been anticipated in the initial lease agreements with the land owners. It is not part of any of the 20 conditions imposed by the wind farm's resource consent.

"Te Apiti is built on two farm properties. It was recognised right from the start that this family could have issues with noise . . . their house was a only a few hundred metres from the turbines," Mr Seay said.

"The possibility of having to shift was part of the initial lease agreement. These were houses actually in the wind farm, as opposed to neighbouring (houses)."

Meridian has also made a confidential deal with the other farm owners affected. Mr Seay said he understands this has involved building alterations, such as double-glazing windows to reduce noise.

There are no other claims for any kind of compensation for nuisance from Te Apiti, and Mr Seay said he does not anticipate any in future. "This one was made because it was a foreseen situation."

Feedback from the Ashhurst community about Te Apiti has "all" been positive, apart from "one or two vociferous" opponents whom he understands to be working with people objecting to Meridian's proposed Makara wind farm.

"Nimby (not in my back yard) syndrome . . . it's what we've got to expect from some of these groups . . . it's misleading and distorting."

Last November, Ashhurst resident Colin Mahy complained that sun reflection flickering into his house from the Te Apiti turbines was "driving him mad". Meridian had told him to draw his curtains.

Mr Seay said that he had given that advice. "Sun flash is a very momentary thing, it only occurs in certain circumstances and it doesn't last long."

Appendix 8

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. They don't belong here, they shine in the sunlight, they glow in the moonlight, they stand out stark white against the dark rain clouds, unlike everything else surrounding them they never change. No lichen, no birds encircling them, no ivy creeping up their metallic towers. There is nothing of nature within them ,they don't belong here on Moelfre overlooking the Tivy Valley.

Those living six, ten, fifteen miles and more away from them agree. They can be seen by the inhabitants of many small towns and villages as totally scarring the wondrous outline of the gentle rise from Moelfre to Frenni Fach Frenni Fawr, Foeldrigarn ,Preseli and Caerningly above
Newport. The council planners must have been mad to grant them permission.

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 effected 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.

06/04/03

Diary Tuesday 8th April.

Sat in the gallery yesterday, in Carmarthen, felt well all day. In the evening went to the Teivy Arts meeting, felt well, enjoyed the company and chat. Came home at ten fifteen sat talking to Henning for a while went to bed [the bed in the house, the wind was fairly light] and the throbbing in my head started. Tried to ignore it, listened to the radio, switched it off, throb throb, feeling of anxiety, tried to sleep, but at twelve thirty I reluctantly took a Nytol tablet. Slept.
This morning I went to see my doctor to have a check up to see if there is some physical cause for my disturbed heart rhythm. She examined my heart, all well, felt my pulse rate, all well, lungs, all well, took my blood pressure, 120/80 that's good. Never felt better, She looked up my records for the hearing test in 1992 but there were no specific detailed figures given for the test only the conclusion that this patient had normal hearing. [had the test because I had been suffering from tinnitus that year]
After lunch I sat down in the living room by the window to read, after five minutes I had to move I couldn't stand the heart rhythm and the churning in my head. I tried to override it I really wanted to get on with my book but I could not stay there any longer. The wind is from the south today and the turbines have their backs turned directly at us.
Went outside to do some gardening and took Tess for a walk, it's always better outside. Thought about buying a wooden garden shed to live in, perhaps in the woods. Back in the house I felt extremely uncomfortable. At five o'clock I baby sat for Lindsay in the old farmhouse until her mother arrived. The noise of the children and telly filled the house so I couldn't compare the two houses for turbine noise.

Wednesday 9th April.

Last night I tried something new, I have a C D of the sound of waves called Ocean Spray, it's called white noise, for relaxation and sound masking. I carried my CD player from the studio up to the bedroom. It's not a portable so it was heavy. The wind was from the south so I knew there would be throbbing in my head. It sounded great,[the sound of waves] I slept quite soon but woke up at five o'clock with a dreadful headache, had to take two soluble aspirins. Wind still from the south and my headache was still with me at ten o'clock. Took more painkillers and kept to our plan of walking on the Preselis.

Three hour walk, beautiful weather, felt great. My mind is going around in circles about what to do in this situation. It's clear that no one else suffers from the same symptoms as me on this farm. There are six adults and three children living here. I really don't want to disrupt everyone else's lives.
Plans: Sell the whole place. Sell only this house; Rent a place and find a tenant for this house; Build a small place for me in some "quiet corner of the farm" if there is such a place; My head is reeling with all the pros and cons. Haven't painted for weeks because of my bed being in the studio. Feel sick again. Trouble is that when I feel ill where can I lie down, in my bedroom? That's where I feel ill.
Later on the wind came from the North, then life gets back to normal again and no way are we going to sell up and move away.

Friday 11th April
North wind, yesterday was no problem to me. What a difference it makes, once the pain has gone there's no need to plan an alternative future for us. Have moved the bed from my studio, I really need to get on with my work. Have moved it to the loft, above another outhouse, I shall sleep there next time the wind is from the south. I'm feeling quite hopeful again that I can live with this once I've learned how to, but in order to make it possible some alterations will have to be made to the loft.
Saturday 12th April
I was far too optimistic yesterday, this is typical of how it goes. Last night was the worst so far. I went to my bed in the house and played the CD of the waves, slept quite soon, CD was on repeat mode. At one forty five am I woke up with the throbbing in my head, really bad, weight on my chest and a distinct pain in my heart. Tried to calm myself, CD was still playing, tried to meditate but was filled with a real sense of panic and felt an urgent need to escape. Too cold to go to the loft so I carried my duvet down to the kitchen which is the furthest room away from the turbines. With the cushions from the settee I made a camp bed but there was no sleep so at six o'clock I dragged it all back upstairs, Got up, had only about three hours sleep.
Shall have to try out the loft tonight, it's the sound of vermin that worries me, and the cold, but nothing could be worse than the way I felt last night.
Sunday 13th April
The loft is as bad as the bedroom. I realized this in the afternoon yesterday when I tried to catch up with some sleep. Spent last night at by brothers' house in the village three miles away. Slept. This is really getting us down, it's taking over our lives. We're now back to selling and moving away, it can't go on like this.
Monday 14th April
Wind from the south again, feel really depressed this morning. Phoned the council about noise pollution, someone will 'phone back today or tomorrow [or never]. I've got to get out of here today, all the symptoms are with me again, Henning is quite sick of hearing about them and I'm sick of suffering them.
Tuesday 14th April,
Wind still from the south, slept in the dining room last night but only after taking a Nytol tablet. Estate agent came out this morning, we'll probably have to move I can see no future for me here. I have to go out today to get some relief from the way I feel.

Gwen has now moved and does not live near wind turbines- she says that all her symptoms have settled.

Appendix 9

A) **Nick Priest on behalf of 30 families, Chybucca, Allet, Truro, Cornwall, TR4 9DL**

……the only two families who lived near to the Carland Cross wind farm, Newquay, have now moved out because of unsolvable noise problems. At least one home now lies derelict.

Is this positive rural diversification or rural community extinction? The Welsh Affairs Select Committee have recommended that no dwellings should be within 1.5km of a wind farm. There are 30 families within such distance.

(Extract from noise abatement society, July 1997, 'Windfarms certainly do make a noise').

Appendix 10

B) Natalie Gregg, The Courier Mail, Queensland, Australia, 04 Oct 2004

Rural residents in two states can't sleep at night because of noise from a Queensland Government owned corporation's alternative energy plant. Homeowners in Queensland and Vixctoria have all but resigned themselves to the noise of the Stanwell Corp. wind turbines, which they claim have devalued their properties.

Mrs 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." Within 12 months the couple, who are in their fifties, had had enough and they decided to move but they still cannot find a buyer.

Appendix 11

C) **Times on Line, 10 Jan, 2004 "wind farms ruin peace, says judge"**
Wind farms can ruin the peace of the countryside and destroy the value of nearby homes, a judge has ruled.

District Judge Michael Buckley said that the noise, visual intrusion and flickering of light through the blades of turbines reduced the value of a house by a fifth. He said that the value of a remote house in Marton, in the Lake District, fell significantly because of the construction of a wind farm 40m high turbines, 500 metres away.

Appendix 12

D) Mag. Lotta Nilson, Laholm, Sweden. (lotta.nilson.fsi@swipnet.se)

Wind turbines produce nothing but a nightmare for neighbourhoods; conflicts between former friends and within families, stress, ill health... ... ...I left my home because of a wind turbine placed 650m from my house. One day in November 1998 mine and my neighbour's lives changed dramatically. The wind turbine, totally about 90m high started to rotate for the first time. The noise is a torture. After one year I understood we would not get any help and that no one can or will measure the sound level... ... .Hundreds of families in my small, former beautiful community on the west coast of Sweden are suffering enormously.

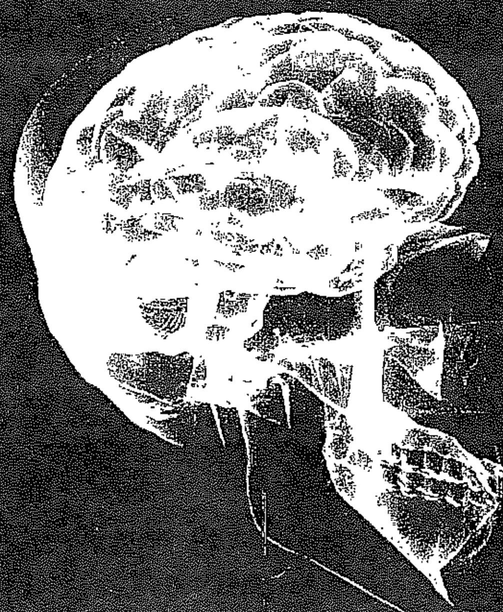
Appendix 13

E) Murray R. Barber, Bradworthy, Devon. 12 July 2005

I understand that Energiekontour A.G. is responsible for operating the Forestmoor wind farm, Bradworthy, Devon. Our home is located 650m from the nearest of three turbines. I wish to complain about noise nuisance created by the wind farm.....

WIND TURBINE SYNDROME & THE BRAIN

Nina Pierpont, MD, PhD
November 15, 2010



The following is the text of Pierpont's keynote address before the "First International Symposium on the Global Wind Industry and Adverse Health Effects: Loss of Social Justice?" in Picton, Ontario, Canada, October 30, 2010. It is followed by a discussion of several other relevant talks at the symposium by Drs. Alec Salt, Michael Nissenbaum, Christopher Hanning, and Mr. Richard James.

Abstract

The latest research, as discussed below, suggests the following mechanism for Wind Turbine Syndrome: air-borne or body-borne low-frequency sound directly stimulates the inner ear, with physiologic responses of both cochlea (hearing organ) and otolith organs (saccule and utricle—organs of balance and motion detection).

Research has now proved conclusively that physiologic responses in the cochlea suppress the hearing response to low-frequency sound but still send signals to the brain, signals whose function is, at present, mostly unknown. The physiologic response of the cochlea to turbine noise is also a trigger for tinnitus and the brain-cell-level reorganization that tinnitus represents—reorganization that can have an impact on language processing and the profound learning processes related to language processing.

New research also demonstrates that the "motion-detecting" otolith organs of mammals also respond to air-borne low-frequency sound. Physiologic responses and signals from the otolith organs are known to generate a wide range of brain responses, including dizziness and nausea (seasickness, even without the movement), fear and alerting (startle, wakefulness), and difficulties with visually-based problem-solving.

Increased alerting in the presence of wind turbine noise disturbs sleep, even when people do not recall being awakened. A population-level survey in Maine now shows clear disturbances of sleep and mental well-being out to 1400 m (4600 ft) from turbines, with diminishing effects out to 5 km (3 miles).

Sensory systems change brain functioning

I confess I have an odd medical practice. I'm a pediatrician by training, but I'm fascinated by brains and development, and essentially practice psychiatry and child development. I'm interested in how to help children's brains grow well, and, at the other end of the spectrum, in what derails normal brain functioning in normal people—like Wind Turbine Syndrome—and how to get that functioning back on track.

So much of brain function is about the sensory systems—vision, hearing, touch—and what the brain does to take basic sensory signals from all over the body and turn them into a coherent picture of where this particular creature—oneself—is at this particular time, and what needs to happen next to meet its needs. Those needs range from the basic and physiologic—like breathing and pumping blood in the right amounts to the different parts of the body—to complex social and language-based needs, like figuring out what your spouse really meant by that last thing he said. Our sensory systems mediate all of these needs.

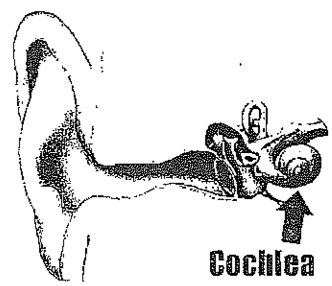
Sensory systems change brain functioning. They affect not only what a person or animal feels or thinks at that very moment, but also how that brain will function in the future, even the near future. This is called neuroplasticity, the neural basis of learning, for which Eric Kandel won the Nobel prize in 2000.[1]

Tinnitus:
The brain makes up sound where no sound exists

Take, for example, tinnitus, or ringing in the ears—an important sensory problem in Wind Turbine Syndrome. Ringing, buzzing, sizzling, or waterfall noises—my study subjects described all of these, sometimes in the head as well as the ears.

58% of the adults and older teens in my sample of affected families had tinnitus. In the general population, it's 4%. People with a prior history of hearing loss or industrial noise exposure were especially likely to get tinnitus, but other people in the study also got it, without these risk factors.

Among people with tinnitus in general, many have damage to their cochlea, the snail-shaped organ of hearing in the inner ear. Because of this damage, many researchers have heretofore thought that tinnitus originates in the cochlea as distorted hearing signals—the cochlea being somehow able to produce nerve signals of sound without the sound being there in the environment.



We are now getting quite a different picture of tinnitus. People with auditory nerves (meaning the nerve from the cochlea to the brain) that have been completely cut (for example, because of a tumor on the nerve) also have tinnitus, although, again, there is no input from the cochlea to the brain at all.

Recently, functional imaging studies (like MRI or PET scans) of people with tinnitus have supported the idea that tinnitus arises not in the ear, but in the parts of the brain that process sound. The trigger is an absence of input from the cochlea or parts of the cochlea. Essentially, your brain makes up sound where no sound exists.

It's like phantom pain that people get when they have lost a limb. There is no nerve input from the limb because it's gone; nevertheless, the person experiences the limb hurting.

The NEW ENGLAND JOURNAL of MEDICINE

Tinnitus is like this—it's phantom noise. It can be an excruciating and unpleasant sensation.

This type of change in the brain (like what happens with tinnitus) happens quickly. We learn this from a journal as unimpeachable as the *New England Journal of Medicine*, the gold standard in America for medical research. Describing the pathophysiology of tinnitus, a review article published in 2002 stated:

> Hearing loss leads to a reorganization of the pathways in the central [brain] auditory system. These changes may occur rapidly and lead to abnormal interactions between auditory and other central [brain] pathways.[2]

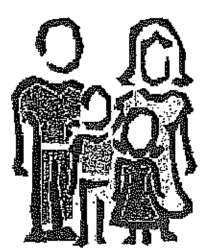
What's happening here is that the cells in the brain are making new connections, not good connections. It's like chaos in the brain, and the result is hearing a noise that isn't really there.

Wind Turbine Syndrome & tinnitus

Now listen to this story from *Wind Turbine Syndrome*.[3] A real Canadian family, family A in my study. We'll call them the Smiths. We'll call them Frank, Marlene, and their 2½ year old boy, Justin.

Frank, age 32, is a healthy fisherman who owns his own boat. Turbines, 10 in a row pointing at the house, the closest 1 km away, go online. For the first three weeks, Frank has repetitive popping in his ears, like pressure changes. After three weeks, a continuous headache starts whenever he's at home. It resolves after several hours every time he leaves the house, and comes back within several hours of coming home. Several weeks after the headache started, tinnitus starts and worsens over the duration of the 5-month exposure, until the family abandoned their home and rented a house in town.

Marlene, his wife, a 33-year-old accountant, likewise noticed repetitive popping in her ears for the first three weeks. She also noticed she couldn't hear as well as before. After three weeks, the tinnitus began. The tinnitus continued and worsened over time during the 5 months of exposure, varying according to how much she was at home and how loud the turbines were. After the exposure ended, she told me, the tinnitus resolved, but she noticed a new difficulty understanding conversation in a noisy room. She noticed she had to watch the speaker's face more closely.



During exposure, young Justin, a healthy 2½-year-old, pulled on his ears and got cranky at the same times that adults in the family noticed more headache and tinnitus. His language development was good before, during, and after exposure, but his mother noticed during exposure that the child began to confuse T with K sounds and W with L sounds, which he had not done before. This sound confusion was ongoing six weeks after exposure ended, when I interviewed the parents.

Let's match the research to the clinical account—match medical science to this real family. These two adults experienced pressure changes in their ears for some weeks, one with some loss of hearing. They then developed tinnitus. The tinnitus resolved when the noise exposure ended, but Marlene still noticed subtle differences in her own auditory processing and in her child's, Justin's.

Picking out one voice against background noise is an example of brain (or central) auditory processing, which means how your brain takes signals coming from your ears and puts them together into language, music, the song of a hermit thrush, or other recognizable and meaningful sounds.

To pick out one sound from background noise, your brain processes simultaneous signals from both ears, integrating the signals into a new type of perception that transcends what either ear can do alone. (It's sort of like depth perception with two eyes.)

Hearing in background noise is one aspect of brain auditory processing, and one that audiologists often test. Distinguishing language sounds is another critical part of how the brain processes sound, especially for children learning language.

So, what do we have? We have the *New England Journal* telling us that auditory pathways in the brain reorganize rapidly when there are deficits in the input from the ears, producing tinnitus. (Let's not ignore that this "reorganization" represents deterioration in function—not an improvement. Contrast this to the process of brain organization that occurs as a child learns language.) We have this research on the one hand, and on the other, younger healthy adults telling us their observations of their own hearing and hearing-related processes as they passed through a substantial bout of noise exposure.

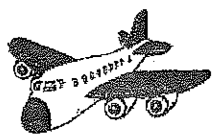
Marlene described the noise, by the way, as, "Not noisy like a chainsaw; more like pulsating annoyance. To another person it wouldn't sound loud."

I suspect that in a child as young as Justin, 2½, who was removed from exposure so quickly, this process is entirely reversible. But such effects are less likely to be reversible with older age or longer exposure. That's a basic principle of how brains develop.

NOISE EXPOSURE, EVEN AT RELATIVELY LOW SOUND LEVELS, FOULS UP THE PARTS OF THE BRAIN RESPONSIBLE FOR FIGURING OUT LANGUAGE SOUNDS, AND THE PARTS RESPONSIBLE FOR UNDERSTANDING AND LEARNING AND REMEMBERING THINGS WE HEAR OR READ

I'm basing this interpretation of the Smith's experience on the tinnitus research and also on another area of research—on the effects of other types of environmental noise (like airport or traffic noise) on children's learning.

Learning to read is a language-intensive process that is especially sensitive to the effects of noise in school or at home. This effect is distinct from the effects of noise on attention or working memory,[4] and is correlated with measures of sound processing such as speech recognition.[5]

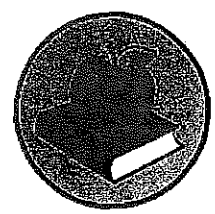


In one study, for example, a German city closed an old airport and built a new one. Researchers had the opportunity to follow the reading skills of both sets of children over time. Those living near the airport that closed showed improvement in their reading. The ones near the new airport slowed down in their learning after the airport opened.[6]

Another study looked at the effects of noise on both reading and auditory processing in children who lived in an apartment building next to a busy highway. Auditory processing, again, is what your brain does with the signals from your ears to turn them into meaningful language or other sounds.

The higher the children lived in the building, the quieter were their apartments and the better their reading and auditory discrimination scores, which means, for example, distinguishing the word *goat* from *boat*. The study factored out the effects of parent education and income, and then found that children exposed to more noise were more delayed in their reading. The amount of delay in reading was explained by how badly the children were doing distinguishing language sounds from each other, which also worsened with more noise.[7]

In other words, the presence of noise in the environment degraded how these children's brains processed language sounds, which in turn degraded their ability to learn to read. It wasn't that the noise just kept them from hearing things they needed to learn; the noise actually harmed their brain's ability to process language, even when that language was coming in through their eyes, as it does when we read.



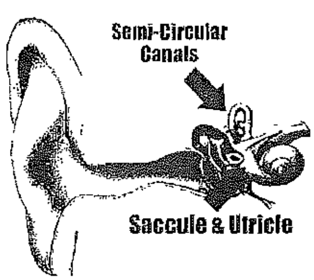
Moreover, these effects of noise on reading occur at sound levels far less than those needed to produce hearing damage.[8] Children at higher grade levels are more affected, and longer exposure produces larger deficits, other studies have shown.[9]

In my wind turbine study, 7 out of the 10 school-age children and teens did worse in school during exposure to turbines, compared to before or after, including unexpected problems in reading, math, concentration, and test performance, noticed by both teachers and parents. Teachers sent notes home asking what was wrong with the children.

Subtle as these effects are, they have serious implications. Noise exposure, even at relatively low sound levels, fouls up the parts of the brain responsible for figuring out language sounds (what we call language processing) and the parts responsible for understanding and learning and remembering things we hear or read (what we call language-based learning).

Let me emphasize: Noise exposure, even at low levels that don't damage hearing, can do this.

The Balance Organs: A protean presence in the brain, in terms of what types of sensations they draw on and how the information is used by the brain



There is another set of organs in the inner ear, the organs of balance (called the vestibular organs), consisting of the utricle and saccule (the two otolith or "ear rock" organs, where microscopic stones control our perception of gravity and movement in a straight line) and the semicircular canals, which detect rotations of the head in three planes.

The balance system is probably the least well known of all the senses for both the general public and physicians. It's a different kind of sense. It has some dedicated organs (the vestibular organs in the inner ear, just described), but these organs do not function on their own, not without the cooperation (and brain integration) of multiple sensory signals from all over the body.

We use this sense not just for balance (staying upright), but also for telling where we are in space and how fast and in what direction the different parts of our bodies are moving, at all times.

The vestibular sense feeds back instantaneously, for example, on the eye movement muscles and on posture-maintaining muscles in the neck and back. It also adapts to gravity by controlling tension in the arteries and smaller blood vessels all over the body, and how hard the heart is pumping, to keep the blood evenly distributed whether you are standing up, lying down, or standing on your head.

Balance and motion detection requires input from the eyes, from stretch receptors in the muscles and joints all over the body, from touch receptors in the skin, and, it is now known, from stretch and pressure receptors in and around internal organs and the great blood vessels in the chest and abdomen.[10] As well as requiring signals from the inner ear—the utricle, saccule, and semicircular canals.

This is a remarkable feat of brain integration, especially when the signals don't all agree with one another. The brain has to figure out which signals to downweight or ignore if they don't all agree, or if the signals from one channel are distorted.

Even fish have otolith organs and semicircular canals. The cochlea, or specialized hearing organ, evolved later, our type specifically in mammals. The brain essentially grew up, through evolution, with vestibular neurons and signals already in place. As a consequence, our systems for detecting movement, gravity, pressure, and vibration have a protean presence in the brain, going everywhere, both in terms of what types of sensations they draw on, and how the information is used by the brain.

In fish and amphibians, the otolith organs are much better detectors of low-frequency noise and vibration than are these animals' own versions of sound-detecting organs.[11,12] We now know that even in mice—a mammal—low-frequency, air-borne sound is detected by the otolith organs.[13] In humans, detection of low frequency sound by the otolith organs has been shown only using bone-conducted sound, meaning a source of vibration placed right against the head.

At 100 Hz, the tone of a moderately low note on the piano, healthy adults can detect a bone-conducted vibration at 15 dB below their own normal hearing thresholds, probably through the utricle.[14,15] "Detection" in this case means that the vibration triggers an automatic reflex in muscles around the eyes or in the neck, a response that can only be due, we know, to vestibular stimulation.

All this by way of saying that we are getting nearer to understanding the pathophysiological mechanisms causing Wind Turbine Syndrome.

Wind Turbine Syndrome resembles inner ear pathology witnessed by otolaryngologists

The symptoms of Wind Turbine Syndrome directly mirror the symptom clusters that practicing otolaryngologists have seen for years in patients with balance problems due to vestibular inner ear pathology.[16,17] With vestibular pathology, however, the symptoms are not known to come and go with noise exposure. Very importantly, the symptoms associated with vestibular pathology are not just about balance or dizziness, as I'll review in a moment. Indeed, the symptoms clinically reveal the linkages between the balance-processing parts of the brain, and cognition and memory—linkages only now being described through experiments and functional brain imaging.

Over 90% of my sample of affected people, both adults and children, had cognitive difficulties during wind turbine exposure—problems that lingered and resolved slowly after exposure ended. These included difficulties with reading, math, spelling, writing, multitasking in kitchen and home, remembering a series of errands, maintaining a train of thought in a telephone conversation, following the plot of a TV show, following recipes, and following directions to put together furniture.

Balance-disordered patients in clinical practice also struggle with short-term memory, concentration, multitasking, arithmetic, and reading. Patients with inner ear fluid leakages, for example, present with symptoms of dizziness, headache, stiff neck, and disturbed sleep, accompanied by marked mental performance deficits compared to baseline.[18]

This kind of inner ear leakage can be set off by whiplash injuries, mild head trauma, or pressure trauma to the ear. The fluid leak is associated with an imbalance of fluid pressures in the inner ear, known as endolymphatic hydrops, which distorts both balance and hearing. (Ménière's disease, in which balance and hearing disturbances fluctuate, is endolymphatic hydrops that comes and goes for unknown reasons.)

Tellingly, Dr. Alec Salt, who will speak next on infrasound effects on the inner ear, has discovered experimentally that infrasound exposure causes temporary endolymphatic hydrops.[19] This is a possible mechanism for the balance disturbances, tinnitus, headache, and cognitive problems of Wind Turbine Syndrome.

The balance system is closely linked to emotions, especially fear, anxiety, and panic

So far, I have talked about how the absence or distortion of *hearing signals* from the inner ear affects thinking and learning at the brain level, and how distortion of *balance signals* from the inner ear affects thinking, memory, and concentration at the brain level. There is one more subject in this cluster of sensory/brain-function linkages, which I would like to discuss.

The balance system is closely linked to emotions, especially fear, anxiety, and panic. When my foot slides on ice under some new snow and I fling my arms out to regain balance, I have a moment of panic. My husband has fear of heights for reasons directly attributable to his brain's style of balance signal integration. I don't, and love to sit on the edge of cliffs over the ocean, watching seabirds.

When he sees me doing this, or if he gets near the edge himself or goes to the top of a tall building, he feels dizzy and nauseated (which are direct balance problem symptoms) and also panicked and irrational—afraid that he or I might fall or even jump off.

(I didn't have a full sense of this until recently, he's so controlled and calm, but now I understand why he doesn't want to take me back to Newfoundland—where there are huge, wonderful seabird cliffs...)

In some studies of balance-anxiety linkages, up to 80% of people with panic disorder have measurable disorders of balance processing. The places where people panic are those in which they "lose their bearings," so to speak, due to distortion of balance signals and their own brains' particular style of dealing with distorted balance signals. Grocery stores have been always a big culprit.

In my wind turbine study, 2/3 of the adult subjects (14 out of 21) experienced a highly disturbing collection of symptoms when exposed to high levels of turbine noise. They felt movement inside their chests, described as quivering, jitteriness, or pulsation, and then an uncomfortable urge to flee—to get out of there. Or, if the feeling awoke them at night, panic, with racing heart, a feeling they could not breathe, or the sense that there just had been an alarming noise—like a window breaking—and that they had to get up to check the house.

Wind Turbine Syndrome panic symptoms linked to previous history of motion sensitivity

None of these people had had panic attacks in their lives before. Several had histories of anxiety or depression, but altogether, among all the adults in the study, a previous mental health problem was not significantly associated with the presence of this panic symptom. What was associated with the panic symptom, with a highly significant statistical relationship, was a previous history of motion sensitivity.

Even a tough cowboy from Missouri, a welder who raises horses, had this symptom awakening him at night near turbines. Once he and his family moved into town, he slept like a baby. No more panic awakening. (It was his wife who had to tell me about it, however.) Even the physician in my study had this symptom. Toddlers and preschool children in my study had a similar symptom—awakening in the night in states of high alarm and unable to go back to bed or to sleep.

In short, noise impinging on the ear is not just about hearing, we are learning, but also about how the brain organizes itself around sound.

Summary

- Wind turbine noise causes tinnitus in many exposed people. Tinnitus at the physiologic level is the result of a change in sound processing by the brain.
- Other types of environmental noise have been shown to impair children's learning by changing how they process language sounds. Families exposed to wind turbines noticed deterioration in their children's thinking and learning abilities during exposure. Adults also had problems with thinking, memory, and concentration during exposure.
- Other clinical and brain studies have shown that diminished thinking and performance are tied to malfunctioning of the vestibular portion of the inner ear.
- Distorted balance signaling has a close connection with panic and anxiety in a variety of situations, a linkage that may explain how panic in the night crops up in previously non-panicked but motion-sensitive people exposed to wind turbines.

Alec Salt, PhD, demolishes A-weighting noise measurements, while demonstrating that the ear has a physiological response to low frequency noise at the intensities produced by wind turbines

Professor Alec Salt is a cochlear physiologist, a laboratory scientist in the Department of Otolaryngology at the Washington University School of Medicine in St. Louis. He and his students study the fluids and physiology of the cochlea (the hearing part of the inner ear) in guinea pigs.

For years, Salt and his colleagues have used infrasound to change the way parts of the cochlea behave—not because they were interested in infrasound, but because it has physiologic effects which are useful in their studies of cochlear fluids and cells.

In the last year or so, Dr. Salt documented that the two types of sensory cells in the cochlea, the inner and outer hair cells, react differently to infrasound. The inner hair cells, which are the ones that send hearing signals to the brain, do not respond to infrasound, but the outer hair cells do.

Infrasound, he discovered, makes the outer hair cells move in such a way that they prevent the inner hair cells from responding. The outer hair cells also send neural signals to the brain and to other outer hair cells, but it is not clear what these signals do once they reach the brain. One thing we do know is that they don't convey sound stimuli, themselves. Some evidence suggests they may play a role in mediating the perception of loud sounds in the cochlear nucleus, the first relay point for sound impulses in the brain.[20,21]

What's significant for Wind Turbine Syndrome is Dr. Salt's discovery that the cochlea does indeed respond to infrasound, and sends signals to the brain in response to infrasound, but the anatomy and cellular responses of the outer hair cells actively prevent us from hearing the infrasound.

Wondering whether these findings had any significance to people and their diseases, Dr. Salt searched the medical literature last winter and came across Wind Turbine Syndrome. He subsequently published a research article linking his findings to the symptoms or clinical manifestations of Wind Turbine Syndrome.[22]

It's worth emphasizing that Professor Salt is an outstanding educator, as is clear from his website. There is a lot to be learned here about the inner ear, complete with moving, colored, 3-D simulations.

His recent research article is posted here, with a user-friendly discussion of its significance. There is also a link to the website of the National Institutes of Health, where his research is featured. He has also posted the slides from his presentation at the Picton conference on October 30.

In his presentation, Dr. Salt compared measured wind turbine sound spectra, not only to the human hearing response curve (as the wind industry consultants do), but also to the separate response curves of the inner and outer hair cells, showing that wind turbine low-frequency noise and infrasound are easily detectable by the normal cochlea. He also demonstrates how A-weighted sound level measurements specifically exclude the low frequencies significant in wind turbine health effects, effectively demolishing the credibility of A-weighted noise measurements.

Dr. Salt's research is exciting and useful because it pointedly disproves the wind industry's assertion that the infrasound produced by wind turbines is not relevant to human health because it is, they claim, below the hearing threshold of most people. On the contrary, the ear has a physiological response to low frequency noise at the intensities produced by wind turbines, even when this noise cannot be heard.

A physiologic response opens the door, of course, to clinical effects.

With regard to the mechanism of Wind Turbine Syndrome, we are now in the interesting position of having, on the one hand, a demonstrated cochlear response to infrasound without a known brain response. On the other hand, if we consider the vestibular (balance) organs in the inner ear (which share physiology and fluid connections with the cochlea), we know a lot about brain responses. There is a large scientific literature on what the brain does with normal or distorted vestibular signals with regard to sensations, symptoms, brain cell pathways, and functional and experimental problems.[23]

We also know that the symptom complex of Wind Turbine Syndrome is very similar to the symptoms of vestibular dysfunction.

What is lacking is direct evidence for air-borne infrasound stimulating the hair cells of the vestibular organs. Dr. Salt told us in his conference talk that the vestibular hair cells are "tuned" (meaning, have their best response) to body-borne vibrations at infrasonic frequencies, but that no one has yet looked at the responses of these cells to "acoustic" (meaning, air-borne) infrasound coming in through the outer and middle ear.

"Jumping mice": Mammalian balance organs detect air-borne low-frequency sound using their otolith organs (saccule & utricle)

I suspect it's only a matter of time—and short time, at that—before some research group shows air-borne infrasound stimulating the vestibular hair cells, or shows a human vestibular response to air-borne infrasound. I base my prediction in part on a new article Dr. Salt sent to me immediately after the conference, titled, "The vestibular system mediates sensation of low-frequency sounds in mice."[24] In it, the authors explain how the "ancestral acoustic sensitivity" of the saccule has been retained not only in fish and amphibians, but also, according to recent evidence, in birds and mammals.

The authors demonstrate how mouse otolith organs respond to air-borne, low-frequency sounds below the detection range of the mouse cochlea.

Mice jump when startled by a beep. They startle more, with a more vigorous jump, in the presence of a low- or mid-frequency background sound. The authors measured this "startle response"—how much the mice jumped—quantitatively on little electronic platforms. Genetically normal mice jump more in response to either low- or mid-frequency background sound, but the authors also tested mice which, for genetic reasons, never developed the otoconia (little stones) in their otolith organs (utricle & saccule). Significantly, these otolith-deficient mice did the extra-large jumps only when the background sound stimulus fell within the frequency range of the mouse cochlea. They didn't detect the low-frequency background sound stimuli the way the mice with functioning otolith organs did.

Jumping mice. The authors of this study have demonstrated that mammalian ears, using their otolith organs of balance and motion detection, detect air-borne low-frequency sound at frequencies too low to be heard by their cochleas. This makes them startle more. Now consider "jumping people"—startled right out of bed in the middle of the night in the presence of sub-audible, low-frequency noise, or infrasound, from wind turbines.

Evidence like this suggests the following mechanism for Wind Turbine Syndrome: air-borne or body-borne low-frequency sound directly stimulates the inner ear, with physiologic responses of both cochlea and otolith organs.

Physiologic responses in the cochlea suppress the hearing response to low-frequency sound but still send some signals to the brain, signals whose function is, at present, mostly unknown. The physiologic response of the cochlea to turbine noise is also a trigger for tinnitus and the brain-cell-level reorganization that tinnitus represents—reorganization that can have an impact on language processing and the learning processes related to language processing. Physiologic responses and signals from the otolith organs tie into a wide range of known brain responses to vestibular signals, including dizziness and nausea (seasickness without the movement), fear and alerting (startle, wakefulness), and difficulties with visually-based problem-solving.

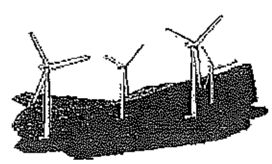
Christopher Hanning, MD, and sleep arousal

The interaction between sleep and these ear-brain mechanisms is interesting. Wind turbines create a particularly disturbing kind of noise with high alert potential, Dr. Chris Hanning, a sleep specialist, explained at the conference.

Our sleep is disturbed not only when we wake up completely, but also by subclinical arousals—in which the body and brain move into a lighter phase of sleep without waking all the way up. This type of disturbance requires even less noise than full awakening, but still disrupts sleep and its restorative properties for mood, memory, thinking, alertness, and coordination.

People vary in how deeply they sleep, and how resistant they are to awakening or arousal by noise. We can reliably measure how much people are disturbed during sleep using questionnaires about their daytime functioning.

Rick James, Noise Control Engineer: Sick Building Syndrome



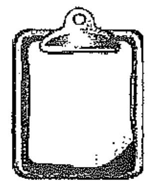
Turning to noise studies around wind turbines, noise control engineer Rick James presented sound monitoring data showing the disturbing, high-alert qualities of wind turbine noise: high levels of low frequency noise and infrasound, and the pulsating quality of the low frequency noise and infrasound. Both the audible noise and the infrasound from turbines are subject to "amplitude modulation" (meaning, the loudness goes up and down)—a quality that adds markedly to its disturbing character.

The arrangement and spacing of turbines in clusters also affects how much noise they make, because a second turbine, beating in the downwind turbulence of the first turbine, makes more noise.

Mr. James reviewed research from the 1980's and '90's on illness in office workers, induced by low-frequency noise from mal-aligned fans or vibrating ducts in the heating, ventilation, and air conditioning systems of large buildings. Research on these specialized cases of "Sick Building Syndrome" focused on the detrimental effects of low frequency noise on work productivity, and included experimental assessment of low frequency noise effects on concentration and mood.[25]

A word of caution, however. The term "Sick Building Syndrome" is associated most commonly with problems of indoor air quality (including particulates, allergens, infectious particles, solvent odor, and the amount of fresh air), and the syndrome includes irritation of the skin, eyes, and respiratory tract, as well as fatigue, headache, poor concentration, nausea, and dizziness.[26] The latter symptoms are commonly associated with low frequency noise exposure in other contexts, whereas skin and mucous membrane irritation are not.

In other words, although Wind Turbine Syndrome shares the noise-related aspects of Sick Building Syndrome, the two terms are not the same.

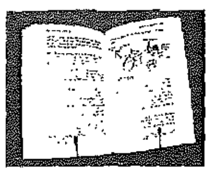


MICHAEL NISSENBAUM, MD, REPORTS THAT SURVEYED SUBJECTS UP TO 3 MILES FROM TURBINES SHOWED EFFECTS ON SLEEP AND MOOD THAT VARIED DIRECTLY WITH DISTANCE FROM THE TURBINES

Finally, Dr. Michael Nissenbaum, a Maine physician, presented results of a study of 79 adults living up to three miles from wind turbines in Maine, who completed (what are clinically called) validated questionnaires on sleep disturbance and general physical and mental well-being, divided into study and control groups based on distance from turbines.

Dr. Nissenbaum found differences between the study and control groups in several sleep quality indices, and in the mental health component of the general questionnaire. Even more remarkable, when he pooled the data from study and control groups, he found a dose-response relationship out to about 5 km (3 miles) from turbines. Subjects up to 3 miles from turbines, whether they were initially considered to be in the study or control groups, showed effects on sleep and mood that varied directly with distance from the turbines, Dr. Nissenbaum reported.

This is a valuable study. The surveys required information only about the subjects' current state of sleep and well-being, without reference to the turbines. The impact of turbine noise is apparently seen much farther away than the 1.5-2 km minimum setback proposed by many researchers (including me), although there was a drop-off in symptoms beyond 1.4 km. The questionnaires did not sample the full range of Wind Turbine Syndrome symptoms, but provide a standardized and quantified measure of one important symptom—sleep disturbance—and of general medical and mental health in relation to turbines.

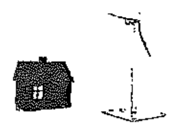


The "Humanness" of Wind Turbine Syndrome

Such is the state of Wind Turbine Syndrome research a year after I published "Wind Turbine Syndrome: A Report on a Natural Experiment." As I said earlier, we have made substantial progress in figuring out the mechanism and other parameters of this industrial plague.

It's worth pointing out that, with one notable exception, none of this was done with government or industry or foundation support —either financial or moral support. Just the opposite, governments (at all levels) and the wind energy industry have actively tried to thwart this research. But—this pleases me immensely—it was accomplished despite their opposition.

The exception being the National Institutes of Health, which funded Dr. Salt's research. All praise to the NIH!



A final word. For me, it was both sobering and energizing to talk, again, with victims of Wind Turbine Syndrome at the conference. At times, distracted by political and journalistic "noise," I forget how serious WTS actually is.

Separately, a man and a woman from different countries told me quietly of their thoughts of committing suicide. Both are older with good marriages and productive lives and adequate resources. One has been driven from her home by relentless nausea and vomiting, and the other is made ill whenever he returns home.

While governments, the wind industry and its scientific and clinical hirelings, and the media continue to belittle and deny the experience of these individuals—Lord knows, the media is filled with denial, ridicule, and venom (Google "Wind Turbine Syndrome")—I am reminded, once more, that the physical, mental, social, and financial consequences of this perfectly correctible condition are appalling.

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Attachment

CANADA
PROVINCE OF SASKTCHEWAN

Q.B. No.______ of A.D. 2010

IN THE COURT OF QUEEN'S BENCH
JUDICIAL CENTRE OF SASKATOON

BETWEEN:

DAVID McKINNON

PLAINTIFF

AND:

RED LILY WIND POWER LIMITED PARTNERSHIP,
a limited partnership by its General Partner
RED LILY ENERGY CORP.,
THE RURAL MUNICIPALITY OF MARTIN NO. 122
and
THE RURAL MUNICIPALITY OF MOOSOMIN NO. 121

DEFENDANTS

AFFIDAVIT OF DR. MICHAEL M. NISSENBAUM, M.D.

I, DR. MICHAEL M. NISSENBAUM, M.D., of the City of Fort Kent, Maine, United States of America, MAKE OATH AND SAY AS THAT:

1. I am a from the University of Toronto Medical School with post-graduate training at McGill University and the University of California.

2. 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.

3. I developed an interest in the health effects of wind turbine projects after becoming aware of complaints related to an industrial wind turbine installation in Mars Hill, Maine, and subsequently investigating the widespread and serious health effects suffered by most of the residents of Mars Hill, who live in proximity (within 1100 meters) to a linear arrangement of twenty-eight 1.5 MW wind turbines.

4. I have recently conducted a study of the health effects of persons living within 1100 meters of the Mars Hill Wind Turbine Project in Aroostook County, Maine, which consists of 28 wind turbines. Each turbine is 389 feet tall, from base to blade tip. This study is important because it represents the first controlled study of adverse health effects attributed to industrial wind turbines.

5. As part of the study, 22 of an estimated 30 adults living in the affected area were interviewed. Subjects interviewed included 10 females, ranging in age from 18 – 73, and 12 males, ranging in age from 43 – 79. The CONTROL group comprised of 27 individuals, 12 female and 13 male, age ranges and averages comparable to the subjects. The control group lived on average 5000 meters away from the turbine installation. A true copy of the map of the study area is attached to this, my Affidavit, and marked as Exhibit "B".

6. Of the 22 subjects I interviewed, 18 of them (82%), reported a new onset or worsened sleep disturbance since the Mars Hill Wind Turbine Project went online in December 2006. 17 of those interviewed (77%) reported their sleep disturbance problems included waking up in the middle of the night, while 10 (45%) reported

difficulty falling asleep. There were 5 new prescription medications for chronic sleep disturbance in this group of 22 subjects. In the CONTROL group, only 1 individual (4%) reported a new or worsened sleep disturbance in the same time period since the turbines went online. There were no new prescriptions for sleep disturbance in the CONTROL group.

7. Of the 22 subjects I interviewed, 9 of them (41%) reported increased headaches since the Mars Hills Wind Turbine Project went online in December 2006, with 7 of them (32%) reporting a new onset of headaches and 2 of them (9%) reporting increased migraine frequency. There were three new prescriptions for headache mediation in this group. The CONTROL group had 1 individual (4%) with a worsened headache problem in this same time period.

8. Of the 22 subjects I interviewed, 3 of them (14%) reported new or worsened problems with dizziness since the Mars Hills Wind Turbine Project went online in December 2006, 3 (14%) reported tinnitus, 3 (14%) reported a new problem with ear pulsation sensations, and 1 (5%) reported periodic ear pain. There were no auditory or vestibular complaints in the CONTROL group.

9. Of the 22 subjects I interviewed, 7 of them (32%) reported they have been troubled by shadow flicker since the Mars Hills Wind Turbine Project went online in December 2006, with 2 (9%)of those reporting nausea, and 4 (18%) reported dizziness. 1 (5%) reported triggering migraine headaches by shadow flicker, and 2 (9%) reported a

feeling of unease created by shadow flicker. There were no complaints related to shadow flicker in the CONTROL group.

10. Of the 22 subjects I interviewed, 8 of them (36%) reported they have experienced unintentional weight changes since the Mars Hills Wind Turbine Project went online in December 2006, with 6 of those reporting weight gain and 1 reporting weight loss. In the CONTROL group, there was 1 person (4%) who experienced unintentional weight change in that period.

11. Many of those affected by the Mars Hill Wind Turbine Project also reported new or worsened psychiatric symptomatology, including feelings of "stress" (13 people or 59%), "anger" (17 people or 77%), "anxiety" (7 people or 32%), "irritability" (6 people or 27%), "hopelessness" (12 people or 55%), and "depression" (10 people or 45%). Of those 8 persons who reported experiencing feelings of "depression," all of those reported that such feelings are new since the Mars Hills Wind Turbine project went online in December 2006. There were 4 new or increased prescriptions for psychiatric medication in the subject group. The control group reported no new or increased psychiatric complaints.

12. In reporting feelings of "anger," a 67 year old woman described it as, "Absolute rage – you feel you want to kill someone, and don't know who to kill." A 65 year old man described it as, "So angry I could kill." And a 65 year old woman described it as, "Makes my blood boil."

13. In reporting feelings of "hopelessness," several of those affected by the Mars Hill Wind Turbine Project described those feelings, making the following comments:

a) "Nobody will help us."

b) "No options – can't leave, and can't live here."

c) "This is an awful thing to have happen to you."

d) "People don't believe us – (our complaints) fall on deaf ears."

e) "No one cares. No one listens."

f) "They just tread on us."

g) "It's very hard watching my child suffer."

14. Those I interviewed reported a total of 15 new and increased prescriptions for various health ailments since the Mars Hills Wind Turbine Project went online in December 2006. The CONTROL group reported 4 new or increased prescriptions in that time period.

15. 21 out of the 22 people in the subject group (95%) reported that their quality of life has been negatively affected by the Mars Hill Wind Turbine Project. Comments made by those persons when reporting that their lives have been affected include the following:

a) "Loss of joy in living ... put a lot of life's plans on hold."

b) "No desire to go outside."

c) "Feel trapped."

d) "Dreams have been dashed."

d) "Was our dream home … it's all been stolen from us."

f) "We have no peace and quiet."

g) "My husband's (who has advanced MS) only pleasure in life was to see the wild animals. They are gone."

h) "No sleep."

i) "Sinking feeling every night when I (come home) and see them."

j) "I used to be able to hear it snow, before. Now, I do not look forward to going home."

There were no perceptions of reduced quality of life in the CONTROL group.

16. One hundred percent of the persons I interviewed reported they had considered moving away. None of the CONTROL group admitted to considering moving away during that time period.

17. It is my professional opinion that there is a high probability of significant adverse health effects for those whose residence is located within 1100 meters of a 1.5 MW turbine installation based upon the experiences of the subject group of individuals living in Mars Hill, Maine. It is my professional opinion, based on the basic medical principle of having the exposure to a substance proven noxious at a given dose before risking an additional exposure, that significant risk of adverse health effects are likely to occur in a significant subset of people out to at least 2000 meters away from an industrial wind turbine installation. These health concerns include:

a) Sleep disturbances/sleep deprivation and the multiple illnesses that cascade from chronic sleep disturbance. These include cardiovascular diseases mediated by chronically increased levels of stress hormones, weight changed, and metabolic disturbances including the continuum of impaired glucose tolerance up to diabetes.

b) Psychological stresses which can result in additional effects including cardiovascular disease, chronic depression, anger, and other psychiatric symptomatology.

c) Increased headaches.

d) Unintentional adverse changes in weight.

e) Auditory and vestibular system disturbances.

i) Increased requirement for and use of prescription medication.

18. I have been provided with a copy of the Red Lily Wind Energy Project Environmental Assessment prepared by Tetres Consultants Inc. dated November 2008 ("Environmental Assessment"), a copy of which I believe has been filed with the Court. My review of the Environmental Assessment indicates that the proposed wind turbines to be constructed will be 1.5 to 2.5 megawatts. The wind turbines constructed in Mars Hill, Main were 1.5 megawatts.

19. In reviewing the Environmental Assessment, there is no definitive setback established with respect to the minimum distance from each resident's home a turbine could be built. The only reference I found in the Environmental Assessment, with respect to the minimum setback distance, is for the wind turbines from each resident's home is approximately "400m (varying from 300m to 600m, depending on site - specific characteristics)". This reference can be found at Page 79 of the Environmental Assessment.

20. Moreover, I have been advised by the Plaintiff and verily believe the same to be true that neither the Rural Municipality of Moosomin nor the Rural Municipality of

Martin have imposed any minimum setbacks with respect to how close a turbine can be constructed to a resident's home.

21. Attached and marked as Exhibit "C" to this, my Affidavit is a map titled Red Lily Wind Energy Partnership, Distance from Turbines to Residences. This map indicates the distance of the proposed initial 16 turbines to 21 residences in the proposed project boundary. As can be seen on this map, all of the residences with the exception of number 5 fall within 2000 meters of where at least one turbine will be located. Moreover, 12 of the 21 residences will have a wind turbine constructed less than 1200 meters from their residence. With respect to the issue of the proposed setbacks, it is important to note that while the initial proposal is for the construction of 16 turbines, the literature attached to the Environmental Assessment, Attachment B, Page 5A, shows that up to an additional 14 wind turbines, for a total of 30 wind turbines will be constructed in this area.

22. In addition to my controlled research with respect to the Mars Hill linear wind turbine project, there has been research in Ontario conducted by Dr. Robert McMurtry and Carmen Krogh with respect to the health risks associated with industrial wind turbine installations. The research conducted by Dr. Robert McMurtry and Carmen Krogh consists of a questionnaire completed by 109 people in Ontario and 9 people from other jurisdictions. It is my understanding that the questionnaire was distributed by word of mouth under a protocol and is uncontrolled, which means that there is no control group against in which to measure these results. Attached and marked as Exhibit "C", to this, my Affidavit, is a true copy of the results of Dr. McMurty and Carmen Krogh's survey.

The results of the survey provide additional confirmation of the types of symptoms that occur among effected people.

23. The Environmental Assessment at Page 79 states, "setback distances to residences and other receptors of about 400m (varying from 300m to 600m, depending on site - specific characteristics) have demonstrated to be generally adequate to reduce the nature and frequency of audible noise emissions to levels within acceptable nuisance thresholds". I strongly disagree with this statement. The authors of the Environmental Assessment, not being medical doctors, did not describe the health significance or severity of the "nuisance" in medical terms. A review of the controlled Mars Hill, Maine findings and the uncontrolled findings of Dr. McMurtry and Carmen Krogh, however, indicates that this "nuisance", is one of the root causes of sleep disturbance and secondary negative health effects suffered by the residents of Mars Hill, Maine.

24. The first slide in Exhibit "F", are additional graphs created by Richard James, which indicate why the measurements taken.demonstrates the fact that there is a statistical standard deviation for each point on a standard 'equal loudness contour graph'. That is to say, the point on the graph represents only an average, with half of the human population being more sensitive, and half less sensitive, to a noise at any given frequency and decibel level combination. An equal loudness contour is a line that maps out a person's perception of a certain degree of loudness by frequency. The standardized equal loudness contour graphs, such as seen in subsequent graphs of appendix 5, represent the cumulative results for a population of test subjects, averaged out. The first graph reminds us that each point on the lines that make up the graphs are in fact average values, with a

normal statistical distribution, whose standard deviation is 6 decibels. This means that one person in 6 or 7 is 4 times as sensitive to a sound as the average person. Moreover, at Page 79 of the Environmental Assessment it is stated that, "there will be inaudible noise and infrasound effects". However, it would appear that the Environmental Assessment attempts to minimize the seriousness of this issue. It is again important to point out that the authors of the Environmental Assessment are not physicians. To my knowledge, there has been no medical refutation of the potential negative health effects of infrasound emitted by wind turbines and the subject is at least an open medical issue of concern, warranting immediate investigation prior to the construction of this project. New investigations performed with state of the art equipment, which has temporal, sound level, and frequency resolution of a much higher degree compared to equipment that is currently and conventionally used to monitor wind turbine sound (and provide the basis for preconstruction sound modeling), indicated that sound levels at low frequencies occur at sufficient decibel levels to be heard by a significant proportion of normal individuals.

25. The second slide of Exhibit "F" is a standard equal loudness contour graph (ISO 2003) which has been taken from the recent American and Canadian Wind Energy Association White paper published in late 2009. The source is not important. It is a standard, accepted graph used by industry, engineers, acousticians and the like. The important point this slide makes is that the sounds that the tests subjects (who were recruited to create this graph) heard we 'pure tones', that is to say, sinusoidal wave forms that were uniform, neither frequency nor amplitude modulated, and free of randomness. These types of tines are less intrusive that more complex tones, and hence are perceived as less loud at any given decibel level compared to complex tones. In the case of a pure

tone at 20 HZ, the blue arrow shows us that the average person will begin to hear it at 79 decibels sound pressure level.

26. The third slide of Exhibit "F" shows us that more complex sounds, in this case random noise with sound pressure level increasing and falling (amplitude modulation) in a temporally random pattern, will be perceived at a lower sound level (even if the peak level has a sound pressure no higher than an otherwise comparable pure tone). In the case of random noise with an average frequency of 20 HZ, it will be perceived at a sound pressure 10 decibels less than a pure tone 20 HZ sound by the average person: it will be perceived at 69 decibels (red arrow).

27. The fourth slide in Exhibit "F" slide demonstrates how, when the 6-decibel standard deviation is added, the threshold of hearing for a 20 HZ average complex tone for one in 6 or 7 people falls to 62 decibels. Given that turbine noise is not a pure tone, and is not random, but actually has a pulsatile, or periodic structure with a repeat rate of around once per second, the threshold of perception likely falls even father, as we are designed, as human beings, to automatically try and derive information from structured sounds as opposed to truly random sounds or pure tones).

28. If we understand the significance of the facts in Exhibit "F" and we revisit Exhibit "E", it becomes clear that the noise put out by a 1.5 MW turbine 1500 feet away contains components that will be readily audible, DIRECTLY, to a significant minority of people (greater than one in 6 or 7, or about 15% of the population).

29. Infrasound, if at a sufficient volume level, will cause windows, walls, and floors to vibrate, and so convert sound that would, on its own, be inaudible to the majority of people into sound that will be audible to most. Attached and marked as Exhibit "G" to this, my Affidavit, is a short segment removed from the spectral graph set out in Exhibit "E". The information on this spectral graph segment was plotted onto standard building science graph of the response of windows, walls and floors of common residential construction as a function of frequency and sound pressure level. For the frequencies plotted here in red dots, we see that they would be expected to result in audible noise, and we find an explanation for why many more people who live in proximity to turbines experience noise than we might expect based purely on the 15% or so of people who would be expected to directly hear very low frequency turbine noise. The homes are 'converting' direct turbine noise that would be inaudible to most, into noise that is in fact audible to most. The sound would be experienced as noise, and because of known effects, would be most pronounced at night, and so result in sleep disturbance and deprivation. If chronic (and wind turbine installations are by definition 'chronic'), this would result in consequent adverse health effects. There are additionally significant issues relating to audible low frequency noise of a persistent, pulsatile nature, such as created by wind turbines.

30. Attached and marked as Exhibit "H" to this, my Affidavit, is a standard ISO 2003 equal loudness contour graph that has the 'blade swish', or 'blade thump' typical of industrial wind turbines plotted on to it (red dot) at the frequency and decibel level measured at Ubly, Michigan, 1,500 ft (500 meters) from a 1.5MW GE industrial wind turbine by well known Acoustic Engineer Richard James, INCE, in December of

2009. This will be a noise audible to essentially everyone, at a loudness of about 45 phon, considered intrusive if unwanted, or containing disturbing noise characteristics, and enough to affect sleep levels, rousing some people from deeper levels of sleep into shallower, and fully waking others.

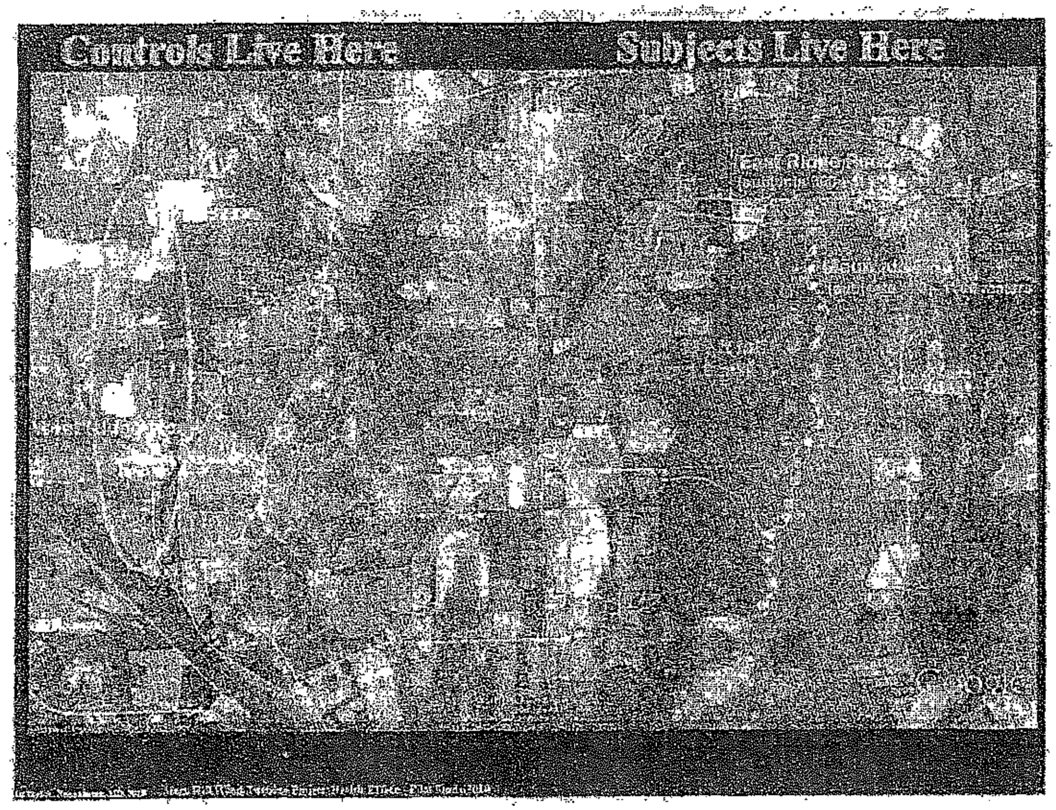
31. It is also important to consider the climate in Saskatchewan. In the winter, these wind turbines will be prone to icing which will increase the sound coming off the turbines by up to 6 dBA. As the icing occurs symmetrically on all blades, imbalance detectors do not kick on, and the blades keep turning, contrary to claims in the Environmental Assessment at Page 77.

32. I make this Affidavit on the basis of providing the Court with expert evidence with respect to the health risks associated with industrial wind turbine installations.

SWORN BEFORE ME at the City of Fort Kent in the State of Maine, this 11th day of August, A.D. 2010. A NOTARY PUBLIC in and for the State of Maine.	DR. MICHAEL A. NISSENBAUM, M.D.

Appendix 1

Study Map, Mars Hill, Maine



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THIS 11th DAY OF Aug A.D. 2010

Nadine Landry

A NOTARY PUBLIC IN AND FOR THE
State ~~PROVINCE~~ OF Maine
BEING A SOLICITOR - or -
MY APPOINTMENT EXPIRES 10-27-2011

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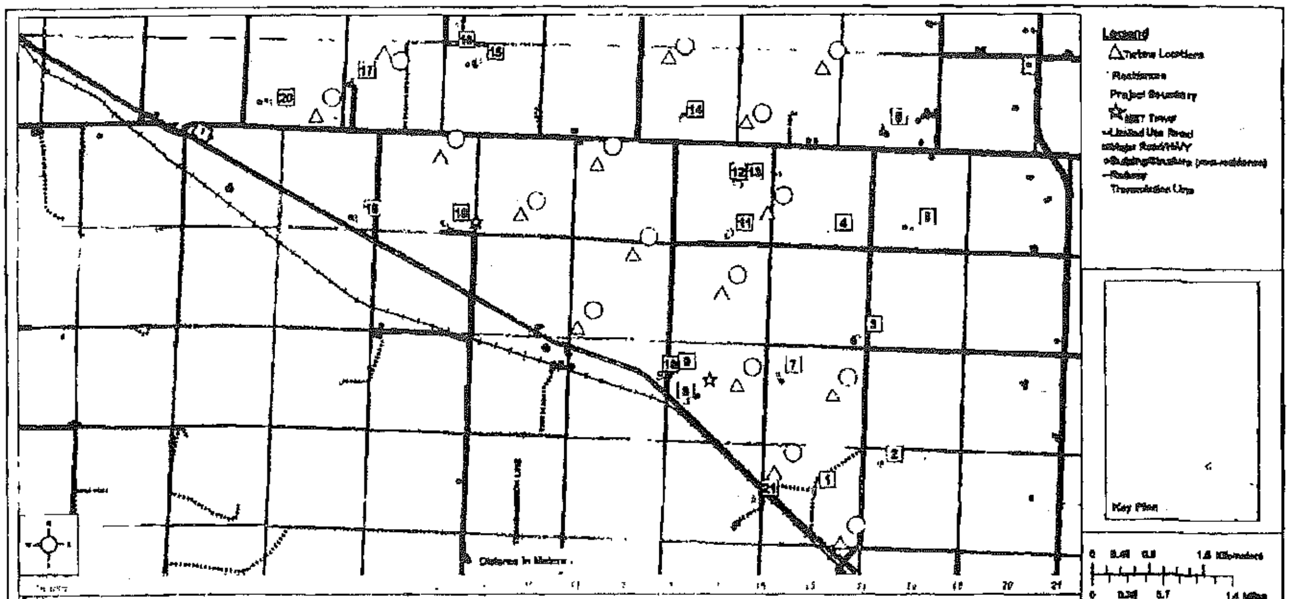

Turbine																				20	21
1	835	1,325	3,205	5,045	5,272	6,515	2,894	3,406	3,834	4,032	6,371	6,128	8,111	7,304	8,877	10,580	11,078	8,278	9,017	11,883	1,281
2	713	1,718	2,852	3,862	4,596	6,810	1,258	1,825	2,345	2,460	3,898	4,779	4,792	5,857	8,288	9,003	9,428	9,807	6,078	10,327	979
3	2,177	2,734	3,158	2,972	3,856	4,830	699	876	1,087	1,278	2,493	3,267	3,279	4,404	6,778	7,478	8,087	8,538	8,869	9,018	1,948
4	4,742	5,478	4,645	4,404	5,780	5,898	3,422	2,312	1,733	1,698	2,825	3,480	3,543	3,748	4,808	8,397	6,493	2,773	4,077	8,382	4,059
5	1,020	1,496	1,342	2,810	3,010	4,428	937	2,402	2,885	2,284	3,122	3,814	5,775	5,135	7,884	8,886	8,476	7,002	6,398	10,459	3,183
6	3,825	3,884	2,372	1,883	3,310	3,788	1,880	1,921	1,588	1,738	938	1,779	1,731	2,889	8,488	8,180	7,042	4,737	6,181	8,118	8,490
7	4,813	5,354	3,890	3,229	4,824	4,587	3,147	3,826	2,078	2,083	1,816	2,016	2,673	3,272	4,029	4,728	6,498	3,171	4,688	6,830	4,834
8	6,880	7,255	5,959	5,114	6,506	6,192	5,085	4,189	3,880	3,584	3,487	2,581	5,954	3,019	2,024	3,213	3,510	1,328	3,726	4,827	4,807
9	4,873	4,880	2,532	1,076	1,410	2,341	2,723	3,409	3,008	3,238	737	716	657	2,078	6,374	5,984	7,227	6,387	8,824	8,458	4,781
10	6,484	6,800	5,176	4,606	6,332	4,787	4,828	4,222	3,674	3,688	2,480	2,302	2,378	1,614	2,549	3,224	4,288	2,723	4,164	8,835	8,520
11	8,100	8,698	7,552	8,575	7,831	7,385	8,889	9,791	8,243	9,164	4,984	4,817	4,891	4,014	1,629	2,118	1,888	1,149	1,738	8,043	7,710
12	10,321	10,885	8,714	9,730	10,077	9,418	8,813	7,782	7,287	7,169	7,150	7,048	7,122	4,038	2,837	2,742	783	2,013	1,889	777	8,886
13	6,202	6,674	5,285	3,313	3,274	2,270	4,241	4,737	4,335	4,431	1,885	1,047	1,044	1,110	4,537	6,044	6,533	5,279	6,884	7,810	9,227
14	6,972	6,984	4,457	2,738	3,038	1,426	5,121	5,828	5,882	5,723	3,128	3,390	2,343	2,516	5,886	6,090	7,808	5,748	8,103	9,172	7,186
15	10,151	10,683	8,160	871	8,247	8,368	8,459	7,670	7,150	7,048	6,496	6,222	6,224	5,048	1,368	1,266	723	3,611	2,794	3,881	8,804
16	7,634	7,557	5,551	3,836	4,825	3,744	6,667	5,884	5,169	5,240	5,080	2,344	2,394	1,078	3,165	3,881	9,202	4,811	5,821	6,681	7,417

ALGONQUIN POWER

RED LILY WIND ENERGY PARTNERSHIP

Distance from Turbines to Residences

NAD83/UTM ZONE 13N	1:20,000
R HARROP	FEB 22 2010
420 - 128	0

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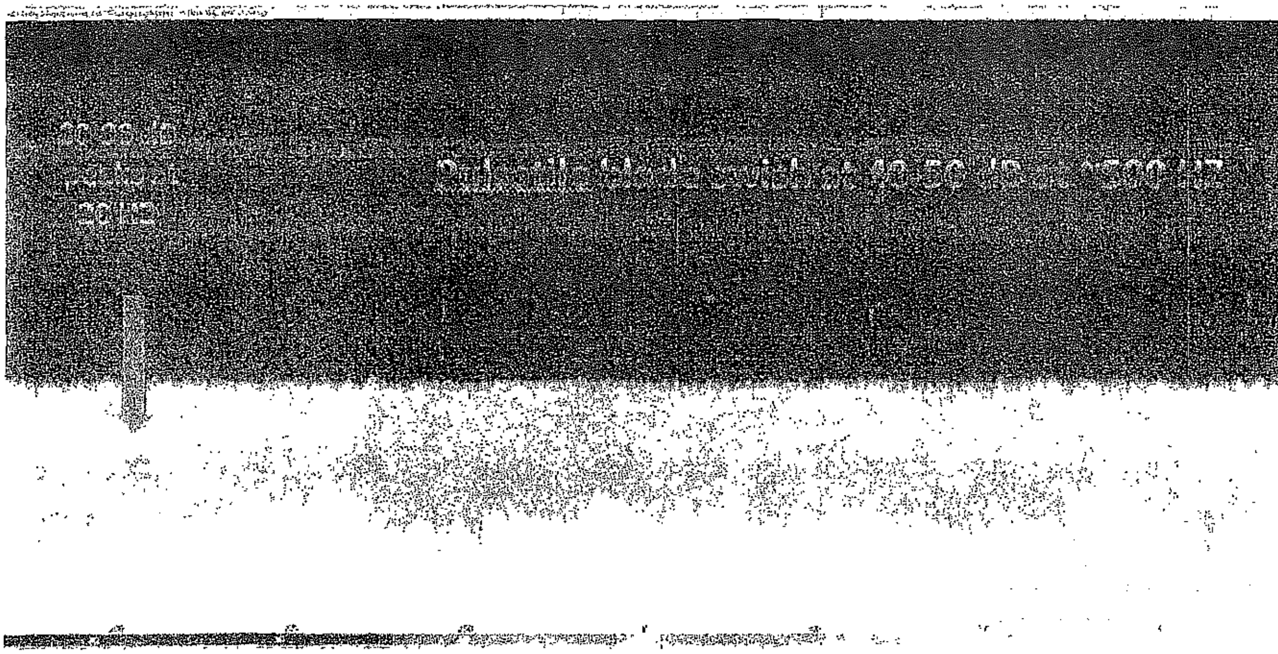
Outdoors 3 A.M.

Modern 1.5 MW GE turbine at 1500 feet, Ubly, MI, Dec. 2009



Courtesy Richard James, E-coustics Solutions

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There is a standard deviation of 6 dB around the 'average' point on the equal loudness contours. This means that one person in 7 is at least 4 times as sensitive to noise as the average person.

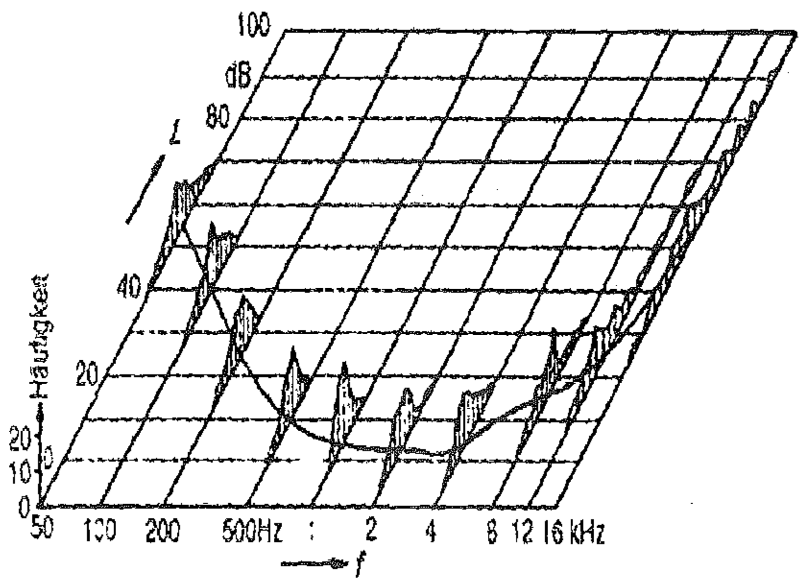
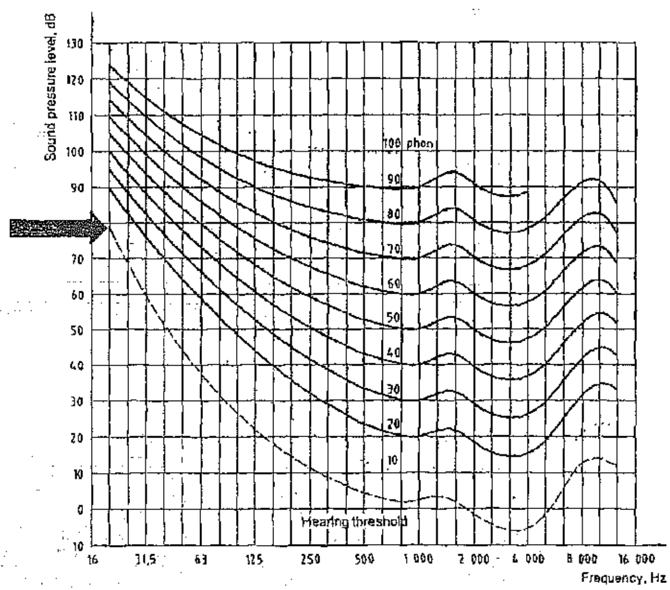


Fig. 9 Threshold in quiet. Also shown, distribution of thresholds [14]

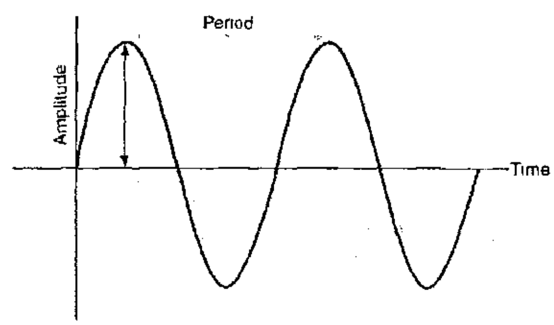
J. Spille, "Messung der Vor- und Nachverdecknung bei Impulsen unter kritischen Bedingungen," Intern.Rep., Thomson Consumer Electronics, Hanover, Germany (1992)

What Can We Actually Hear?

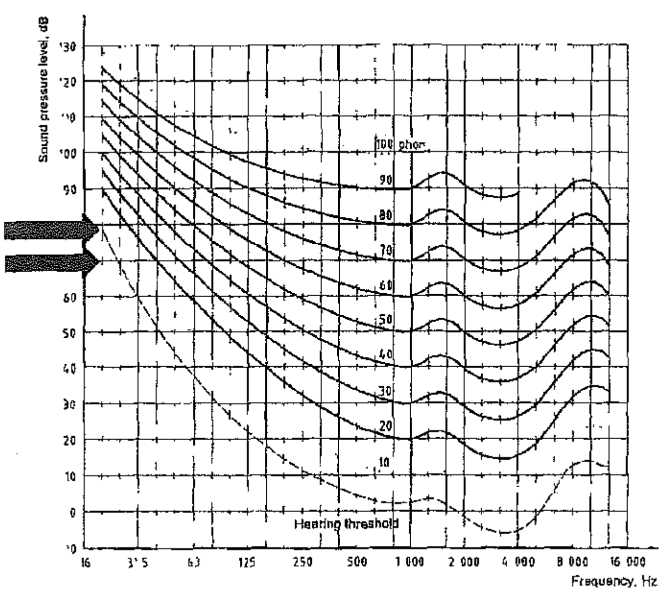


Hearing Contours for Equal Loudness Level (ISO 2003) from A/ConWEA 12/2009 'White Paper'

Traditional ***equal loudness contours*** were obtained by playing pure tone, sinusoidal wave forms.
20HZ discernable at 79dB

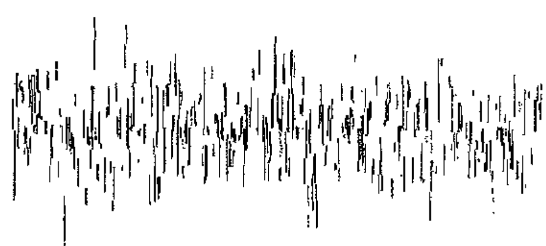


What Can We Actually Hear?



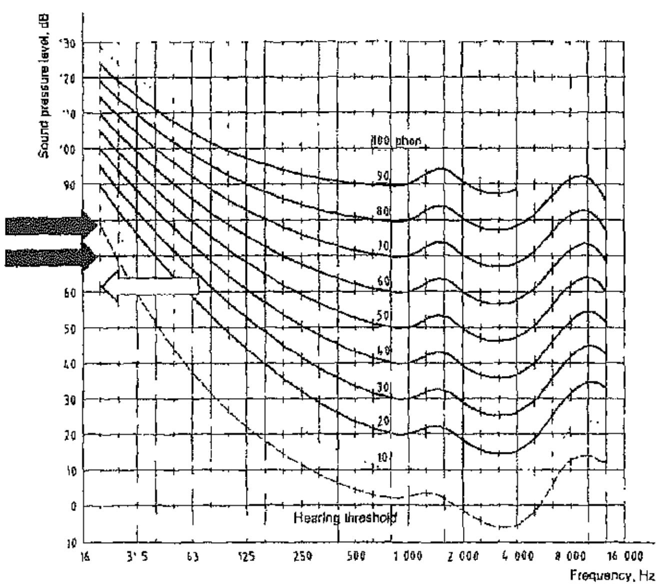
Hearing Contours for Equal Loudness Level (ISO 2003) from A/CanWEA 12/2009 'White Paper'

Random Noise is mixture of frequencies and amplitudes. It has a 'crest factor' which refers to the above average peaks. The hearing threshold drops by up to 10dB at 20HZ*



***Moller H & Pedersen C.S. Hearing at Low & Infrasonic Frequencies, Noise & Health, Volume 6, issue 23, April-June 2004**

What Can We Actually Hear?



Hearing Contours for Equal Loudness Level (ISO 2003) from A/CanWEA 12/2009 'White Paper'

The organized, pulsatile broadband turbine noise results in even greater reduction in the hearing threshold.

Also, 6 dB SD means 16% of us will have at least a further 6 dB increase in sensitivity at 20 HZ.

<u>This brings us to 62 dB or lower threshold for one in 6 people.</u>

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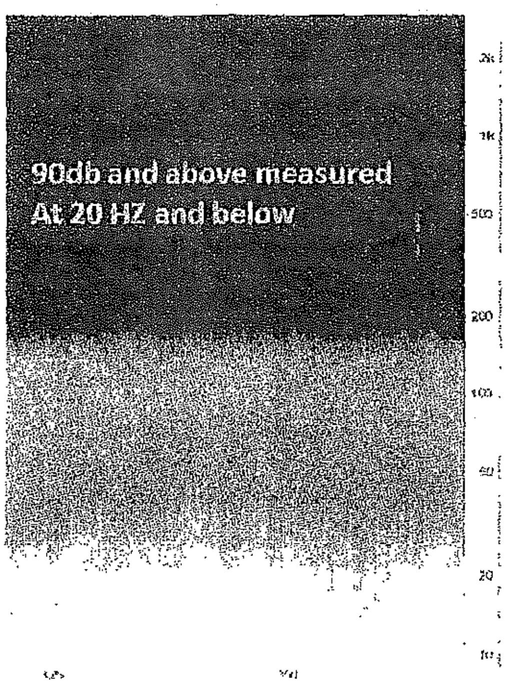
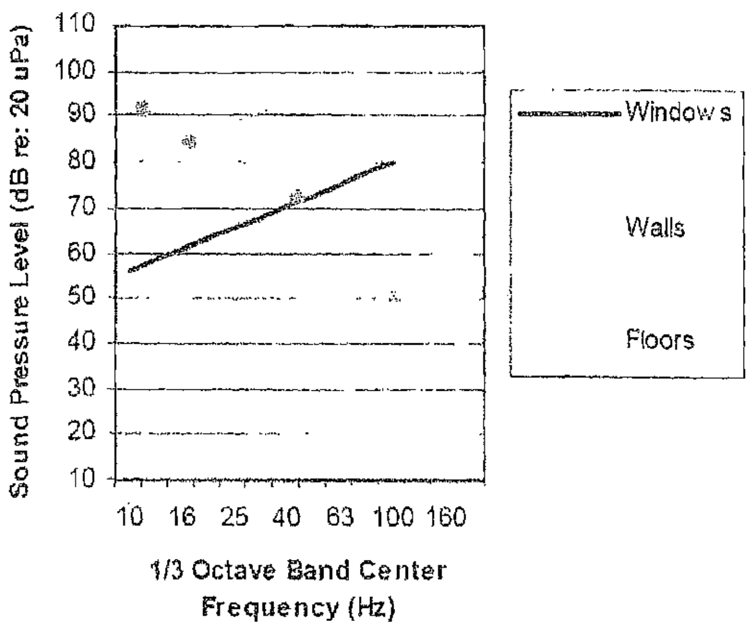
Dwelling Vibration and Rattle

Perceptible vibration in residential structures by low frequency noise

Outdoors 1500ft 1.5MW, Ubly Michigan, Dec 2009





Courtesy Richard James, INCE

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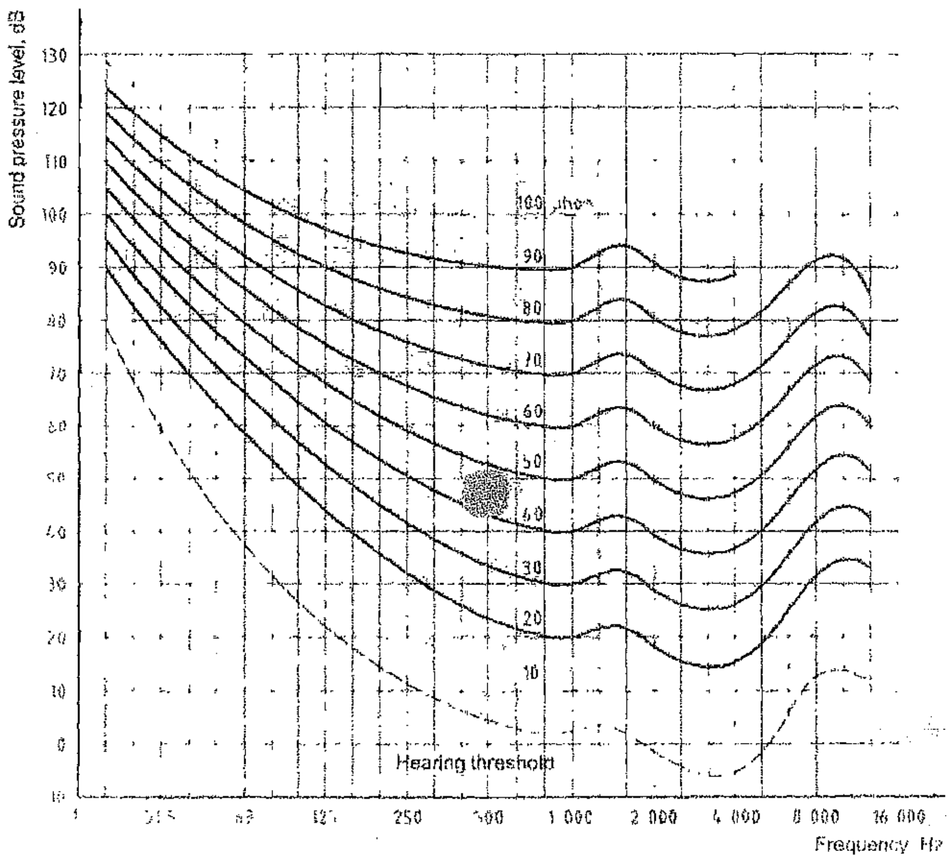
'Blade Swish'



Sound pressure level, dB
130
120
110
100
90
80
70
60
50
40
30
20
10
0
100 phon
90
80
70
60
50
40
30
20
10
Hearing threshold
250
500
1 000
2 000
4 000
8 000
16 000
Frequency Hz

A Review of Published Research on Low Frequency Noise and its Effects

Report for Defra by Dr Geoff Leventhall
Assisted by Dr Peter Pelmear and Dr Stephen Benton

May 2003

Contract ref:
EPG 1/2/50

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Contents

1. Preamble

Low frequency noise causes extreme distress to a number of people who are sensitive to its effects. Such sensitivity may be a result of heightened sensory response within the whole or part of the auditory range or may be acquired. The noise levels are often low, occurring in the region of the hearing threshold, where there are considerable individual differences. There is still much to be done to gain a fuller understanding of low level, low frequency noise, its effects, assessment and management. Survey papers of low frequency noise and its occurrence include (Backteman et al., 1983a; Backteman et al., 1983b; Backteman et al., 1984a; Backteman et al., 1984b; Berglund et al., 1996; Broner, 1978a; Hood and Leventhall, 1971).

Historically, early work on low frequency noise and its subjective effects was stimulated by the American space programme, a source of very high levels of low frequency noise. The launch vehicles produce their maximum noise energy in the low frequency region. Furthermore, as the vehicle accelerates, the crew compartment is subjected to boundary layer turbulence noise for about two minutes after lift-off. Experiments were carried out, in low frequency noise chambers, on short term subjective tolerance to bands of noise at very high levels of 140 to 150dB in the frequency range up to 100Hz It was concluded that the subjects, who were experienced in noise exposure and wearing ear protection, could tolerate both broadband and discrete frequency noise in the range 1Hz to 100Hz at sound pressure levels up to 150dB. Later work suggests that, for 24 hour exposure, levels of 120-130dB are tolerable below 20Hz. These limits were set to prevent direct physiological damage (Mohr et al., 1965; von Gierke and Nixon, 1976; Westin, 1975). It is not suggested that the exposure was pleasant, or even subjectively acceptable, for anybody except those who might have had a personal interest in the noise. The levels used in the experiments are considerably higher than the exposure levels of people in their homes, arising from environmental, traffic, industrial and other sources.

The early American work was published in the mid 1960's and created no great sensation, but a few years later infrasound entered upon its "mythological" phase, echoes of which still occur. Infrasound – the "silent sound" - was blamed for many misfortunes for which another explanation had not yet been found (e.g., brain tumours, cot deaths, road accidents). A selection of some press headlines from the early years is:

- *The Silent Sound Menaces Drivers - Daily Mirror, 19th October 1969*
- *Does Infrasound Make Drivers Drunk - New Scientist, 16th March 1972*
- *Brain Tumours 'caused by noise' - The Times, 29th September 1973*
- *Crowd Control by Light and Sound - The Guardian, 3rd October 1973*
- *Danger in Unheard Car Sounds - The Observer, 21st April 1974*
- *The Silent Killer All Around Us - Evening News, 25th May 1974*
- *Noise is the Invisible Danger - Care on the Road (ROSPA) August 1974*

Blatantly incorrect claims were made in the book 'Supernature' by Lyall Watson, first published in 1973 as 'A natural history of the supernatural' and which had large sales as a paperback. For example, it stated that, in an experiment with infrasonic generators, all the windows were broken within a half mile of the test site and further, that two infrasonic generators "focused on a point even five miles away produce a resonance that can knock a building down as effectively as a major earthquake".

Those who were investigating low frequency noise problems at this time were often asked "It's dangerous, isn't it?" Public concern over infrasound was one of the stimuli for a growth in complaints about low frequency noise during the 1970's and 1980's and may still have lingering effects.

However, infrasound has long been a respected area of study in meteorology, where the frequencies range from as low as one cycle in 1000 seconds up to a few cycles per second. Large arrays of infrasound microphones detect low frequencies originating in atmospheric effects, meteorites, supersonic aircraft, explosions etc. There is also a worldwide system of about 60 infrasound arrays, which are part of the monitoring for the Nuclear Test Ban Treaty.

It is a big step from the American endurance exposures and the exaggerated effects of infrasound to the very real low frequency noise difficulties faced in a number of environmental noise problems, where low frequency noise occurs at low levels, often in the region of an individual's hearing threshold. The noise, typically classed as "not a Statutory Nuisance", causes immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances.

The World Health Organization is one of the bodies which recognizes the special place of low frequency noise as an environmental problem. Its publication on Community Noise (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:

- *" It should be noted that low frequency noise, for example, from ventilation systems can disturb rest and sleep even at low sound levels"*
- *"For noise with a large proportion of low frequency sounds a still lower guideline* (than 30dBA) *is recommended"*
- *" When prominent low frequency components are present, noise measures based on A-weighting are inappropriate"*
- *"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"*
- *"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"*

This present study considers some properties of low frequency sounds, their perception, effects on people and the criteria which have been developed for assessment of their effects. Proposals are made for further research, to help to solve the continuing problems of low frequency environmental noise.

2. Introduction to the physics of low frequency noise

2.1 **Noise and sound.** Noise and sound are physically the same, differences arising in their acoustic quality as perceived by listeners. This leads to a definition of noise as undesired sound, whilst physically both noise and sound are similar acoustic waves, carried on oscillating particles in the air. Sound is detected by the ear in a mechanical process, which converts the sound waves to vibrations within the ear.

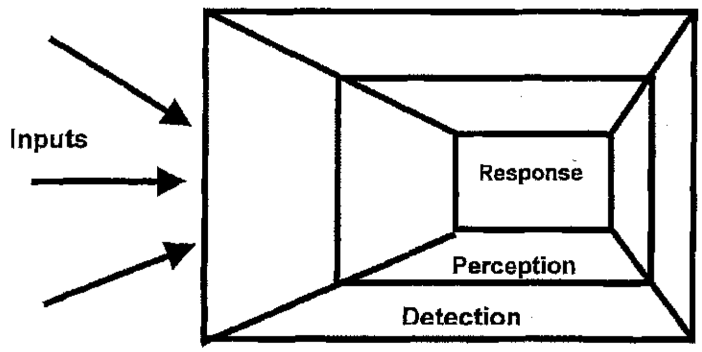


Figure 1. The response chain.

Figure 1 is a simplified diagram of the process, which leads to perception and response. Electrical signals, stimulated by the vibrations in the ear, are transmitted to the brain, in which perception occurs and the sensation of sound is developed. Response is the reaction to perception and is very variable between people, depending on many personal and situational factors, conditioned by both previous experiences and current expectations.

2.2 **Frequency and wavelength.** The frequency of a sound is the number of oscillations which occur per second (Hz), denoted, for example, as 100Hz. Sound travels in air at about $340ms^{-1}$, but this velocity varies slightly with temperature. Figure 2 represents sound waves generated by the oscillating strip at the left. As the strip oscillates, it alternately compresses the air, shown by light bands and expands the air, shown by dark bands.

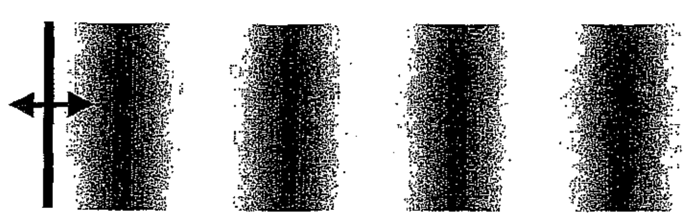


Figure 2. Sound waves.

Since each compression travels at about $340ms^{-1}$, after one second the first compression is 340m away from the source. If the frequency of oscillation is, say 10Hz, then there will be 10 compressions in the distance of 340m, which has been travelled in one second, or 34m between each compression. This distance is called the wavelength of the sound, leading to the relation:

velocity = wavelength x frequency, written in symbols as

$$c = \lambda f$$

where c is the velocity of sound, λ the wavelength and f the frequency. The equation gives the relation between frequency and wavelength as in Table 1.

Frequency Hz	1	10	25	50	100	150	200
Wavelength m	340	34	13.6	6.8	3.4	2.27	1.7

Table 1. Frequency and wavelengths of low frequency sound.

In the frequency region 25Hz to 150Hz, wavelengths are of similar size to room dimensions, which can lead to resonances in rooms, discussed in later sections.

2.3 **Noise character and quality.** Pleasant sounds convey pleasant associations. For example, music and birdsong, although early morning seagulls may be considered as noise, because they are an unwanted sound. Here, "unwantedness" is determined by the cognitive environment in which each sound is detected, Character and quality of a noise, combined with our expectations and situation, are important contributors to our response and are considered later.

2.4 **Low frequency noise and infrasound.** The frequency range of infrasound is normally taken to be below 20Hz and that of audible noise from 20Hz to 20,000Hz. However, frequencies below 20Hz are audible, illustrating that there is some lack of clarity in the interpretations of infrasonic and audible noise. Although audibility remains below 20Hz, tonality is lost below 16-18Hz, thus losing a key element of perception. Low frequency noise spans the infrasonic and audible ranges and may be considered as the range from about 10Hz to 200Hz. The boundaries are not fixed, but the range from about 10Hz to 100Hz is of most interest. In later chapters we will not separate infrasound and low frequency noise, but consider the range from 10Hz to 200Hz as continuous.

2.5 **Sources.** Low frequency noise and infrasound are produced by machinery, both rotational and reciprocating, all forms of transport and turbulence. For example, typical sources might be, pumps, compressors, diesel engines, aircraft, shipping, combustion, air turbulence, wind and fans. Structure borne noise, originating in vibration, is also of low frequency, as is neighbour noise heard through a wall, since the wall blocks higher frequencies more than it blocks lower frequencies (Hood and Leventhall, 1971; Leventhall, 1988).

2.6 **Infrasound.** There are a number of misconceptions about infrasound, such as that infrasound is not audible. As will be shown later, frequencies down to a few hertz are audible at high enough levels. Sometimes, although infrasound is audible, it is not recognised as a sound and there is uncertainty over the detection mechanism. Very low frequency infrasound, from one cycle in, say 1000 seconds (0.001Hz) to several cycles a second are produced by meteorological and similar effects and, having been present during all of our evolution, are not a hazard to us. Much of what has been written about infrasound in the press and in popular books is grossly misleading and should be discounted.

2.6.1 **Propagation.** The attenuation of sound in air increases with the square of the frequency of the sound and is very low at low frequencies. Other attenuating factors, such as absorption by the ground and shielding by barriers, are also low at low frequencies. The net result is that the very low frequencies of infrasound are not attenuated during propagation as much as higher frequencies, although the reduction in intensity due to spreading out from the source still applies. This is a reduction of 6dB for each doubling of distance. Wind and temperature also affect the propagation of sound.

2.6.2 **Control.** Infrasound is difficult to stop or absorb. Attenuation by an enclosure requires extremely heavy walls, whilst absorption requires a thickness of absorbing material up to about a quarter wavelength thick, which could be several metres.

2.6.3 **Resonance.** Resonance occurs in enclosed, or partially open, spaces. When the wavelength of a sound is twice the longest dimensions of a room, the condition for lowest frequency resonance occurs. From $c = \lambda f$, if a room is 5m long, the lowest resonance is at 34Hz, which is above the infrasonic range. However, a room with an open door or window can act as a Helmholtz resonator. This is the effect which is similar to that obtained when blowing across the top of an empty bottle. The resonance frequency is lower for greater volumes, with the result that Helmholtz resonances in the range of about 5Hz to 10Hz are possible in rooms with a suitable door, window or ventilation opening.

2.7 **Low frequency noise.** The range from about 10Hz to 200Hz covers low frequency noise. For comparison, the lowest C note on a full range piano is at about 32Hz whilst middle C is at about 261Hz. All the low frequency noise range is audible, although high levels are required to exceed the hearing thresholds at the lower frequencies.

2.7.1 **Propagation.** Similar factors influence the propagation of low frequency noise to those which influence infrasound. However, because of the higher frequencies, air and other attenuations are greater for low frequency noise than for infrasound and more is known about them. Typical air attenuations at 20^0C and 70% relative humidity are:

63Hz	-	0.1dB/km
125Hz	-	0.35dB/km
250Hz	-	1.1dB/km

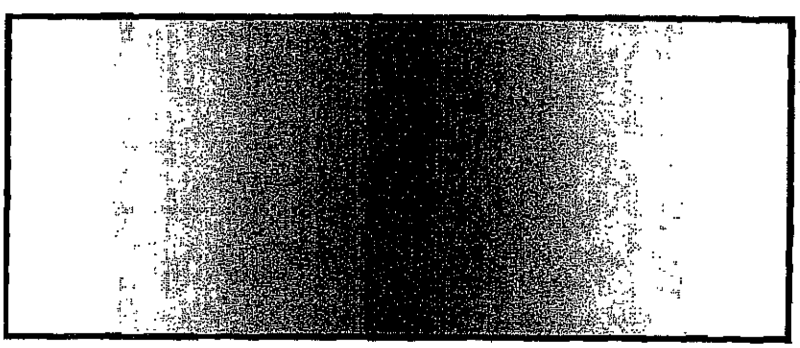
which shows very low attenuation at 63Hz.

In addition to these there is reduction of 6dB per doubling of distance due to spreading out of the wave and any reduction which might occur due to absorption over the ground or by shielding. It is seen that air attenuations are a small contributor to losses at low frequencies but, since attenuation increase rapidly as frequency rises, air attenuation can be a main contributor at much higher frequencies in the kilohertz range. As a result, noise which has travelled over long distances is normally biased towards the low frequencies.

2.7.2 **Control.** Low frequency noise and infrasound are steps along the same physical process of wave propagation, so that similar considerations apply to their control, although the shorter wavelengths of low frequency noise make control easier. Thus, a massive single partition, or a complex multiple partition, is needed to stop low frequency noise, with results which improve as the frequency increases. But most walls in buildings are deficient in the low frequency region, so that noise transmission between rooms, and from outside to inside, is a problem. Absorption of low frequency noise requires thick material, such that most sound absorbing linings, typically a few centimetre thick, are ineffective at the low frequencies.

2.7.3 **Resonance effects.** Resonances in a normal sized domestic room occur in the low frequency region. For example, a room of dimensions 4m by 5m by 2.5m has low frequency resonances from 34 Hz upwards. Resonances increase the sound level in parts of the room whilst decreasing it in others.

Figure 3 illustrates the standing wave of a lowest room resonance, in which the room dimension is one half wavelength of the sound. The level is highest at the end walls and lowest in the centre of the room. It is often possible to detect the differences in level, at different room locations, within a room which has been driven into resonance by low frequency noise.



← **Half wavelength** →

Figure 3. Lowest room resonance.

3. Decibels and measurements

3.1 Noise Levels – the 'decibel'

3.1.1 **Definition:** The decibel is the logarithm of the ratio between two values of some characteristic quantity such as power, pressure or intensity, with a multiplying constant to give convenient numerical factors. Logarithms are useful for compressing a wide range of quantities into a smaller range. For example:

$$\log_{10}10 = 1$$

$$\log_{10}100 = 2$$

$$\log_{10}1000 = 3$$

and the ratio of 1000:10 is compressed into a ratio of 3:1.

This approach is advantageous for handling sound levels, where the ratio of the highest to the lowest sound which we are likely to encounter can be as high as 1,000,000:1. A useful development, many years ago, was to take the ratios with respect to the quietest sound we can hear. This is the threshold of hearing at about 1000Hz, which is taken as 20μPa (2×10^{-5}Pa) of pressure for the average person. When the word "level" is added to the word that describes a physical quantity, decibels are implied. Thus, "sound level" is a decibel quantity. When the sound pressure is doubled, the sound pressure level increases by 6dB.

3.2 Measurements

3.2.1 **Weighting networks.** The majority of noise measurements are made using sound level meters (IEC:60651, 2001), which give numerical levels as a representation of the noise. For environmental noise it is normal to use the sound level meter A-weighting, which gradually reduces the significance of frequencies below 1000Hz, until at 10Hz the attenuation is 70dB. The C-weighting is flat to within 1dB down to about 50Hz and then drops by 3dB at 31.5Hz and 14dB at 10Hz. Figure 4 shows the A and C weighting curves.

The G weighting, (ISO7196, 1995), specifically designed for infrasound, falls off rapidly above 20Hz, whilst below 20Hz it follows assumed hearing contours with a slope of 12dB per octave down to 2Hz. This slope is intended to give a subjective assessment to noise in the infrasonic range. A G-weighted level of 95 - 100dBG is close to the perception level. G-weighted levels below 85-90dBG are not normally significant for human perception. However, too much reliance on the G-weighting, which is of limited application, may divert attention from problems at higher frequencies, say, in the 30Hz to 80Hz range.

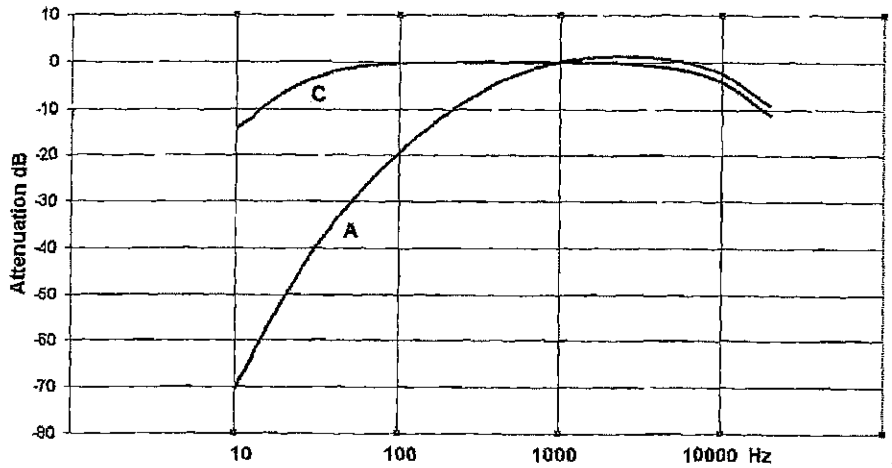


Figure 4. Sound level meter weighting curves – A and C.

Figure 5 shows the G-weighting curve. There is a Linear Weighting, also known as Z-weighting, which has a flat frequency response from 10Hz to 20kHz. More detail of the noise, in particular the presence of tones, can be found from a third octave or narrow band analysis.

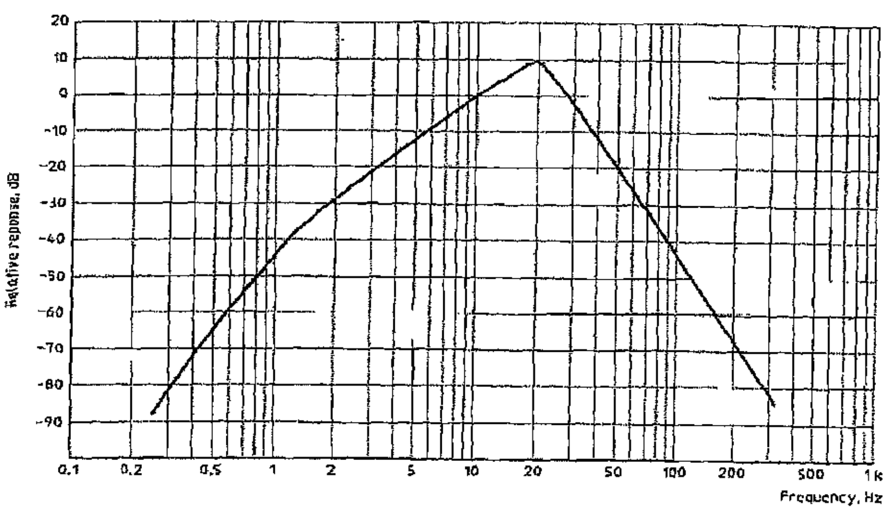


Figure 5. G-weighting for infrasound.

3.2.2 Averaging. Sound level meters give a numerical representation of the noise. However, this is obtained by averaging over a period of time that, for fluctuating noises, is generally longer than the period of the fluctuations, leading to a loss of information on the fluctuations. The widespread use of the equivalent level discards important information on the quality of the noise, its spectral properties and corresponding perceived sound character.

4. The low frequency hearing threshold and loudness

4.1 **Average thresholds.** The aim of studies on the low frequency threshold has been to determine the lowest levels which are audible to an average person, often a young person, with normal hearing. Thus, the threshold is a "quasi-objective" measurement in the sense that it is free from emotional responses. Threshold studies have been carried out on relatively small groups, typically about 10 to 20 subjects, so that differences between experimenters are to be expected. However, the different studies follow the same trend, and the threshold region at low frequencies is now well established. For example, (Corso, 1958; Lydolf and Møller, 1997a; Lydolf and Møller, 1997b; Moller and Andresen, 1984; Møller and Andresen, 1984; Watanabe and Møller, 1990a; Watanabe and Møller, 1990b; Whittle et al., 1972; Yeowart, 1976; Yeowart and Evans, 1974) have all carried out careful studies and give references to earlier work. The frequency ranges covered and method of exposure are as follows.

Corso	5Hz to 200Hz	Monaural headphone
Whittle et al	3.15Hz to 50Hz	Pressure chamber
Yeowart and Evans	1.5Hz to 100Hz	Monaural headphone
	5Hz to 100Hz	Binaural headphone
	2Hz to 20Hz	Pressure chamber
Møller and Andresen	2Hz to 50Hz	Pressure chamber
Watanabe and Møller (a)	25Hz to 1kHz	Free Field
Watanabe and Møller (b)	4Hz to 125Hz	Pressure chamber
Lydolf and Møller	20Hz to 1kHz	Pressure chamber/free field

(Yeowart 1976 is a review of work up to that date)

The different measurement methods – monaural/binaural headphones, pressure chamber, free field – potentially produce different results. For example, binaural listening is 3dB more sensitive than monaural listening - the "binaural advantage". An individual's sensitivity and measured hearing threshold will also be influenced by the method of presentation of the sounds.

Free field levels are often taken in the absence of the subject, whilst pressure chamber measurements are taken in the presence of the subject. However Watanabe and Møller (1990b) found no significant difference between their two measurements in the frequency range of overlap.

Thresholds above 20Hz are standardised by ISO for otologically normal persons within the age range from 18 to 30 years inclusive (ISO226, 1987). Early studies of the low frequency threshold showed discrepancies between low frequency measurements and ISO 226 at frequencies above 20Hz, where the measurements overlapped. Later measurements have partially resolved these, showing that where the measurements are made in the same laboratory, there is closer agreement in the overlap region between very low frequency pressure chamber measurements and the free field measurements above 20Hz (Lydolf and Møller, 1997a; Watanabe and Møller, 1990b). However, ISO 226 is itself under review and the threshold has been standardised separately for audiometric equipment (ISO 398 - 7, 1996). A German Standard for environmental low frequency noise (DIN:4560, 1997) circumvents the difference by extrapolating the threshold of ISO 226 from 20Hz, the lowest standardised frequency, by 8dB rise per third octave down to 8Hz. This gives thresholds which are lower than most measured ones in the infrasonic region.

4.1.1 Current threshold values. The thresholds found by Watanabe and Møller (1990b) are shown in Figure 6, which also includes the limit of 85dBG up to 20Hz and 20dBA in the range 10-160Hz. The threshold measurements from 20Hz to 125Hz are very close to the ISO 389-7 threshold (ISO389-7, 1996). Figure 6 gives the threshold at 4Hz as about 107dB, at 10Hz it is 97dB, at 20Hz it is 79dB and at 50Hz it is 46dB. Note that, at about 15Hz, there is a change in threshold slope from approximately 20dB/octave at higher frequencies to 12dB/octave at lower frequencies. This is a consistent finding by different experimenters, occurring within the range 15Hz to 20Hz, depending on which frequencies have been used in the measurements. It has not been fully explained, but is thought to be due to a change in the aural detection process, occurring in the frequency region at which tonality of the auditory sensation is lost.

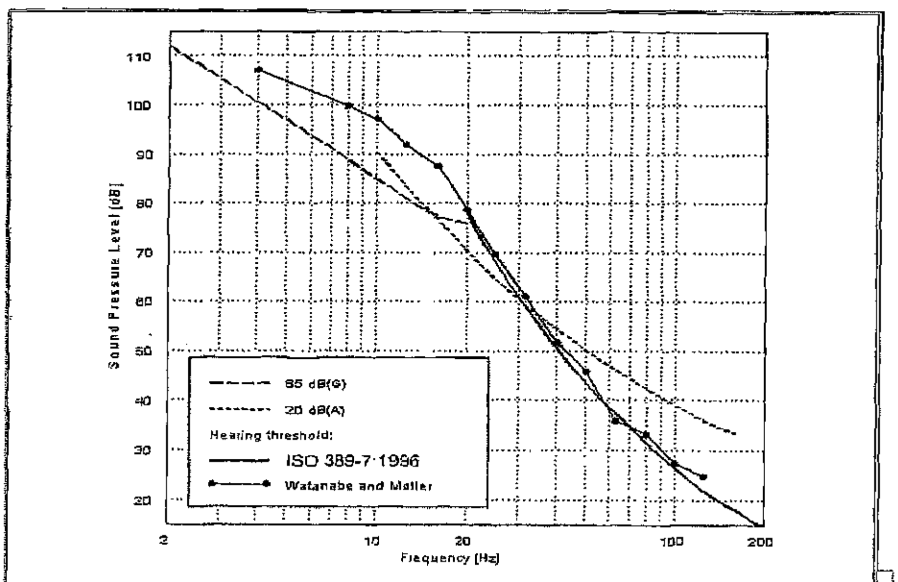


Figure 6. Threshold levels after Watanabe and Møller (1990b).

The 50% and 10% hearing thresholds for an otologically unselected 50 – 60 year old age group has been compared with that for otologically selected young adults. (van den Berg and Passchier-Vermeer, 1999a). The older population is typically 6 – 7dB less sensitive than the younger one, whilst the hearing sensitivity which is exceeded by 10% of the population is, typically, 10-12dB below the average, 50% level. It was also estimated that the 5% hearing level was 2dB below the 10% hearing level.

4.2 **Individual thresholds.** The threshold levels described above are averaged over groups of subjects. The threshold of an individual may differ from the average. Investigations at higher frequencies have shown that an individual threshold exhibits a "microstructure" in which there are fluctuations in sensitivity of up to 12dB at specific tones. (Cohen, 1982).

Further investigations of this effect were made at both low and high frequencies (Benton, 1984; Frost, 1980; Frost, 1987). For example, Frost (1987) measured thresholds at 5Hz intervals over the range 20Hz to 120Hz with results such as in Figure 7, which compares two subjects, one of whom is about 15dB more sensitive than the other at 40Hz. Both subjects had similar audiograms at 250, 500 and 1000Hz.

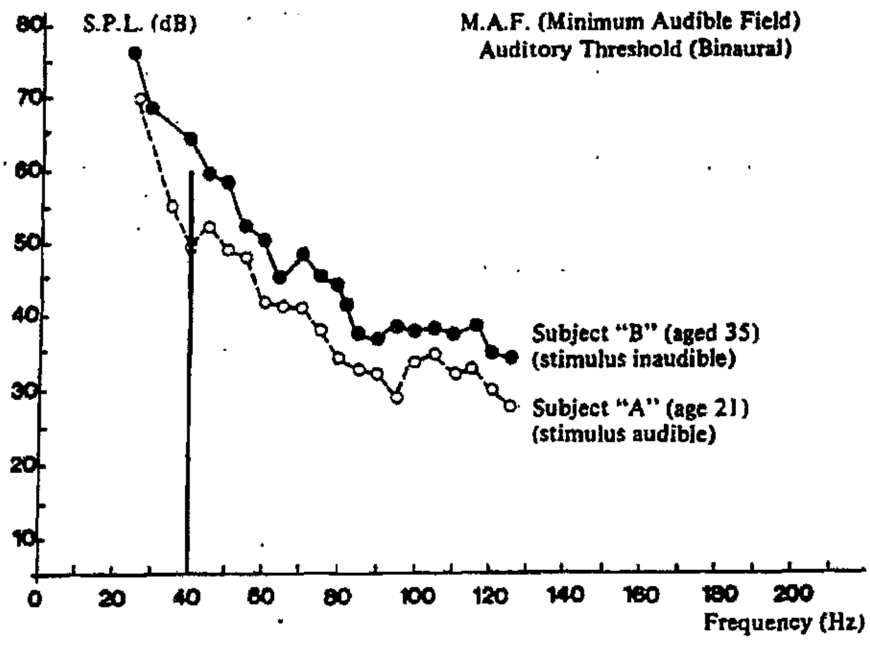


Figure 7. Individual thresholds showing regions of enhanced sensitivity.

Yamada and colleagues (Yamada, 1980) reported male and female thresholds separately, measured in a pressure chamber at third octave frequencies from 8Hz to 63Hz. For his subjects, women were about 3dB more sensitive than men except at the lowest two frequencies, 8Hz and 10Hz. It was also found that individual differences are large, one male subject having a threshold which was 15dB more sensitive than the average.

It is clear that the audiogram is not a smooth curve and that there are pronounced individual differences. Low frequency audiograms of complainants have shown that some hum complainants have low frequency hearing which is more sensitive than the average threshold, whilst others are less sensitive (Walford, 1978; Walford, 1983), as would be expected in any population of subjects. Thus, complainants do not necessarily have enhanced hearing acuity at low frequencies.

4.3 **Loudness at low frequencies.** Loudness is also a "quasi-objective" measurement, although, as with the threshold, its determination depends on the subject's responses. Loudness is measured against the loudness of a tone at 1000Hz. Experimentally, the subject adjusts the level of the sound under investigation until it sounds equally loud to the 1000Hz reference tone. This is the way in which the equal loudness contours of ISO 226:1987, shown in Figure 8 were developed. It is also possible to use an intermediate frequency, F2, first comparing F2 with the 1000Hz reference and then the test tone, F3, with F2, in order to compare F3 with 1000Hz. For example, 50Hz might be compared directly with 1000Hz, but lower frequencies compared directly with 50Hz and indirectly with 1000Hz. The unit of loudness is the "phon", which is the level of a 1000Hz tone that has the same loudness as the test tone when the tones are presented as plane waves, with the subject facing the direction of the waves.

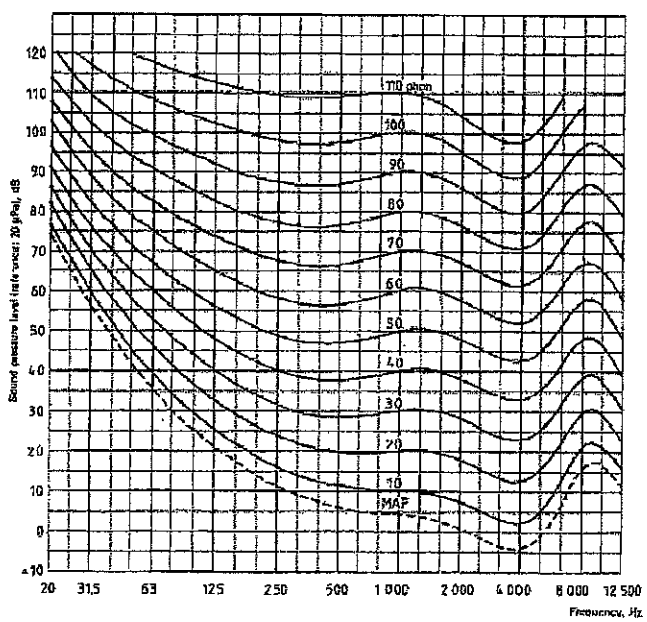


Figure 8. Equal loudness contours (ISO 226).

Some threshold investigations at low frequencies have also included measurement of equal loudness contours (Lydolf and Møller, 1997a; Watanabe and Møller, 1990a; Whittle et al., 1972; Yeowart, 1976). Figure 8 , showing the equal loudness contours above 20Hz, illustrates the trend that, as the frequency reduces, the contours come closer together. Thus, in Figure 8, the 80 phon range of loudness at 1000Hz, from 10dB to 90dB, spanning 80dB, is compressed into 40dB at 20Hz. The mid-frequency rule of thumb that a 10dB increase in level represents a doubling of loudness, fails at low frequencies. At 20Hz a doubling of loudness occurs for a level change about 5dB, and requires a smaller change at lower frequencies.

The main loudness level measurements at very low frequencies have been by (Moller and Andresen, 1984; Møller and Andresen, 1984; Whittle et al., 1972). Figure 9, from Møller and Andresen, compares the results. Møller and Andresen made measurements at octave frequencies from 2Hz up to 63Hz. Whittle's measurement frequencies were at octaves between 3.15Hz and 25Hz, followed by third octave frequencies to 50Hz. There is good agreement over the main range with the continuing tendency for the contours to become closer as the frequency reduces. The more rapid growth in loudness at low frequencies is an important factor in its subjective effects.

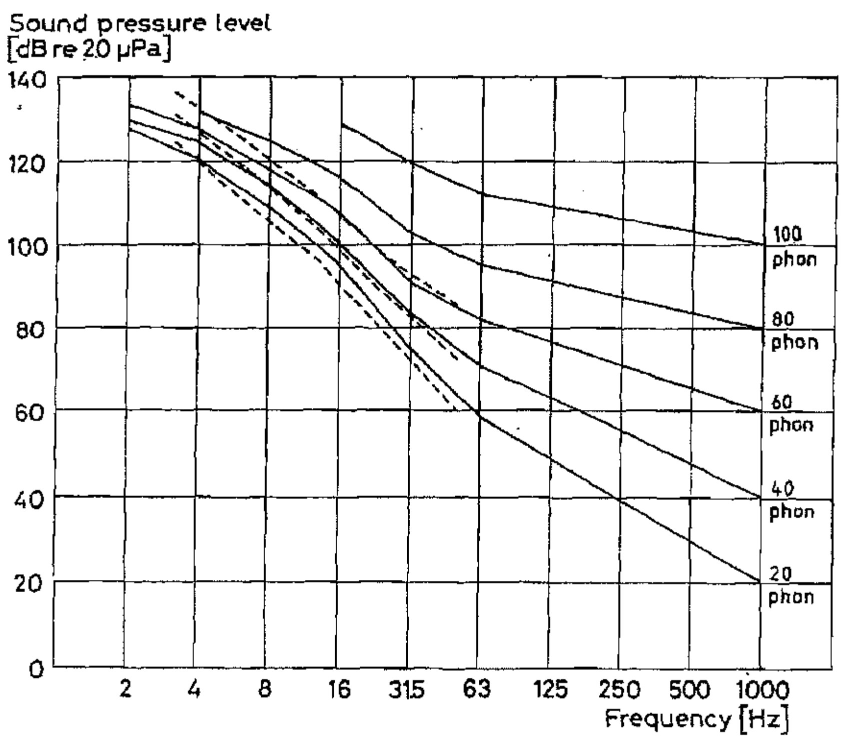


Figure 9. Loudness measurements.

——— Møller and Andresen
------- Whittle

5. False Perceptions

There is always low frequency noise present in an ambient "quiet" background. Origins are often from transportation or industrial sources, which are too far away to be clearly identified. However, depending on the type of location, typical levels might rise rapidly below 50Hz and reach 40-50dB at frequencies below 20Hz. An investigator may conclude that this rise in low frequency levels is the source of the complaint, neglecting that the threshold at 20Hz is higher than 70dB. As a general rule, broadband noise which is more than 20dB below the average threshold is unlikely to be a problem, as it lies below the threshold of the most sensitive persons.

The instances when a noise is heard by a complainant, but cannot be measured or detected by instruments at significant levels, make it necessary to consider the possibility that a mechanism other than an airborne sound is responsible, leading to a false perception of noise. Potential origins of false perceptions include tinnitus, electromagnetic waves, synaesthesia, hypnagogic effects and the "cognitive itch".

5.1 **Tinnitus.** Tinnitus has often been used as the "fall back" explanation, when it has not been possible to measure a noise. In addition to tinnitus arising in the hearing mechanism, there are low frequency fluctuations within the body, mainly associated with blood flow, which are known to produce audible effects. In an investigation which included both hum sufferers and tinnitus sufferers, Walford (1983) attempted to separate the responses of the two groups. Both experimental groups were asked to match the frequencies of their sensations, in both level and rate of throb. This was done by adjusting the frequency, throb rate and amplitude of an oscillator. There was overlap between the two groups, with matched frequencies ranging from 15Hz to 196Hz and throb rates from zero to over 5 per second. There was a clustering of frequencies around 40Hz with throb rates of 1 – 2 per second. The overlap in sensations emphasises the difficulties of separating tinnitus patients from those who hear an external noise. Walford attempted the separation by an earmuff test. First the effectiveness of the earmuffs was tested against a matched tone from an oscillator, in order to demonstrate their attenuation at that frequency. If the earmuffs, in the presence of the problem noise, then do not reduce this noise, it is likely to be tinnitus. If they are effective against the noise, there is likely to be an external source.

An important element of this work was when the low frequency noise sensitives were matching, from memory, the levels at which they hear the noise in their homes. The matching sounds were all above average threshold levels, in many cases by 20dB to 40dB. This means that these sounds would have been audible to most listeners, although they were not heard by investigators and others. Several points come from this:

If the matching levels were correct, the effects were likely to be tinnitus.

The subjects may have a very imperfect memory of the sounds they hear in their homes.

The subjects were matching how they felt about the noise, rather than what they heard, determined by long-term antagonistic conditioning.

5.2 **Electromagnetic waves.** It has been known for some time that electromagnetic waves may produce auditory sensations in persons close to a transmitter although, as shown by calculations later in this section, in most practical exposures the levels of electromagnetic radiation are considerably below those where auditory sensations have been observed.

5.2.1 **Review.** An early paper (Frey, 1962) showed that good high frequency hearing in the listener was necessary for perception. Frey also listed other effects, depending on the transmitter parameters. These effects included buffeting of the head, dizziness or nausea and pins-and-needles sensations. However, his main work was on hearing sensations produced by pulsed waves in the range 425MHz to 3000MHz. He found that a peak electrical field strength of around 15V/cm (1500V/m) was the threshold value for perception when using pulse duty cycles of around 0.001 to 0.01. Very low duty cycles (0.0004) required higher peak fields. The work was carried out in a laboratory area of 70-90dB acoustic background noise and Frey considered that thresholds would be lower in quieter surroundings.

A recent review gives a clear survey of existing material (Elder and Chou, 2003 (submitted for publication)) and also available under the title of the paper on grouper.ieee.org/groups/scc28/sc4/.

Auditory perception, which follows from a rapid transient heating of about 10^{-6} ^{0}C, depends on the energy in a single pulse and not on the average power density, typical sensations being click, buzz, hiss, knock or chirp. The effective stimulation range is 200MHz to 10,000MHz and the ability to hear the effects of radio frequencies in this range depends on good high frequency acoustic hearing, in the kilohertz range. Conversion starts outside the cochlea, by absorption of RF energy in tissues in the head, leading to rapid thermal expansion. The resulting pulse feeds by bone conduction to the cochlea, which is very sensitive. (Note that the displacement of the eardrum at the level of ordinary conversation is about 10^{-10} m, which is sufficient to stimulate the cochlea to sense a sound of moderate level (Stephens and Bate, 1966)).

Elder and Chou give examples of values of RF stimulation to produce distinct clicks such as:

Frequency, 3000MHz: 5μs pulse widths: repetition rate $0.5s^{-1}$:

peak power density $2.5W/cm^2$.

In experiments on exposure of humans to radar waves, the RF induced sounds disappeared when an aluminium fly screen was placed between the subject and the radar. It was also found that a small metal screen, about 50mm x 50mm, placed over the temporal lobe of the brain, completely stopped the sound. Additional information and international standards are given in a survey of effects of radio wave exposure (Firstenberg, 2001).

5.2.2 **EM waves and sensitivity to LF noise.** The audible sensations produced by electromagnetic waves do not closely match the sounds reported by low frequency noise sensitives. As good high frequency hearing is required, the older complainants may not be able to perceive the sounds. However, the buffeting of the head, dizziness or nausea and pins-and needles sensations noted by Frey do match some complainants. These effects do not appear to have been followed up and are not referred to in the comprehensive review by Elder and Chou. It is possible that the effects will manifest only at very high exposure levels, which requires a subject to be close to a transmitter.

It is necessary to relate the electromagnetic levels used in the hearing experiments with those to which people are normally exposed. Simple predictions can be made of energy density and field strength at distances from a transmitter. For example, www.mitedu.freeserve.co.uk/Theory/antenna.htm gives the power density (power received per unit area) at a distance d from a transmitter of power P_t as

$$P_r = \frac{P_t}{4\pi d^2} \text{ W/m}^2$$

The field strength is

$$E = \frac{\sqrt{30P_t}}{d} \text{ volts/m}$$

Then, say, at a distance of 10m from a transmitter of power 100W,

$$\mathrm{Pr} = 0.08 \text{ W/m}^2 = 8\times10^{-6} \text{ W/cm}^2$$

$$\mathrm{E} = 5.5 \text{ V/m} = 0.055 \text{ V/cm}$$

These values are considerably below the levels of 15V/cm and 2.5W/cm^2 quoted above as typical levels for an effect.

Pulsed radars generate very high peak powers, say, 1MW. (WHO, 1999) The radiation is very directional and falls off rapidly at the side of the main beam. For a 1MW peak power, at a distance of 100m, the formula for P_r above gives P_r = 8W/m^2. However, this must be multiplied to allow for the directionality of the aerial, which might typically lead to a power gain on the axis of the main beam of 30dB (1000 times), resulting in 8000W/m^2, or 0.8W/cm^2. This is lower than the levels given by Elder and Chou for the auditory effect. Additionally, it is unlikely that people will be exposed to the main beam. The experimental work on audibility of RF pulses has been carried out with subjects close to the RF sources and consequently exposed to higher levels than would be received by the public at normal source distances.

5.2.3 Growth of EM waves. The growth of EM waves is one of the major environmental changes over the past 100 years, particularly in the last 50 years. Frequencies have been extended at both low and high ends of the spectrum. For example, Extremely Low Frequencies (ELF) start at about 3Hz and extend to a few kilohertz, such that electromagnetic frequencies overlap with audio frequencies. ELF is used for communication with submerged submarines, since the low frequencies penetrate deep into water. The transmission frequency is 76Hz, modulated between 72Hz and 80Hz. It is not known whether work has been carried out to detect auditory effects from ELF. Coincidentally, the transmission commenced in the 1960's, which is a start time for growth in complaints of low frequency noise, but absorption of energy by body tissues is very low at low frequencies.

5.2.4 Power lines. Much work has been carried out on biological effects of power lines which, at 50Hz or 60Hz, are similar frequency to the ELF transmissions. A detailed explanation of the effects of power line radiations does not mention auditory effects.(National Institute of Environmental Health Sciences and National Institute of Health (Australia), 2002). This may be because the audible sensations produced by electromagnetic waves depend on fluctuation in the stimulus wave, typically as short pulses. Steady waves from power lines, if they have an effect, will produce a steady change in the head, which will not result in audible signals. A requirement for auditory sensations induced by the thermal effect is that the transient electromagnetic energy is absorbed in the tissues of the head. This is a frequency dependent effect, occurring mostly between about 200MHz and 10,000MHz (Elder and Chou 2003). Absorption is very low at ELF.

5.2.5 Conclusions. A conclusion is that, although auditory signals are produced by pulsed electromagnetic waves, there is, as yet, no evidence to show that the effects are similar to those experienced by people who are sensitive to low frequency noise. There is a gap in knowledge, which might be clarified if the non-auditory effects referred to by Frey (1962), can be replicated at typical environmental exposure levels of electromagnetic waves. However, the weight of evidence is against EM waves being a source of the types of effects experienced by low frequency noise complainants.

5.3 Synaesthesia. Synaesthesia is a "cross talk" effect in the brain in which one sensory pathway links across to another, resulting in two outputs from one input. ((Baron-Cohen and Harrison, 1997; Grossenbacher, 1997; Rich and Mattingley, 2002). This is indicated in Figure.10. The auditory input leads to both auditory and visual perceptions. Another model requires feedback from a multimodal nexus which receives inputs from multiple sense modalities, thus acting as a link between them.

The question to be addressed is: In the cases where complaints persist, but noise cannot be measured, could the complainants have a form of synaesthesia in which a sensory input of another modality leads to an auditory percept?

The commonest form of synaesthesia is the linking of colours to printed letters and numbers. The letters may appear to be coloured even though they are printed as black. Other effects are to "see" music in colours. It is estimated that about 1 in 2500 people are synaesthetes, of whom more are women than men and a high proportion are left-handed.

5.3.1 **Auditory effects.** Associate Professor Sean Day of Miami University, also President of the American Synaesthesia Association, gives statistics based on a sample size of 572, some of whom have more than one type of synaesthesia. See Sean Day's personal web page www.users.muohio.edu/daysa/types.htm. The commonest occurrence is black printed letters appearing as coloured (68.8%), but there is a small number, about 1%, who hear sound when the stimulus is from smell, taste or touch.

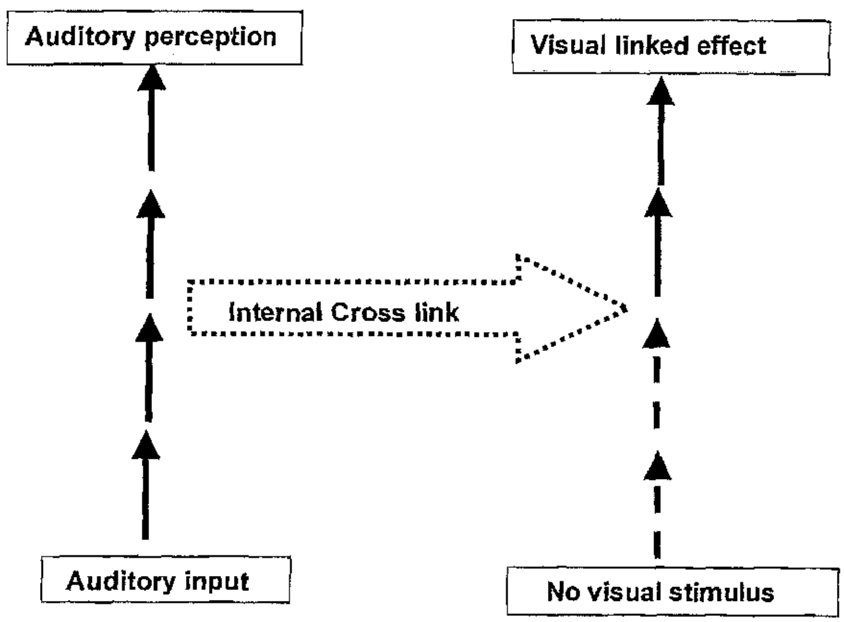


Figure 10. Illustrating synaesthesia, a sound causing a visual effect.

Baron-Cohen (Baron-Cohen, 1996) describes a synaesthete who links colours to sounds and also has the reverse experience, hearing sounds when seeing colours. The effect is described as leading to "massive interference, stress, dizziness, a feeling of information overload and a need to avoid those situations which are either too noisy or too colourful".

It is difficult to assert that synaesthesia is an explanation of some of the unsolvable low frequency noise problems. Synaesthesia is often a lifelong condition, whilst many low frequency noise complaints have a sudden onset. However, synaesthesia can be acquired through seizures or drug use, neuron degeneration and damage to the brain or spinal cord. Thus, synaesthesia is a candidate explanation where noise cannot be measured, but not a very strong candidate.

5.4 **Reception through the skin.** The skin contains multiple sensors which respond to touch, pressure, temperature, pain etc. The Merkel cell, Meissners corpuscles and Pancinian corpuscles respond to vibration as indicated in Figure 11, reproduced from Jones (Jones, undated). There is the question: are these more or less sensitive receivers than the ear at very low frequencies? The high displacement thresholds shown in Figure 11 indicate that, to a normally hearing person, perception through the ear will take precedence. This is borne out by experiments with normally hearing and profoundly deaf persons (Yamada et al., 1983). The threshold of sensation of the deaf subjects was 40-50dB above the hearing threshold of those with normal hearing up to 63Hz and greater at higher frequencies. For example about 100dB greater at 1kHz, at which level perception was by the subject's residual hearing. Deaf subjects felt sensations mainly in the chest.

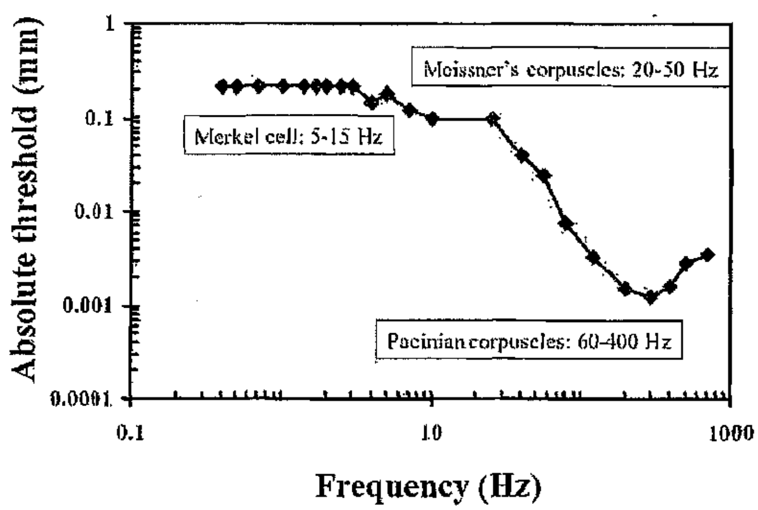


Figure 11. Threshold sensitivity of receptors in the skin.

5.5 **Hypnagogic and hypnopompic experiences.** These terms describe the unusual experiences which might occur when a person is falling asleep (hypnagogic) or waking up (hypnopompic). They are sometimes associated with sleep paralysis, when it is not possible to move, although aware of the surroundings. In addition to immobility, there may also be a sensed presence, pressure on the body, floating sensations, sounds, a visible form and fear. The effects, which are associated with the rapid eye movement (REM) sleep stage, have been investigated amongst a large group of undergraduates (Cheyne et al., 1999). The frequency of occurrences amongst a sample of 870 students is shown in Table 2. About 12% of the sample experience sounds. Cheyne gives a description of the auditory effects on http://watarts.uwaterloo.ca/~acheyne/.

Experience	Frequency	Proportion
Immobility		
Never	616	0.71
Once	70	0.08
2 – 5 times	105	0.13
5 times	75	0.09
Hallucinoid experiences		
Sensed presence	130	0.15
Body pressure	106	0.12
Floating	93	0.11
Sounds	99	0.12
Visible form	75	0.09
Fear	117	0.14

Table 2. Frequencies and proportions of individuals experiencing sleep paralysis and associated hallucinoid experiences. (Cheyne et al 1999).

The auditory effects are described as buzzing, grinding, humming, ringing, roaring, rushing, screeching, squeaking, vibrating, whirring, and whistling. Bodily sensations of tingling, numbness or vibrations sometimes accompany the sounds. There is a parallel between these descriptors and complainants of low frequency noises, especially for those whose experience is worse when trying to sleep.

It is not suggested that hypnagogic effects are the explanation for low frequency noise disturbance, but it is possible that they could explain some of the extreme effects which complainants feel in bed and which are attributed to the complaint noise.

5.6 **The "cognitive itch".** It has been suggested by Sargent (Sargent, 1996) that subjects could become sensitive to a noise, possibly developing an ongoing "memory" of it. We have all experienced certain "catchy" tunes repeating in the head – the "cognitive itch" (Kellaris, 2001). The main characteristics of such tunes are repetition, simplicity and incongruity, all of which hold the attention. In particular, repetition causes an automatic pattern echo in the brain. The "cognitive itch" metaphor arises since, in the same way that one scratches an itch, the cognitive itch demands attention through internal repetition of its sounds. It is related to endomusia, a syndrome in which melodies are recalled in the head, possibly to an obsessive extent .

A similar effect to the cognitive itch may be relevant to some of the low frequency noise problems, in which exposure has developed a memory of the noise.

6. Development of enhanced susceptibility

It is known that different regions of the brain are responsible for different functions. The brain also possesses "plasticity", in the sense that parts within the same region may change their function. (Schnupp and Kacelnick, 2002). For example, extensive training in a frequency discrimination task leads to improved discrimination ability and an expansion of the cortical area responsive to the frequencies used during training. Schnupp and Kacelnick quote supporting work on animals as follows:

> Guinea pigs, trained to associate presentation of a particular pure tone with an unpleasant, but mild, electric shock to the paw, learned to avoid the shock by withdrawing their paw when presented with the tone. Subsequent electro -physiological examination indicated that neurons, originally tuned to frequencies on either side of the conditioning frequency, had shifted their tuning curves towards that frequency. The shift of frequency tuning meant that more cells in the cortex were available to signal the presence of the conditioned stimulus and that this signal is sensed clearly and unambiguously.
>
> Owl monkeys, trained through a reward and denial regime to discriminate a target frequency from different frequencies, were shown to have a shift in neural tuning curves and a sharpening of frequency tuning for the target.

In humans, there is considerable plasticity in the brain during its early development, requiring appropriate stimuli for proper growth. Plastic adaptation is slower in the adult brain. Two examples of plastic adaptation are:

> London taxi drivers have been shown, through magnetic resonance imaging, to have an enlarged posterior hippocampus compared with control subjects who did not drive taxis.(Maguire et al., 2000). Taxi driver's anterior hippocampal regions were, however, smaller than controls. Posterior hippocampal volume correlated positively with time spent as a taxi driver, whilst anterior hippocampal volume correlated negatively. The conclusion is that, in order to learn the thousands of routes required for their work, that part of the brain associated with spatial navigation, the posterior hippocampus, enlarged at the expense of neighbouring regions.
>
> There has been a similar finding for skilled musicians (Pantev et al., 1998). Cortical reorganisation was greater the younger the age at which learning began.

The significance of these findings for low frequency noise sufferers is:

- *There is clear evidence that the brain is able to adapt to stimuli.*
- *If sufferers spend a great deal of time listening to, and listening for, their particular noise, it is possible that they may develop enhanced susceptibility to this noise.*
- *Enhanced susceptibility is therefore a potential factor in low frequency noise problems.*

7. Objective effects

7.1 **Hearing loss.** High levels of A-weighted noise lead to damage to hearing. Do high levels of low frequency noise, whose measured levels would be depressed on an A-weighted measurement, have similar effects? This was one of the early investigations in the American Space Programme (Mohr et al., 1965). Mohr exposed subjects to single tones and narrow bands of noise in the range 10-20Hz, at levels of 150-154dB for two minutes. There was no change in hearing sensitivity as reported by the subjects and no measured temporary threshold shift (TTS) at about one hour after exposure. In other work (Jerger et al., 1966), subjects were exposed for 3 minutes to 7-12Hz at levels 119-144dB. TTS of 20-25dB was found at high frequencies (3kHz to 6kHz), but recovery was complete in a few hours. Nixon (Nixon, 1973) used a piston-phone coupled to the subject's ear via an earmuff to produce levels of 135dB at 18Hz. Six five minute exposures were used with one to two minute rest periods between. TTS was observed in one third of the subjects used, but this recovered after about half an hour. Later work (Burdick et al., 1978) indicated that there may be some permanent threshold shift (PTS) for long term high level exposure. In one experiment, chinchilla were exposed for three days to octave band noise at, 100dB, 110dB and 120dB centred on 63Hz. The highest level led to PTS of up to 40dB at 2kHz in the chinchilla. When human subjects were exposed to the same low frequency noise at 110dB and 120dB for four hours, a TTS of about 15dB resulted, extending from low frequencies up to 2kHz. The frequency used by Burdick et al is higher than in the other experiments and might be expected to have a greater effect. There is an indication that long-term exposure to very high levels may cause permanent hearing loss.

Aural pain is produced by exposure to high levels of noise, occurring when the displacement of the middle ear system exceeds its normal limits. Thresholds of pain are given as rising from about 140dB at 30Hz to 165dB at 2Hz (von Gierke and Nixon, 1976). However, there may be people with middle ear problems whose pain threshold is lower than this.

It appears that low frequency noise will produce TTS in some subjects after short exposure, but that the recovery is rapid and complete. Work has not been carried out on the effects of very long exposures to high levels of low frequency noise. The levels experienced in exposure to environmental low frequency noise are considerably lower than the levels used in the hearing loss experiments described above.

7.2 **Body Vibrations.** It is possible that body organs resonate within the low frequency range. Complainants of low frequency noise sometimes report a feeling of vibrations through their body.

7.2.1 **Whole body exposure.** Work has been carried out on body vibrations produced by whole body exposure to low frequency noise.(Brown, 1976; Kyriakides, 1974; Leventhall et al., 1977; Takahashi et al., 2002; Takahashi and Maeda, 2002). The vibratory response of the body to acoustic stimulation is different from its response to mechanical vibration through the feet or seat. Low frequency acoustic stimulation acts over the whole body surface. The work by Brown, Kyriakides and Leventhall was carried out in a small chamber, in which it was possible to maintain a constant excitation level of noise over the frequency range from 3Hz to 100Hz at up to 107dB. Resonance was detected by an accelerometer mounted on a small plate on an elastic belt, which held the accelerometer in contact with the body. For chest resonance measurements, the accelerometer was positioned over the sternum. Other measurement sites were at the front of the stomach and on the shin muscles. The output of the accelerometer was recorded during a frequency sweep from 3Hz to 100Hz at 107dB. The most prominent effect was a chest resonance, occurring in the range from about 30Hz to 80Hz, depending on stature and gender, but mostly near the centre region of this range. The vibration was clearly felt by the subjects and modulated their voices, producing a croaky effect. Repeating the measurements with the subjects breathing a helium-oxygen mixture resulted in the same chest resonance frequency, although voices acquired the typical higher pitch of helium speech. This isolates the resonance to a structural source, the rib cage, rather than within body cavities, such as the lungs. A chest resonance is shown in Figure 12 for a male subject and excitation at 107dB. The maximum acceleration is 0.05g. There were smaller effects at other body locations.

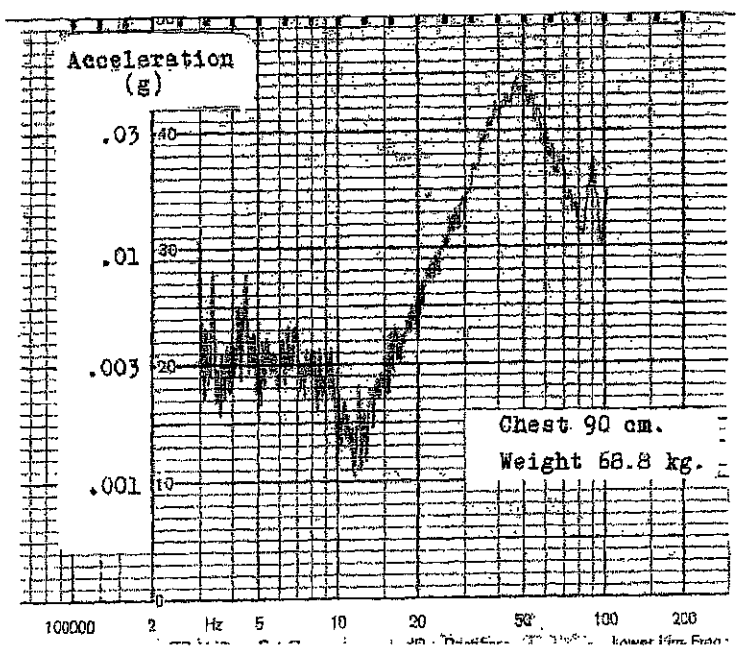


Figure 12. Example of male chest vibration at 107dB

Takahashi and colleagues used a chamber which, because of its size, was limited to a maximum frequency of 50Hz, above which the spatial uniformity of the sound field deteriorated. Measurements were made using single frequencies (20, 25, 31.5, 40 and 50Hz) at levels of 100, 105 and 110dB at the following locations: the forehead, the right and left anterior chest and the right and left anterior abdomen. Further work used white noise and complex noise (combined 31.5Hz and 50Hz) excitation. The general trend was for vibration levels to increase as the frequency increased, but resonance was not shown, due to the limited frequency range of the measurements. The results of the complex tone measurements led to the conclusion that the human body acts as a mechanically linear system in response to airborne excitation.

7.2.2 **Conclusions.** The work on body vibrations has a limited significance for people in their daily life. Vibrations are sometimes experienced when, as a pedestrian, a bus or lorry passes by, since these vehicles often emit noise at around 60Hz. Body vibrations are a pleasurable effect at discos and rock concerts, as shown by the attendees who cluster near the bass loudspeakers. Typical levels of infrasound and low frequency noise, as experienced in homes, are not high enough to cause significant body vibrations, since, as shown in Figure 12. the resonant gain for the chest vibrations was about 25dB and inherent body vibrations will mask excitations resulting from levels of noise below 70-80dB.

8. Annoyance

8.1 **The meaning of annoyance.** Annoyance has roots in a complex of responses, which are moderated by personal and social characteristics of the listeners. (Belojevic and Jokovljevic, 2001; Benton and Leventhall, 1982; Fields, 1993; Grime, 2000; Guski, 1999; Guski et al., 1999; Kalveram, 2000; Kalveram et al., 1999; Stallen, 1999).

For example, Guski (1999) proposes that noise annoyance is partly due to acoustic factors and partly due to personal and social moderating variables, which are shown in Table 3. Noise annoyance in the home is considered as a long-term negative evaluation of living conditions, dependent on past disturbances and current attitudes and expectations. Annoyance brings feelings of disturbance, aggravation, dissatisfaction, concern, bother, displeasure, harassment, irritation, nuisance, vexation, exasperation, discomfort, uneasiness, distress, hate etc, some of which combine to produce the adverse reaction.

Personal Moderators	**Social Moderators**
Sensitivity to noise	Evaluation of the source
Anxiety about the source	Suspicion of source controllers
Personal evaluation of the source	History of noise exposure
Coping capacity with respect to noise	Expectations

Table 3. Noise Annoyance Moderators.

Figure 13, modified from Guski (1999) in order to emphasise the central nature of the personal factors, summarises the interactions. The interpretation of Figure 13 is as follows. The noise load causes activity interference (e.g. to communication, recreation, sleep), together with vegetative reactions (e.g. blood pressure changes, defensive reactions). Activity interference develops into annoyance and disturbance. Prolonged vegetative reactions may lead to effects on health. Personal factors feed into the outer boxes of Figure 13, moderating the complainant's complex of responses. The social factors moderate how the complainant interacts with external authorities in attempting to deal with the annoyance. Social factors may also interact with health effects, as some social classes may more readily seek medical assistance. The personal and social moderating factors are so variable that Grime (2000) questions the feasibility of a national noise policy.

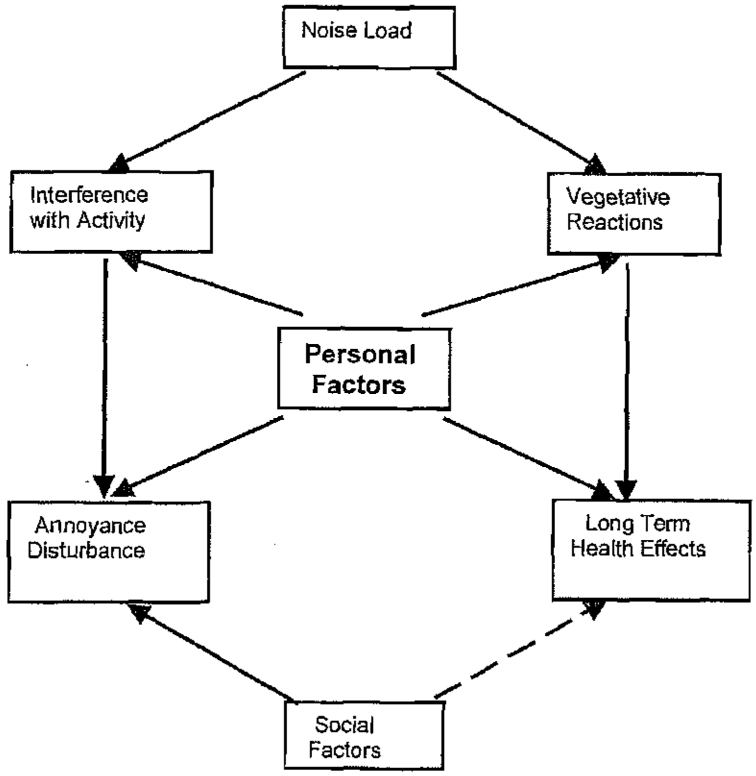


Figure 13. Factors moderating noise annoyance.

8.1.2 Annoyance and the "meaning" of noise. Kalveram (2000) points out that much psychoacoustical noise research has limitations, because it is based upon the correlation between annoyance ratings and physical measurements of sound energy, with subsequent correlation of annoyance and sound level. But equivalent level, A-weighted or linear, is only a part of the total process. Noise level and noise dose approaches neglect the "meaning" of a noise and are contrary to the interactive model in Figure 13. Kalveram proposes an "ecological" approach to noise research, which emphasises the psychological functions of sounds. Annoyance originates from acoustical signals which are not compatible with, or which disturb, these psychological functions. In particular, disturbance of current activities is a primary effect of noise exposure. Kalveram has extended his approach to include "psycho-biological" effects. Annoyance conveys a "possible loss of fitness" (PLOF), which Kalveram links to the message that an individual's Darwinian fitness will decrease if they stay in that situation. Darwinian fitness, in this context, refers to the ability to generate behaviour patterns which permit coping with changes in the environment. For example, to either eliminate a threat or to reduce it to a level which is within the individual's handling capacity. Darwinian fitness may clearly be under threat from noise, to an extent depending on personal factors. A few persons are known to have modified their responses to low frequency noise, thereby removing it from the category of a threat and challenge.

Kalveram summaries the PLOF concept as follows.

"First a harmful variable is assumed to be present in the environment, which affects the individual's (Darwinian) fitness. Then a chance is given that a neural detector will evolve, the input of which is the sensory – here acoustical – stimulation correlated with this harmful variable, while the output is motivating to actions which diminish the sensory input, thereby interrupting current behaviour."

Those who experience long-term exposure to low frequency noise may recognise this process within themselves.

Most field work on noise annoyance has been where there is a known source, for example air or road transport. The particular circumstances of some low frequency noise problems, where the noise source is not known, adds an additional element to annoyance. Those affected suffer extreme frustration and may find it necessary to assume a source, thus enabling themselves to cope through provision of a focus for anger and resentment. Assumed sources have included gas pipelines, radio transmissions and defence establishments.

8.2 Annoyance Measurements. Annoyance measurements are generally of the type described by Kalveram (2000), an attempt to relate annoyance ratings directly to measured noise levels. As described above, these measurements are limited in their results, since they deal with only part of the annoyance complex.

8.2.1 Laboratory determinations. There have been a large number of laboratory determinations of annoyance of low frequency sounds, mainly measurements using either 'normal' or 'sensitive' subjects. Stimuli have included tones, bands of noise or specially developed spectra. There is of course, a wide range of possible stimuli, which experimenters have chosen according to their experience of what is required.(Adam, 1999; Andresen and Møller, 1984; Broner and Leventhall, 1978b; Broner and Leventhall, 1984; Broner and Leventhall, 1985; Goldstein, 1994; Goldstein and Kjellberg, 1985; Inukai et al., 2000; Kjellberg and Goldstein, 1985; Kjellberg et al., 1984; Møller, 1987; Nakamura and Inukai, 1998; Persson and Bjorkman, 1988; Persson-Waye, 1985; Poulsen, 2002; Poulsen and Mortensen, 2002). Some laboratory studies have used recordings of real noises as stimuli, whilst others have worked with the actual noises as experienced by subjects in their own work places or homes. (Holmberg et al., 1993; Landström et al., 1994; Manley et al., 2002; Mirowska, 1998; Tesarz et al., 1997; Vasudevan and Gordon, 1977; Vasudevan and Leventhall, 1982).

Determinations have also been aimed at relating the A-weighted level of the low frequency noise to its annoyance.

8.2.2 Experimental methods. The responses required from subjects vary with experimental method. In laboratory investigations, subjects may be asked to 'imagine' themselves relaxing in their homes in the evening and to rate annoyance by, for example, choice on a semantic scale ranging from 'Not Annoying' to 'Extremely Annoying'. Other methods include marking the level of annoyance on an unnumbered linear scale at a point between 'Not at all annoying' and 'Very annoying', or assigning a number to a reference noise and appropriate numbers to other noises in order to estimate their magnitudes. These psychological techniques are well established, but need care in their performance, as they are sensitive to experimental factors.

8.2.3 **Equal annoyance contours.** The main results of this work are as follows. Møller (1987) investigated contours of equal annoyance for pure tones in the frequency range 4Hz to 31.5Hz. The annoyance contours are influenced by the narrowing of the range of equal loudness contours, discussed above. Møller's results are shown in Figure 14. The vertical scale is the annoyance rating in terms of the distance marked for the tone along a 150mm linear scale. The lowest frequencies have to be at a higher level in order to be audible but, once they become audible, their annoyance increases rapidly. For example, the range for 4Hz is about 10dB between extremes. 8Hz and 16Hz have a 20dB range, whilst 31.5Hz has nearly 40dB range. The 1000Hz comparison, which is for an octave band of noise, has a range of nearly 60dB. These findings are important, as they confirm that the hearing contours are reflected in annoyance, although loudness and annoyance are not necessarily the same. Figure 14 gives averages for 18 subjects with normal hearing.

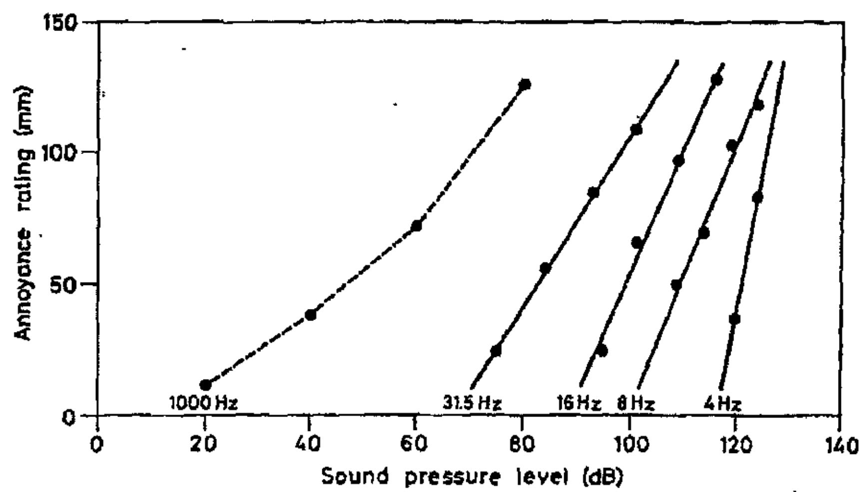


Figure 14. Annoyance rating, showing rapid growth at low frequencies.

8.2.3 **Individual annoyance functions.** Broner and Leventhall (1978) measured individual annoyance functions for 20 subjects using ten low frequency noise stimuli. The psychophysical function was assumed to be a simple power function

$$\psi = k\varepsilon^{\beta}$$

Where ψ represents the estimation of psychological magnitude, ε is the stimulus intensity and β a subject-specific exponent. It was shown that there was a wide range of individual exponents, β, from a low of 0.045 to a high of

0.4 and three groupings of individual differences were identified. Previous work at higher frequencies had also shown individual loudness functions (Barbenza et al., 1970) and had posed the question of whether one set of regulations should be applied to all people (Bryan and Tempest, 1973).

8.2.4 Annoyance and the dBA. A comparison of a band of noise peaking at 250Hz with a band peaking at 100Hz, whilst both were adjusted to the same A-weighted level, showed that the annoyance from the low frequency noise was greater than that from the higher frequency noise at the same A-weighted level (Persson et al., 1985). This work was subsequently extended (Persson and Bjorkman, 1988; Persson et al., 1990) using a wider range of noises, for example, peaking at 80Hz, 250Hz. 500Hz and 1000Hz, leading to the following conclusions:

There is a large variability between subjects.

The dBA underestimates annoyance for frequencies below about 200Hz.

For broadband low frequency noise, the underestimate was found to be 3dB for levels around 65dB(Linear) and 6dB for levels around 70dB(Linear). Similar results had been obtained in earlier work (Kjellberg et al., 1984). Two broadband noises were investigated, in which one was dominated by energy in the 15-50Hz range. Twenty subjects compared the two noises within the dynamic range 49-86dBA. At equal A-weighted levels, the noise dominated by the low frequency component was perceived as 4-7dB louder and 5-8dB more annoying.

Investigations have also been made to compare the effects on task performance of either 100Hz and 1000Hz. tones or bands of noise centred on 100Hz (~ 2 octaves wide) and 1000Hz(~ 1 octave wide) (Landström et al., 1993). During the experiment the subjects adjusted the tones or noises to levels which they found to be acceptable for performance of the tasks. The results indicated that, when the A-weighted levels were compared, it under-rated the effects of the 100Hz tone by about 14dB, but over-rated the effects of the band of noise centred on 100Hz by 10-15.5dB, depending on sound level. There are clearly differences in the perceptions of tones and bands of noise.

8.2.5 Unpleasantness. The "unpleasantness" of low frequency noise has also been estimated (Inukai et al., 2000; Nakamura and Inukai, 1998). Nakamura and Inukai used a stimulus sound of a pure tone in 20 conditions from 3Hz to 40Hz and pressure levels from 70dB to125dB, with evaluation by 17 subjects. There were four main subjective factors in response to low frequency noise: auditory perception, pressure on the eardrum, perception through the chest and more general feeling of vibration. (In actual problems in the field, a fifth factor is the failure of assessment methods, which intensifies other responses). Analysis of the responses showed that auditory perception was the controlling factor.

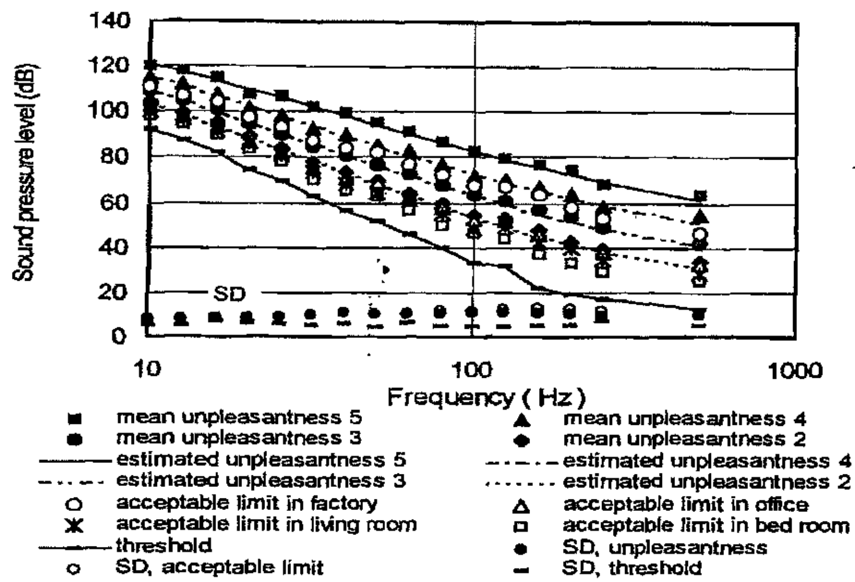


Figure 15. Equal unpleasantness contours and acceptable limits (Inukai).

Inukai et al (2000) determined "equal unpleasantness" contours for 39 subjects over a tone frequency range of 10Hz to 500 Hz (Figure 15). A verbal scale was used ranging through: *Not at all unpleasant (1) - somewhat unpleasant (2) – unpleasant(3) – quite unpleasant(4) – very unpleasant(5).* Subjects in a test chamber were asked to assume different home and work situations and adjust the level of a tone to match a level on the scale, as requested by the experimenter. For example if instructed to match to level 4 (*quite unpleasant*), subjects would adjust the tone until they judged that this level was reached. Results are shown in Figure 16. The numbers 1,2,3,4,5 refer to the unpleasantness level. All levels of unpleasantness are approximately linear with a slope of 5 - 6dB per octave. The acceptable limits for different locations are all above the hearing threshold in this laboratory setting. For example, the self-adjusted acceptable limit in an assumed bedroom is more than 10dB above threshold, but this might not be replicated for long term night exposure in a real bedroom. This work emphasises the point that a sound which is audible is not necessarily unacceptable.

8.2.6 **Spectrum balance** The work by Inukai et al (2000) was for single tones. Spectrum balance has also been considered a factor in noise annoyance of a wideband spectrum. Correlation of a number of complaints with the corresponding spectra (Bryan, 1976) led to the conclusion that, for spectra which averaged as shown in Figure 16, a fall off above 32Hz of 5.7dB/octave was acceptable, whilst a fall off from 63Hz at 7.9 dB/octave was unacceptable. Work on acceptable spectra of air conditioning noise in offices led to similar conclusions (Blazier, 1981). Blazier found that, on average, acceptable office environments had a fall off of 5dB/octave. An excess of low frequency noise led to rumble, an excess of mid frequency noise led to roar, whilst an excess of high frequency noise led to hiss. Later work (Blazier, 1997) developed a "Quality Assessment Index" for an HVAC noise through the balance of low, mid and high frequencies.

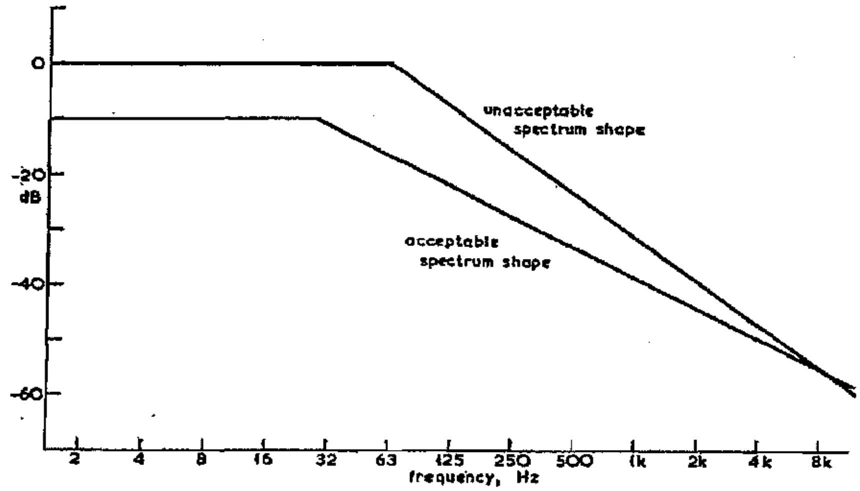


Figure 16. Acceptable and unacceptable spectrum slopes.

A contrary view was given following work on different shapes of spectra (Goldstein and Kjellberg, 1985). It was found that noise which fell by 3dB/octave was more annoying than noise which fell by 6dB/octave or 9dB/octave. This has not been resolved, but Bryan's subjects had long term exposure in real settings, whilst Goldstein and Kjellberg's listened to 10 second samples in the laboratory, so removing any temporal growth of annoyance from the responses. It is also possible that, for the lower rates of fall off, the subjects were responding to the high frequencies in the noise. Goldstein and Kjellberg did show that the A-weighted level underestimates the perceived annoyance of the noises.

8.2.7 **(dBC – dBA) weighting.** The difference between C- and A-weightings has also been considered as a predictor of annoyance (Broner, 1979; Kjellberg et al., 1997), as this difference is an indication of the amount of low frequency energy in the noise. If the difference is greater than 20dB, there is the potential for a low frequency noise problem. Kjellberg et al used existing noise in work places (offices, laboratories, industry etc) with 508 subjects. Three sub- groups were obtained with a maximum difference in low and high frequency exposure. The conclusions on correlations of (dBC – dBA) difference and annoyance were that the difference is of limited value, but, when the difference exceeds 15dB, an addition of 6dB to the A-weighted level is a simple procedure. However, the difference breaks down when the levels are low, since the low frequencies may then be below threshold. The difference cannot be used as an annoyance predictor, but is a simple indicator of when further investigations may be necessary.

8.2.8 **(dBLIN – dBA) weighting.** Disturbance from noise of industrial plants was investigated by Cocchi et al (Cocchi et al., 1992). Comparisons were made of loudness evaluations and various weighted levels and it was suggested that the difference between linear and A-weighting could be used as an assessment. For the spectra investigated, lower values of dBA (20 – 35dBA) correlated with higher (dBLIN - dBA) differences of 20 to 30dB. For high values of dBA (60 - 70dBA), the difference varied from 10-30dB, but mainly clustered in the 10 – 20dB range. This is possibly because noise with low dBA values might be associated with a higher proportion of low frequencies. Advantages of (dBLIN - dBA) over (dBC – dBA) were not discussed.

8.2.9 Home and work environments. Other work, which has assessed low frequency noise in real or assumed work environments or in the home, has included (Bryan, 1976; Cocchi et al., 1992; Holmberg et al., 1997; Holmberg et al., 1993; Holmberg et al., 1996; Landström et al., 1993; Landström et al., 1994; Lundin and Ahman, 1998; Mirowska, 1998; Vasudevan and Gordon, 1977; Vasudevan and Leventhall, 1982).

Studies of simulated ventilation noise in a test laboratory (Holmberg et al., 1993) showed that, for the same A-weighted levels, a ventilation noise with a spectrum which fell gradually with increasing frequency was more annoying than a noise with a band of raised levels around 43Hz. Difference in acceptable comfort levels was 7dB. It was suggested that an A-weighted criterion for ventilation noise should be 35dBA rather than 40dBA and be lower still for environments designed for intellectual work. However, Landström et al. (1994) investigated subjective adjustments to the frequency of a tone , in order to produce the most and least acceptable frequencies, whilst maintaining the overall level at 40dBA. The majority of subjects chose the most acceptable frequency to be in the 50Hz - 63Hz third octave bands and the least acceptable frequency to be in the 500Hz band. Whilst this may appear to contradict other work, note that very few acceptable frequencies were chosen to be below 50Hz.

Homlberg et al (1996 and 1997) assessed noise in real environments. The 1996 paper compared responses of about 240 subjects with the noise measures which might be available on a sound level meter i.e. dBLIN, dBA, dBB, dBC and dBD and the difference (dBC-dBA). Additionally, Zwicker loudness (ISO532, 1975) and Low Frequency Noise Rating (LFNR) (Broner and Leventhall, 1983) were calculated. There was poor correlation between the sound level meter weightings and annoyance. Similarly, the loudness in sones and the difference (dBC – dBA) did not correlate well. The LFNR did separate out annoying and not annoying noises, but no more effectively than the (dBC – dBA).

8.2.10 Level variations. Holmberg et al (1997) investigated noise in workplaces, using the (dBC – dBA) difference as an indicator. Low frequency noise exposure was found in a group of 35 out of a total of 337 persons. Measurements of temporal variation of the levels of low frequency noise at the workplaces, averaged over 0.5, 1.0 or 2.0 seconds, was correlated with subjective annoyance. Significant correlation was found between the irregularity of the noise levels and annoyance.

This work represents an advance, in that it shows the importance of fluctuations in noise level. A limitation of much work on assessment of low frequency noise has been that long term averaged measurements were used and, consequently, information on fluctuations was lost. Many complaints of low frequency noise refer to its throbbing or pulsing nature. Broner and

Leventhall(1983) had noted the importance of fluctuations and suggested a fluctuation penalty of 3B in the Low Frequency Noise Rating Assessment. The importance of fluctuations has also been assessed in laboratory experiments (Bradley, 1994). Subjects listened first to steady wideband noises which peaked at 31.5Hz and adjusted the overall level of these to be equally annoying to a reference spectrum which fell at 5dB/octave. It was found that the more prominent the low frequency noise, the greater the reduction in level required for equality of annoyance with the reference spectrum. The test spectra were now amplitude modulated, in the low frequency region only, at modulation frequencies of 0.25, 0.5, 1.0, 2.0 and 4.0Hz and depths of 10dB and 17dB. Subjects again adjusted the level of the noises to produce equal annoyance with the (unmodulated) reference noise. The reductions varied with modulation frequency and modulation depth. An example is that, for the highest modulation depth at 2.0Hz modulation frequency, the level was reduced by 12.9dB averaged over the subjects. This work confirms the importance of fluctuations as a contributor to annoyance and the limitation of those assessment methods, which do not include fluctuations in the assessment.

8.2.11 Field investigations. Vasudevan and Gordon (1977) carried out field measurements and laboratory studies of persons who complained of low frequency noise in their homes. A number of common factors were shown:

The problems arose in quiet rural or suburban environments
The noise was often close to inaudibility and heard by a minority of people
The noise was typically audible indoors and not outdoors
The noise was more audible at night than day
The noise had a throbbing and rumbly characteristic
The main complaints came from the 55-70 years age group
The complainants had normal hearing.
Medical examination excluded tinnitus.

These are now recognised as classic "hum" descriptors.

Further work in the laboratory showed that gradually falling spectra, as measured in the field and simulated in the laboratory possessed a rumble characteristic. Figure 17 compares a measured noise on the left with a simulated noise on the right. Both fell at 7 – 8 dB/octave and had similar rumble characteristics. It is also known that a rapidly falling spectrum, such as one which follows the curve of the NR or NC ratings has an unpleasant quality.

This was one reason for the development of the PNC rating as an improvement of the NC rating (Beranek et al., 1971). Further work (Vasudevan and Leventhall, 1982), confirmed that levels close to threshold caused annoyance, which increased if the noise also fluctuated. This work included spectra with tonal peaks and emphasised that the nature (quality) of the noise was important. Fluctuating noises may be far more annoying than predicted by their average sound levels.

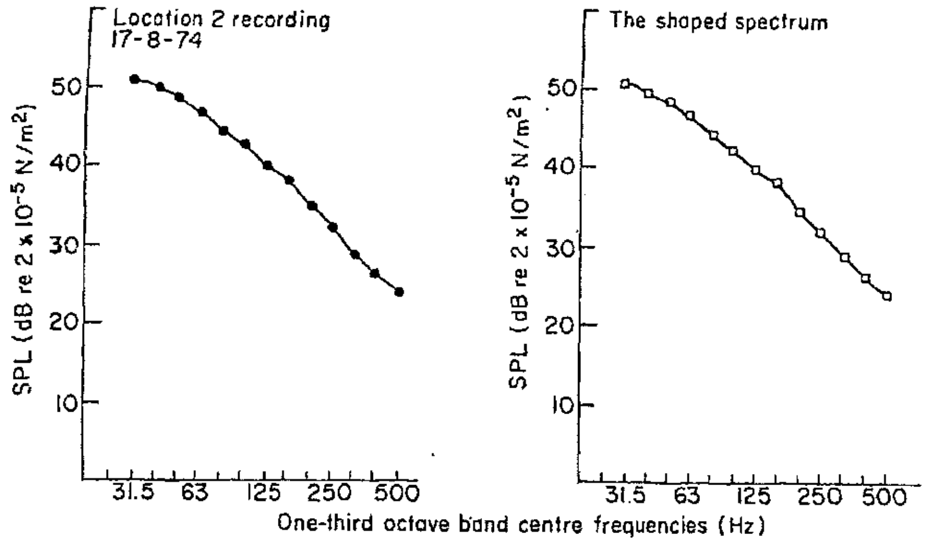


Figure 17. Measured spectrum (left) and simulated spectrum (right).

8.2.12 **Inherent fluctuations.** A narrow band of noise possesses inherent fluctuations. The band has a central "carrier" frequency at approximately the centre frequency of the band and a randomly fluctuating envelope with a mean frequency of (0.64x bandwidth) (Rice, 1954). This means, for example, that a third octave band of noise at 10Hz, which has a bandwidth of about 2.5Hz, will have amplitude fluctuations of mean frequency 1.6Hz. The amplitude fluctuations follow a Raleigh probability distribution. Physically one can interpret the phenomenon as a beating between components within the noise band and, as the components are of similar amplitude, the amplitude fluctuations are large.

The preceding paragraphs show that both wideband falling noise spectra and narrow band noise spectra may possess rumble characteristics.

8.2.13 **Annoyance in homes.** Recent work on annoyance to people in their homes has been by Mirowska (1998) and Lundin and Ahman (1998). Both these papers considered annoyance due to plant or appliances, installed in, or adjacent to, living accommodation. Mirowska found problems from transformers in electricity substations, ventilation fans, refrigeration units and central heating pumps. Lundin and Ahman investigated a husband and wife who experienced typical symptoms of aversion to low frequency noise. Refrigerators and freezers were suspected as the source of the offending noise which, in some parts of the building, was high at 50Hz. The time varying pattern of the noise, due to equipment cycling, was considered to add to its annoyance. However, there was no totally convincing link between effects on health and the noise.

9. Effects of low frequency noise on behaviour, sleep periods, task performance and social attitudes

9.1 **Naturally occurring infrasound.** The effects of infrasound generated by storms up to 1500 miles away were investigated in Chicago during May 1967, a period when the weather in Chicago was calm (Green and Dunn, 1968). Statistics on road traffic accidents and school absences indicated higher correlations on days of intense infrasonic disturbances, as compared with days of mild infrasound. The Föhn wind is a warm, dry down-current, which occurs in mountainous areas. It is associated with a sharp temperature rise, decrease in humidity and drop in barometric pressure. (Moos, 1963; Moos, 1964). It is not known whether infrasound has been measured under the conditions of the Föhn wind, but the shearing effects of the wind are potential sources of infrasound. Moos' suggestions, following a study of local statistics, included the following:

- *Pre-Föhn weather has biological effects.*
- *Mortality and birth rates are higher during Föhn periods than under other weather conditions.*

These papers refer to low frequency infrasound of natural occurrence. They are exploratory and have not been followed up by other workers.

9.2 **Low frequency noise and sleep.** Although exposure to low frequency noise in the home at night causes loss of sleep, there is evidence that low frequency noise under other conditions induces short sleep periods (Fecci et al., 1971; Landström and Byström, 1984; Landström et al., 1985; Landström et al., 1991; Landström et al., 1982; Landström et al., 1983).

Fecci et al monitored workers exposed to noise from air conditioning in a laboratory. The noise peaked at 8Hz with a level of 80dB, but also included broadband noise at higher frequencies. It was found, by EEG recording, that subjects exposed to the noise exhibited a much higher percentage of drowsiness than that found in a non-exposed population.

Landström and his colleagues carried out a series of laboratory evaluations of physiological effects of low frequency sound, with particular reference to sleep periods, as detected by EEG recordings. The main conclusions from this work are:

- *Exposure to intermittent noise at 16Hz and a level of 125dB was an effective stimulus of reduced wakefulness*
- *When stimuli at 6Hz and 16Hz were at 10dB below and 10dB above the hearing threshold, the levels above threshold led to a reduced wakefulness. The levels below threshold did not have this effect.*

- *When 10 deaf and 10 hearing subjects were exposed to 6Hz at 115dB for 20 minutes, reduced wakefulness was found amongst the hearing subjects, but not the deaf ones. This indicates that the effects depend on cochlear stimulation, since the noise was above threshold level.*
- *A reduction in wakefulness occurred during a repeating 42Hz signal at 70dB, whilst an increase in wakefulness occurred for a repeating 1000Hz signal at 30dB.*
- *Exposure to ventilation noise with and without tones indicated greater fatigue in the presence of the tone. A masking noise (pink noise) added to the ventilation noise tended to counteract this effect.*

The work by Landström and colleagues shows that low frequency noise above the threshold of hearing leads to reduction in wakefulness. This does not contradict Fecci, although the spectrum for the workers investigated by him was below threshold at the peak of 8Hz, as the spectrum was above the threshold at frequencies greater than 20Hz. Fecci may have been mistaken in attributing the effects he observed to the frequencies below 20Hz.

9.3 **Low frequency noise and task performance.** The hypothesis that low frequency noise may cause deterioration in the performance of tasks has been tested a number of times (Kyriakides and Leventhall, 1977; Landström et al., 1991; Persson-Waye et al., 2001; Persson-Waye et al., 1997).

Kyriakides and Leventhall used a continuous pointer-following task as the central task, whilst a peripheral task required a response to the onset of lights located both in front of the subject and on the periphery of vision. The test conditions were obtained from: audio frequency noise at 70dBA as the reference, an infrasound noise band from 2Hz to 15Hz at 115dB, an audio frequency noise band from 40Hz to 16kHz at 90dBA, alcohol (94mm^3 of vodka taken with fizzy orange) or a placebo (fizzy orange), combined alcohol and infrasound, combined audible noise and infrasound. The tasks were performed for 36 minutes. Results showed that, under the noise condition, performance was maintained for the central task, but the peripheral task deteriorated. The alcohol, which put subjects into a condition where they failed a breathalyser test, produced deterioration of both the central and peripheral tasks. The effects of infrasound were similar to alcohol in character, but not statistically significant. However, there was an indication that the effect of infrasound increased with time spent on the task.

Landström used figure identification as a test of performance, in which the subject had to identify five different patterns hidden in 15 different figures. Noise exposures were either to broadband ventilation noise, to which a tone at 100Hz, 40dBA, had been added, or to the tone noise with a pink masking noise (50 – 200Hz, 41dBA). The number of correct answers was lower without the masking noise.

Persson Waye et al (1977) assessed effects of low frequency noise on performance in a simulated office environment, in order to study both subjective and objective effects. Two ventilation noises were used, both of the same A-weighted level (41-42dBA) and NC / NR35 rating. One was mid frequency broadband, whilst the other had an added peak at 31.5Hz of 70dB, as shown in Figure 18. Subjects were selected from those who felt eardrum pressure from low frequency noise. The subjects performed three cognitive tasks under both noise conditions. The work showed that low frequency noise interfered more strongly with performance and that cognitive demands were less well coped with under these conditions. There was an indication of effects developing over time. Effects on mood included a lower social orientation and lowered feeling of pleasantness.

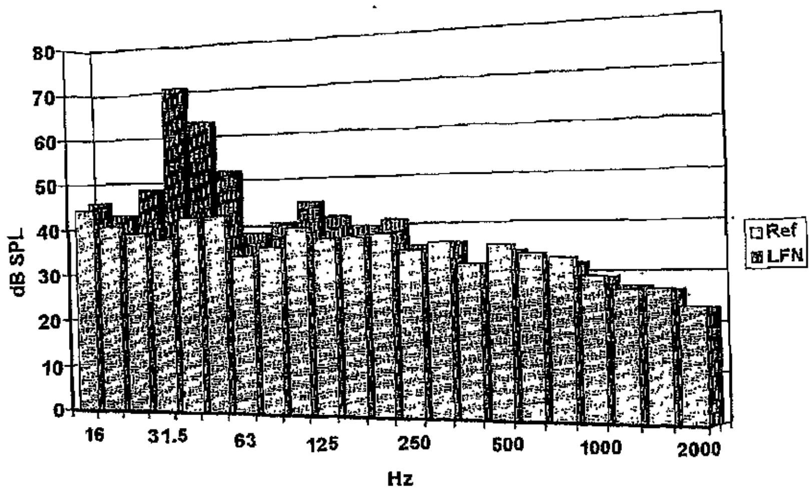


Figure 18. Test spectra, low frequency and mid frequency.

Perrson Waye et al (2001) refined and extended this work in order to answer the following questions:

- *Can low frequency noise, at a level normally present in control rooms and offices, influence performance and subjective well being?*
- *What kind of performance tasks are affected by low frequency noise?*
- *How is the performance affected by duration of exposure?*
- *What is the relation between self rated sensitivity and noise effects?*

A total of 32 subjects, assessed for sensitivity to low frequency noise, took part.18 subjects had high sensitivity to low frequency noise. Three computer-based and one pen and paper based performance tasks were used. Additionally, a questionnaire, to evaluate effort, mood, annoyance, adverse symptoms etc. was completed by the subjects. The results showed that low frequency noise, at levels occurring in office and control rooms, had a negative influence on more demanding verbal tasks, but its effects on more routine tasks was less clear. There was an indication that the low frequency noise was more difficult to ignore or habituate to, which may reduce available information processing resources. The study supports the hypothesis that low frequency noise may impair work performance.

Although these studies were directed at work environments, they have a clear application to effects of low frequency noise in the home.

10. Low frequency noise and stress

Stresses may be grouped into three broad types: cataclysmic stress, personal stress and background stress. Cataclysmic stress includes widespread and devastating physical events. Personal stress includes bereavements and similar personal tragedies. Cataclysmic and personal stresses are evident occurrences, which are met with sympathy and support, whilst their impacts normally reduce with time. Background stresses are persistent events, which may become routine elements of our life. Constant low frequency noise has been classified as a background stressor (Benton, 1997b; Benton and Leventhall, 1994). Whilst it is acceptable, under the effects of cataclysmic and personal stress, to withdraw from coping with normal daily demands, this is not permitted for low level background stresses. Inadequate reserves of coping ability then leads to the development of stress symptoms. In this way, chronic psychophysiological damage may result from long-term exposure to low-level low frequency noise.

Changes in behaviour also follow from long-term exposure to low frequency noise. Those exposed may adopt protective strategies, such as sleeping in their garage if the noise is less disturbing there. Or they may sleep elsewhere, returning to their own homes only during the day. Others tense into the noise and, over time, may undergo character changes, particularly in relation to social orientation, consistent with their failure to recruit support and consent that they do have a genuine noise problem. Their families and the investigating EHO may also become part of their problem. The claim that their "lives have been ruined" by the noise is not an exaggeration, although their reaction to the noise might have been modifiable at an earlier stage.

10.1 Low frequency noise and cortisol secretion. It is difficult to measure stress directly, but cortisol secretion has been used as a stress indicator (Ising and Ising, 2002; Persson-Waye et al., 2002; Persson-Waye et al., 2003). Under normal circumstances, cortisol levels follow a distinct circadian pattern in which the diurnal variation of cortisol is to drop to very low levels during the early morning sleep period, rising towards the awakening time. The rise continues until about 30 minutes after awakening, followed by a fall until midday and further fluctuations. Stress disrupts the normal cortisol pattern.

Ising and Ising (2002) discuss how noise, perceived as a threat , stimulates release of cortisol. This also occurs during sleep, thus increasing the level of night cortisol, which may interrupt recreative and other qualities of sleep. Measurements were made of the effect on children who, because of traffic changes, had become exposed to a high level of night lorry noise. There were two groups of subjects, exposed to high and low noise levels. The indoor noise spectrum for high levels typically peaked at around 60Hz, at 65dB, with a difference of maximum L_C and L_A of 26dB. The difference of average levels was 25dB, thus indicating a low frequency noise problem. Children exposed to the higher noise levels in the sample had significantly more problems with concentration, memory and sleep and also had higher cortisol secretions.

Conclusions of the work were that the A-weighting is inadequate and that safer limits are needed for low frequency noise at night.

Perrson Waye et al (2003), studied the effect on sleep quality and wakening of traffic noise (35dB L_{Aeq}, 50dBL_{Amax}) and low frequency noise (40dBL_{Aeq}). The low frequency noise peaked at 50Hz with a level of 70dB. In addition to cortisol determinations from saliva samples, the subjects completed questionnaires on their quality of sleep, relaxation and social inclinations. The main findings of the study were that levels of the cortisol awakening response were depressed after exposure to low frequency noise and that this was associated with tiredness and a negative mood.

In a laboratory study of noise sensitive subjects performing work tasks, it was found that enhanced salivary cortisol levels were produced by exposure to low frequency noise (Persson-Waye et al., 2002). A finding was that subjects who were sensitive to low frequency noise generally maintained higher cortisol levels and also had impaired performance. A hypothesis from the study is that changes in cortisol levels, such as produced by low frequency noise, may have a negative influence on health, heightened by chronic noise exposure.

The three studies reviewed above show how low frequency noise disturbs the normal cortisol pattern during night, awakening and daytime exposure. The disturbances are associated with stress related effects.

EEG recording has been used to study sleep disturbance by low frequency noise (Inaba and Okada, 1988). Subjects in a sleep laboratory were exposed to levels up to 105dB at 10Hz and 20Hz, up to 100dB at 40Hz and up to 90dB at 63Hz. The effects were assessed by the "sleep efficiency index", which is the ratio of total sleep time to time in bed. Sleep times were determined from continuous EEG recordings. There was little effect for sound levels under 85dB, but reactions for the highest sound levels were significantly greater at 40Hz and 63Hz than for 10Hz and 20Hz.

11. The HUM

11.1 **Occurrence.** The Hum is the name given to a low frequency noise which is causing persistent complaints, but often cannot be traced to a single, or any, source. If a source is located, the problem moves into the category of engineering noise control and is no longer "the Hum", although there may be a long period between first complaint and final solution. The Hum is widespread, affecting scattered individuals, but periodically a Hum focus arises where there are multiple complaints within a town or area. There has been the Bristol Hum (England), Largs Hum (Scotland), Copenhagen Hum (Denmark), Vancouver Hum (Canada), Taos Hum (New Mexico USA), Kokomo Hum (Indiana USA) etc. A feature of these Hums is that they have been publicised in local and national press, so gathering a momentum which otherwise might not have occurred. The concepts of memetics are applicable here. Memetics studies how ideas are spread by "memes", where a meme is defined as a cognitive or behavioural pattern, held in an individual's memory, which is capable of being copied to another individual's memory. As examples, Marsden considers an extreme application (Marsden, 2001) whilst Ross deals with the role of memes in psychosomatic illness (Ross, 1999).

Although the named Hums, such as Kokomo, have gained much attention, they should not be allowed to detract from the individuals who suffer on their own.

11.2 **Hum character.** The sound of the Hum differs between individuals. Even in the areas of multiple complaints, the description is not completely consistent, although this may be because people use different words to describe the same property of a noise. Publicity tends to pull the descriptions together. The general descriptors of the sound of the Hum include: a steady hum, a throb, a low speed diesel engine, rumble and pulsing. A higher pitch, such as a hiss, is sometimes attributed. The effects of the Hum may include pressure or pain in the ear or head, body vibration or pain, loss of concentration, nausea and sleep disturbance. These general descriptions and effects occur internationally, with close similarity.

Unsympathetic handling of the complaint leads to a build-up of stress, which exacerbates the problems. Hum sufferers tend to be middle aged and elderly, with a majority of women. They may have a low tolerance level and be prone to negative reactions. The knowledge that complaints are being taken seriously by the authorities helps to reduce personal tensions, by easing the additional stresses consequent upon not being believed. This is particularly so when, as is often the case, only one person in a family is sensitive to the noise. Whilst some Hum sufferers may have tinnitus, they will, of course, also be troubled by noise at a different frequency from their tinnitus.

11.3 **Psychological aspects.** Psychosocial factors affect the physiological impact of noise (Hatfield et al., 2001). Adverse physiological consequences may be mediated by psychological factors related to the noise exposure. It is plausible that excessive noise exposure promotes negative psychological reactions, leading to adverse physiological effects, as was shown by Hatfield et al. Therefore, psychological factors must be addressed to help ameliorate the effects of the Hum.

Some Hum sufferers have achieved this for themselves, saying that they have "learnt to live with the Hum" so that it no longer worries them. Others are "cured" by prescription of relaxant drugs. For a few, the Hum goes away after a time. Some escape the Hum by moving house. One long term sufferer, and leading campaigner for official help with low frequency noise problems, decided that it was time to leave the low frequency treadmill and now has no problem, remaining detached from low frequency noise and of the opinion that to become involved with other sufferers heightens ones awareness of the noise. Some sufferers accept that the noises are not at a high level, but that their reactions are equivalent to those which might be expected from a high level of noise – "As soon as I hear the noise, something builds up inside me". This is a similar response to that of hyperacusis sufferers, although more specialised in its triggers. A form of hyperacusis may be indicated.

Combined acoustical and psychological studies (Kitamura and Yamada, 2002) have explored involvement of the limbic system of the brain in the responses.[1] The limbic system commands survival and emotional behaviours, which we cannot always control, although we may learn to do so.

11.4 **Sources.** The Hum remains a puzzling aspect of low frequency noise. No widespread Hum has been unequivocally traced to specific sources, although suspicion has pointed at industrial complexes. At the time of writing, an investigation of the Kokomo Hum is in progress, fully financed by the local authorities.

In the absence of known sources, Hum sufferers often search their neighbourhoods for a source, walking or driving around at night. It is important for them to find a target for their frustrations. Some general ones include the main gas pipelines, radio transmissions (particularly pulsed signals for navigation), defence establishments etc. Gas pipelines have been investigated as a source (Krylov, 1995; Krylov, 1997). It was shown that there are circumstances where turbulence in the pipes could result in ground waves, which might couple with buildings and produce low frequency noise, although this has not been measured. However, a different explanation must be sought in areas remote from pipelines and it is possible that there are a number of unrelated sources, whilst in some cases there may be no sources. There have been other suggestions that the Hum may have its source in ground borne vibrations (Manley et al., 2002; Rushforth et al., 1999).

[1] The human brain has three layers representing its three stages of development. The primitive (reptilian) brain is connected with self preservation. The intermediate (old mammalian) brain is the brain of the inferior animals and related to emotions. This is the limbic system. The superior (new mammalian) brain is related to rational thought and intellectual tasks. The limbic system is activated by perceived threats.

11.5 **Auditory sensitivity.** Special difficulties arise when, despite persistent complaints, there is no "measurable" noise, or the noise levels at low frequencies are in the 40 - 50dB range, well below threshold. van den Berg supports tinnitus as an explanation in these circumstances (van den Berg, 2001). With respect to audibility, the average threshold levels must be interpreted carefully. van den Berg's choice of a limit criterion is the low frequency binaural hearing threshold level for 10% of the 50 – 60 year old population, which is 10-12 dB below their average hearing level (van den Berg and Passchier-Vermeer, 1999a). This may be too strict, since 10% of the age group has more sensitive hearing. For example, in England, which has a population of about 49,000,000, there are nearly 5,000,000 in the 50 – 59 year age group (see www.statistics.gov.uk). Thus, 500,000 of this age group in England will be more sensitive than the suggested cut-off for perception of low frequency noise. Yamada et al (1980) found one subject to be 15dB more sensitive than the average, whilst recent work (Kitamura and Yamada, 2002), gives two standard deviations from the average threshold as about 12dB. However, the average threshold of the complainants in this work is somewhat higher than the ISO 226 threshold. A range of two standard deviations covers 95% of people, Based on Kitamura and Yamada, three standard deviations, assuming a random distribution, is given by 18dB from the average threshold and covers 99% of the population. The remaining 1% includes 0.5% who are more sensitive than the three standard deviation limit and 0.5% less sensitive than this limit, at the opposite side of the average threshold. 0.5% of the population of England is about 245,000 persons, whilst 0.5% of the 50 – 60 year age group is about 25,000 people, who might have very sensitive low frequency hearing. A "rule of thumb" may be to take 15 - 20dB below the ISO 226 threshold as the cut off for perception, but this is a very generous level, depending on the complainants hearing level at low frequencies.

Advice on how to approach problems of the Hum is given in Section 14.

12. Surveys of occurrence and effects

In a catalogue of 521 social surveys (Fields, 2001), there are four which are specific to low frequency noise. Two of these are for clearly identified transport sources - air and rail – two are for noise from other sources (Mirowska and Mroz, 2000; Persson and Rylander, 1988) However, a number of additional surveys, either not listed by Fields or too recent for inclusion, have also been carried out (Møller and Lydolf, 2002; Persson-Waye and Bengtsson, 2002; Persson-Waye and Rylander, 2001; Tempest, 1989; Yamada et al., 1987).

12.1 Complaint surveys

12.1.1 Sweden. Persson and Rylander (1988) surveyed all the 284 local authorities in Sweden with respect to complaints from heat pumps, heavy traffic and fan and ventilation installations. These three sources were 71% of all noise complaints, comprising 42% ventilation systems, 20% heavy traffic, 9% heat pumps. Where there had been an increase in complaints over time, heat pumps and ventilation systems were the main problems. A recent follow-up (Persson-Waye and Bengtsson 2002) investigated changes over a 14 year period from 1988 by questioning a random selection of 41 environmental authorities, including 11 from districts with less than 50,000 inhabitants, 10 with 50,000 to 100,000 inhabitants and 11 with greater than 100,000 inhabitants. Low frequency noise represented 44% of the noise complaints, although some authorities had no complaints of low frequency noise, whilst one had over 200.

The sources of low frequency noise are shown in Figure 19.

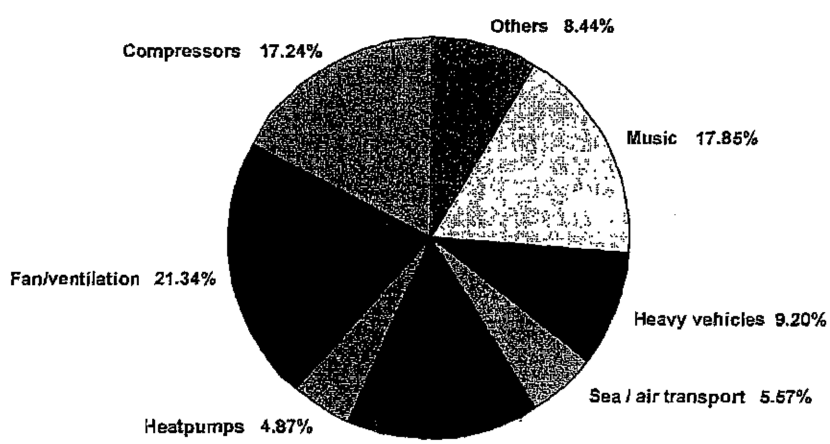


Figure 19. Percentages of sources causing complaints

This follow-up study showed a relative reduction of low frequency noise complaints compared with total noise complaints – 44% compared with 71%. This was thought to be due to a higher number of general noise complaints or to the limited selection of environmental authorities. Most of the authorities preferred assessment of low frequency noise by third octave analysis in preference to the use of A-weighting.

12.1.2 **UK.** Tempest (1989) conducted a survey amongst 242 UK local authorities, which was 50% of the total number. There was an 87% response (210) and 453 complaints of low frequency noise identified in the two year period covered by the survey. The distribution of complaints between categories is shown in Figure 20. It will be noted, in this UK survey, that there are very few internal sources. The conclusions of the survey were that, in the UK, there may be 526 complaints of low frequency noise a year and positive identification is made in 88% of cases. This leaves over 60 complaints a year which are potentially in the "Hum" unsolved category.

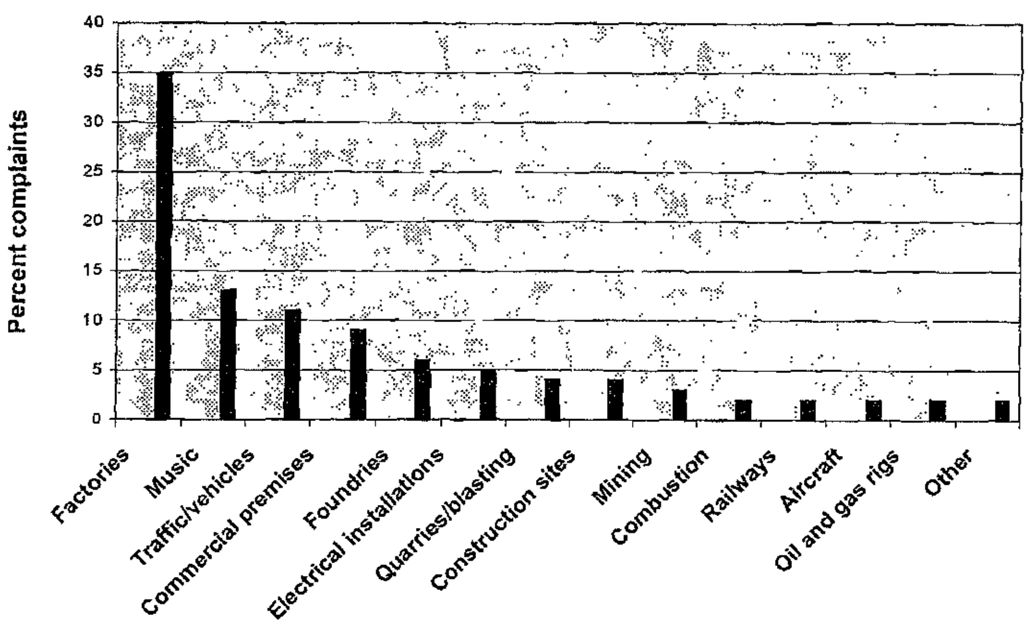


Figure 20. Complaint categories (Tempest 1989).

12.1.3 **Japan.** A database of low frequency noise problems has been established in Japan by collecting the results of published work (Yamada et al., 1987). 206 datasets were obtained giving personal details, including individual threshold measurements, the type of complaint and measured levels. Some main points from the survey are:

At the lower frequencies, below 16Hz, the levels which cause complaints of rattling of light-weight building components are below the hearing threshold.

The minimum measured threshold is 10-15dB below the average threshold.

12.1.4 **Denmark.** An extensive survey of individual complainants has been carried out in Denmark (Møller and Lydolf, 2002). 198 fully completed questionnaires were returned. The survey was detailed, containing 45 questions. The main results are:

Descriptions of the sound: Humming, rumbling, constant and unpleasant, pressure in ears, affects whole body, sounds like large idling engine, coming from far away.

Where and when heard: Mainly indoors at home (81.8%), some experience the noise outside, particularly close to home, only a slight preponderance for night time awareness.

Sensory perception: 92.9% heard the noise through their ears. Others were aware of it but did not register the noise as a sound. There was some vibration perception either through the body and by feeling vibration in buildings.

Time before trouble starts. Respondents were asked how long it was between awareness of the sound and adverse reactions to it. For over 60% it started immediately. About 25% required a few minutes awareness, 6% required ½ to 1 hour. A small percentage took longer.

Do other people hear or sense the sound? Nearly 40% were the only ones who perceived the sound. Nearly 30% said that just a few other persons did so, whilst 14% claimed that everybody did.

Type of effects. There were multiple effects. Disturbance while falling asleep (77.2%). Awakened from sleep (53.8%). Frequent awareness (68%). Frequent irritation (75.1%). Disturbed when reading (61.9%). The sound is a torment (76.1%).

Other troubles. Insomnia (67.5%). Dizziness (29.4%). Headaches (40.1%). Palpitation (41.1%). Lack of concentration (67%). Other effects (39.1%).

12.2 **Effects on health.** In an epidemiological survey of low frequency noise from plant and appliances in or near domestic buildings, the focus was on health effects (Mirowska and Mroz, 2000).

Percentages of exposed adults and the sources were as in Table 4.

Noise source	L_A dB	Percentage people exposed	Kind of exposure
Fans	26 – 31	33	Day, intermittent
Central heating pumps	23 – 33	18	Night, day intermittent
Transformers	20 – 23	30	Continuous
Refrigeration units	21 - 32	19	Night, day intermittent

Table 4. Noise exposures in survey.

In 81% of the test flats, levels were below the 25dBA night and 35dBA day criteria.

A control group of dwellings had comparable conditions to the test group, with similar A-weighted levels, except that there was no low frequency noise. There were 27 individuals in the test group and 22 in the control group.

The test group suffered more from their noise than the control group did, particularly in terms of annoyance and sleep disturbance. They were also less happy, less confident and more inclined to depression.

The comparison of the symptoms between the tested group and the control group show clear differences, as in Table 5.

Symptom	Test group %	Control group %
Chronic fatigue	59	38
Heart ailments anxiety, stitch, beating palpitation	81	54
Chronic insomnia	41	9
Repeated headaches	89	59
Repeated ear pulsation, pains in neck, backache	70	40
Frequent ear vibration, eye ball and other pressure	55	5
Shortness of breath, shallow breathing, chest trembling	58	10
Frequent irritation, nervousness, anxiety	93	59
Frustration, depression, indecision	85	19
Depression	30	5

Table 5. Health comparison of exposed and control group.

These results are extremely interesting as an epidemiological survey of an affected and a control group. Table 5 shows very adverse effects from low frequency noise levels which are close to the threshold and which do not exceed A-weighted limits.

Other work has investigated a group of 279 persons exposed to noise from heat pump and ventilation installations in their homes (Persson-Waye and Rylander, 2001). The experimental groups were 108 persons exposed to low frequency noise and 171 non-exposed controls. There was no significant difference in medical or psycho-social symptoms between the groups. This work did show that the prevalence of annoyance and disturbed concentration and rest was significantly greater among the persons exposed to low frequency noise. The A-weighted levels did not predict annoyance.

Effects of low frequency noise have also been investigated in the laboratory using the same subjects performing intellectual tasks, with and without low frequency noise in the noise climate, but at the same A-weighted level. It has been shown that, after the exposure session with low frequency noise, the subjects were less happy and recorded a poorer social orientation. (Persson-Waye et al., 1997).

12.3 **Defra survey.** The survey carried out in conjunction with this report for Defra was deliberately kept simple, asking a few questions as follows, in addition to personal details:

- *Date the noise was first heard*
- *Where the noise is heard*
- *The type of location*
- *Is there a suspected source?*
- *What does the noise sound like*
- *When is the noise heard most?*
- *What are the effects on you?*

Additional comments were also invited.

The distribution of survey forms was to known complainants of low frequency noise who had joined a pressure group: the Low Frequency Noise Sufferers Association, the Noise Abatement Society or the UK Noise Association. About 700 survey forms were distributed and 157 were returned. Some of the returns were not from genuine "hum" sufferers as they knew the source of the noise, for example traffic from a nearby busy roundabout, a nearby commercial or manufacturing establishment, vehicle reversing signals at a nearby supermarket goods-in area, a gunnery range, a police helicopter at night etc. However, they are people who react strongly to noise.

Main conclusions from the survey are:

12.3.1 Age range of complainants.

Below 25	none
26 – 35	0.65%
36 – 45	3.8%
46 - 55	15.9%
56 – 65	24.8%
66 – 75	32.5%
Above 75	12.7%
Unknown	9.5%

There is a clear increase with age. These figures are for men and women combined. Nearly two thirds of the respondents were female.

12.3.2 Where the noise is heard most

Generally in the home (Including the bedroom)	65%
House and garden	21%
Mainly the bedroom	8.9%
Outside only	1.9%
Only in the living room	1.3%
At a neighbours	0.65%
At the office	0.65%
Not given	0.65%

The great majority, about 95%, hear the noise in and around their homes.

12.3.3 When is the noise heard most?

At night only	48.4%
All the time	29.9%
Daytime	7%
Irregular	5%
Low background noise	3.2%
Evening	3%
Morning	1.3% (continued)
Depends on the wind	1.3%
Not given	1.9%

The majority , 78.3%, hear the noise all the time (including night) or at night only.

12.3.4 What does the noise sound like?

There were varied responses to this question. Over 20 different descriptions were given, ranging from the familiar "hum" to morse code dots, jiggling rattles and explosions. However, by combining similar responses, the following were produced.

Hum	39.5%
Pulsing	21.6%
Engine and similar	22.3%
Vibration	1.9%
Other	14.2%

The "engine and similar" group is made up of "engine, machinery, rumble and throb".

83.4% hear a hum, a pulsing or an engine. The engine is typically described as an idling diesel.

12.3.5 Is there a suspected source? The source was sometimes local and well known to the complainant. However, others were unable to suggest the source of their noise.

A total of 37 returns did not know the source. 30 returns blamed the gas supply system, but this response may have been partly due to previous publicity. The remaining 90 returns gave a wide range of sources, usually local.

12.3.6 Type of location. The respondents lived in a range of locations, spread widely across the UK. Rural, coastal, urban and suburban locations were included.

12.3.7 What is the effect of the noise on you? The effects were a close parallel to those in the Møller and Lydolf survey described above. Pain or pressure in the ears and head, sleep disturbance, irritation, body vibration and nausea were all present. A small number had habituated to the noise, so that they were no longer disturbed. One considered it as an intriguing, but harmless, curiosity.

13. General Review of Effects of Low Frequency Noise on Health[1]

The results of a recent survey of complaints about infrasound and low frequency noise on 198 persons in Denmark (Møller and Lydolf, 2002) revealed that nearly all reported a sensory perception of sound. They perceived the sound with their ears, but many mentioned also the perception of vibration, either in their body or in external objects. The sound disturbs and irritates during most activities, and many considered its presence as a torment to them. Many reported secondary effects, such as insomnia, headache and palpitation. These findings support earlier reports in the published literature.

13.1 **Historical**. Almost thirty years ago in a review paper of the effects of infrasound on man (Westin, 1975) drew attention to the fact that the amount of natural and man-made infrasound that man is subjected to is larger than is generally realised. He stated that the few studies that have concerned themselves uniquely with the physiological effects of moderate-to-high levels of infrasound exposure (as opposed to audible sound or vibration exposures) have failed to demonstrate significant effects on man other than those concerning the inner ear and balance control. But the existing studies indicate that inner ear symptoms due to moderate-to-high levels of infrasound may be more common than is generally appreciated. At very high sound pressure levels (greater than 140dB), ear pain and pressure become the limiting factors. Direct evidence of adverse effects of exposure to low-intensity signals (less than 90dB) is lacking.

Harris et al. (Harris et al., 1976) were of the opinion that the claims that infrasound adversely affects human performance, makes people "drunk" and directly elicits nystagmus, have not been clearly demonstrated in any experimental study. The effects obtained at low intensity levels of 105 to 120dB, if they can be substantiated at all, have been exaggerated. Recent well-designed studies conducted at higher intensity levels have found no adverse effects of infrasound on reaction time or human equilibrium. The levels at which infrasound becomes a hazard to man are still unknown. Previously, (Slarve and Johnson, 1975) had exposed four male subjects to infrasound ranging from 1 through 20Hz for a period of 8 minutes up to levels of 144dB. There was no objective evidence (including audiograms) of any detrimental effect of infrasound. However, all subjects experienced painless "pressure build-up" in the middle ear that was relieved by valsalva manoeuvre or by cessation of infrasound, and voice modulation and body vibration consistently occurred. They concluded that infrasound pressures as high as 144dB are safe for healthy subjects, at least for periods of 8 minutes, and they predicted that longer periods would also be safe. Borredon (Borredon, 1972) exposed 42 young men to 7.5Hz at 130 dB for 50 minutes. This exposure caused no adverse effects. The only statistically significant change reported among the

[1] This section was contributed by Dr P L Pelmear

many parameters measured was an insignificant (< 1.5 mm Hg) increase in the minimal arterial blood pressure. However, Borredon also reported that several of his subjects felt drowsy after the infrasound exposure.

13.2 **Effects on humans.** Infrasound exposure is ubiquitous in modern life. It is generated by natural sources such as earthquakes and wind. It is common in urban environments, and as an emission from many artificial sources: automobiles, rail traffic, aircraft, industrial machinery, artillery and mining explosions, air movement machinery including wind turbines, compressors, and ventilation or air-conditioning units, household appliances such as washing machines, and some therapeutic devices. The effects of infrasound or low frequency noise are of particular concern because of its pervasiveness due to numerous sources, efficient propagation, and reduced efficiency of many structures (dwellings, walls, and hearing protection) in attenuating low-frequency noise compared with other noise.

In humans the effects studied have been on the cardiovascular and nervous systems, eye structure, hearing and vestibular function, and the endocrine system. Special central nervous system (CNS) effects studied included annoyance, sleep and wakefulness, perception, evoked potentials, electroencephalographic changes, and cognition. Reduction in wakefulness during periods of infrasonic exposure above the hearing threshold has been identified through changes in EEG, blood pressure, respiration, hormonal production, performance and heart activity. Infrasound has been observed to affect the pattern of sleep minutely. Exposure to 6 and 16 Hz levels at 10 dB above the auditory threshold have been associated with a reduction in wakefulness (Landström and Byström, 1984). It has also been possible to confirm that the reduction on wakefulness is based on hearing perception since deaf subjects have an absence of weariness (Landström, 1987).

In moderate infrasonic exposures, the physiological effects observed in experimental studies often seem to reflect a general slowdown of the physiological and psychological state. The reduction in wakefulness and the correlated physiological responses are not isolated phenomena and the physiological changes are considered to be secondary reactions to a primary effect on the CNS. The effects of moderate infrasound exposure are thought to arise from a correlation between hearing perception and a following stimulation of the CNS. The participation of the reticular activating system (RAS) and the hypothalamus is thought to be of great importance. Taking this into account, changes in the physiological reactions are not just a question of whether the sound waves are above the hearing threshold. Furthermore reactions within the CNS, including RAS, hypothalamus, limbic system, and cortical regions are probably highly influenced by the quality of the sound. Some frequencies and characters of the noise are probably more effective than others for producing weariness.

A high degree of caution is necessary before ascribing the origin of physiological changes in working situations to infrasonic exposure because of their association. When analysing the factors promoting fatigue e.g. driving, many aspects have to be considered. The environment is usually a combination of many factors such as seat comfort, visibility, instrumentation, vibration and noise. However, it is an important fact that in many situations e.g. transport operations, there is a high degree of prolonged monotonous low frequency noise stimulation. This could be crucial in inducing worker fatigue and thereby constitute a safety hazard. Thus although exposure to infrasound at the levels normally experienced by man does not tend to produce dramatic health effects, exposure above the hearing perception level will produce symptoms including weariness, annoyance, and unease. This may precipitate safety concerns in some environmental and many work situations (Landström and Pelmear, 1993).

The primary effect of infrasound in humans appears to be annoyance. (Andresen and Møller, 1984; Broner, 1978a; Møller, 1984). To achieve a given amount of annoyance, low frequencies were found to require greater sound pressure than with higher frequencies; small changes in sound pressure could then possibly cause significantly large changes in annoyance in the infrasonic region (Andresen and Møller, 1984). Beginning at 127 to 133dB, pressure sensation is experienced in the middle ear (Broner 1978a). Regarding potential hearing damage Johnson (Johnson, 1982) concluded that short periods of continuous exposure to infrasound below. 150dB are safe and that continuous exposures up to 24 hours are safe if the levels are below 118dB.

13.3 **Biological effects on humans,** In the numerous published studies there is little or no agreement about the biological activity following exposure to infrasound. Reported effects include those on the inner ear, vertigo, imbalance etc.; intolerable sensations, incapacitation, disorientation, nausea, vomiting, bowl spasm; and resonances in inner organs, such as the abdomen and heart. Workers exposed to simulated industrial infrasound of 5 and 10Hz and levels of 100 and 135dB for 15 minutes reported feelings of fatigue, apathy and depression, pressure in the ears, loss of concentration, drowsiness, and vibration of internal organs. In addition, effects were found in the CNS, cardiovascular and respiratory systems (Karpova et al., 1970). In contrast, a study of drivers of long distance transport trucks exposed to infrasound at 115 dB found no statistically significant incidence of such symptoms (e.g. fatigue, subdued sensation, abdominal symptoms, and hypertension (Kawano et al., 1991).

Danielson and Landstrom (Danielsson and Landstrom, 1985) exposed twenty healthy male volunteers to infrasound in a pressure chamber and the effects on blood pressure, pulse rate and serum cortisol levels of acute infrasonic stimulation were studied. Varying frequencies (6, 12, 16Hz) and sound pressure levels (95, 110, 125dB) were tested. Significantly increased diastolic and decreased systolic blood pressures were recorded without any rise in pulse rate. The increase in blood pressure reached a maximal mean of about 8 mm Hg after 30 minutes exposure. Lidstrom (Lidstrom, 1978) found that long-term exposure of active aircraft pilots to infrasound of 14 or 16Hz at 125dB produced the same changes. Additional findings in the pilots were decreased alertness, faster decrease in the electrical resistance of the skin compared to unexposed individuals, and alteration of hearing threshold and time perception.

In several experiments to assess cognitive performance during exposure to infrasound (7 Hz tones at 125, 132, and 142dB plus ambient noise or a low frequency noise up to 30 minutes), no reduction in performance was observed in the subjects (Harris and Johnson, 1978). Sole exposure to infrasound at 10 to 15Hz and 130 to 135dB for 30 minutes also did not produce changes in autonomic nervous function (Taenaka, 1989). The ability of infrasound (5 and 16Hz at 95dB for five minutes) to alter body sway responses suggested effects on inner ear function and balance (Tagikawa et al., 1988).

To study vestibular effects in humans, both a rail-balancing task and direct nystagmus (involuntary eye movements) measurements have been used. In the balancing task subjects were required to balance on narrow rails while being presented with various acoustic stimuli. The task results indicated that humans were affected in the audible range as low as 95dB. For frequencies of 0.6, 1.6, 2.4, 7 and 12Hz, aural stimulation at levels as high as 14 dB, either monaural or bilateral, did not significantly affect rail-task performance (Harris, 1976; von Gierke, 1973). However, Evans (Evans and Tempest, 1972) examining the effect of infrasonic environments on human behaviour found that 30% of normal subjects exposed to tones of 2 – 10Hz through earphones at SPLs of 120 – 150Hz had nystagmus within 60 seconds of exposure to the 120dB signal, with 7Hz being most effective in causing it. Higher intensities resulted in faster onset of nystagmus, but there were no complaints of discomfort from any of the subjects at any SPL. Subsequently, Johnson (Johnson, 1975), who investigated nystagmus in many experiments under different conditions with aural infrasound stimulations from 142 to 155dB had negative results. For example, an investigator stood on one leg with his eyes closed, listening aurally to 165dB at 7Hz and 172dB at 1 to 8Hz (frequency sweep) without effect.

Research on the effect of infrasound on mental performance has also shown negative results. For example, infrasound at 125dB (7Hz) did not significantly affect subjects' ability to perform a serial search, a mental task requiring searching and linking pairs of numbers together into a progression (Harris and Johnson, 1978). Because of the lack of CNS effects in controlled studies, the reports of fatigue, drowsiness, or sleepiness have generally been discounted as unimportant. ACGIH believes these are the consequence of the simple relaxation effects of infrasound rather then any adverse health effect (ACGIH, 2001).

Although the effects of lower intensities are difficult to establish for methodological reasons, evidence suggests that a number of adverse effects of noise in general arise from exposure to low frequency noise: loudness judgements and annoyance reactions are sometimes reported to be greater for low frequency noise than other noises for equal sound pressure level; annoyance is exacerbated by rattle or vibration induced by low frequency noise; and speech intelligibility may be reduced more by low frequency noise than other noises except those in the frequency range of speech itself, because of the upward spread of masking. Intense low frequency noise appears to produce clear symptoms including respiratory impairment and aural pain. On the other hand it is also possible that low frequency noise provides some protection against the effects of simultaneous higher frequency noise on hearing (Berglund et al., 1996).

13.4 **Infrasound studies in laboratory animals.** The results of some animal studies reporting adverse effects from infrasound exposure may be relevant for indicating possible human health effects. The following studies would seem to be of interest.

a) Vascular - Myocardium

Alekseev (Alekseev et al., 1985) exposed rats and guinea pigs (5 test animals, 2 controls per group) to infrasound (4 to 16Hz) at 90 to 145dB for 3 h/day for 45 days; and tissues were collected on days 5, 10, 15, 25, and 45 for pathomorphological examination. A single exposure to 4 to 10 Hz at 120 to 125dB led to short-term arterial constriction and capillary dilatation in the myocardium. Prolonged exposure led to nuclear deformation, mitochondrial damage and other pathologies. Effects were most marked after 10 to 15Hz exposures at 135 to 145dB. Regenerative changes were observed within 40 days after exposure.

Gordeladze (Gordeladze et al., 1986) exposed rats and guinea pigs (10 animals per group) to 8Hz at 120dB for 3 h/day for 1, 5, 10, 15, 25, or 40 days. Concentrations of oxidation-reduction enzymes were measured in the myocardium. Pathological changes in myocardial cells, disturbances of the microcirculation, and mitochondrial destruction in endothelial cells of the capillaries increased in severity with increasing length of exposure. Ischemic foci formed in the myocardium. However, changes were reversible after exposure ceased.

Rats and guinea pigs exposed to infrasound (8 or 16Hz) at 120 to 140dB for 3 h/day for 1 to 40 days showed morphological and physiological changes in the myocardium. (Nekhoroshev and Glinchikov, 1991)

- Conjunctiva

Male rats (10 /group) exposed to infrasound (8Hz) at 100 and 140dB for 3 h/day for 5, 10, 15, or 25 days showed constriction of all parts of the conjunctival vasculature within 5 days (Svidovyi and Kuklina, 1985). Swelling of the cytoplasm and the nuclei of the endotheliocytes accompanied the decrease in the lumen of the capillaries. The capillaries, pre-capillaries, and arterioles became crimped. Morphological changes were reported in the vessels after exposure for 10, 15, and 25 days. After 25 days, increased permeability of the blood vessels led to swelling of tissues and surrounding capillaries and to peri-vascular leukocyte infiltration. Significant aggregates of formed elements of the blood were observed in the large vessels.

b) Liver

Infrasound exposure damaged the nuclei apparatus, intracellular membrane, and mitochondria of rat hepatocytes in vivo (Alekseev et al., 1987). Infrasound (2, 4, 8, or 16Hz) at 90 to 140 dB for 3 h/day for 40 days induced histopathological and morphological changes in hepatocytes from rats on days

5 to 40. Infrasound (8Hz) at 120 to 140dB induced pathological changes in hepatocytes from the glandular parenchyma and sinusoids.

Morphological and histochemical changes were studied in the hepatocytes of rats and guinea pigs exposed to infrasound (2, 4, 8, or 16Hz) at 90, 100, 110, 120, 130 or 140dB for 3 h/day for 5 to 40 days (Nekhoroshev and Glinchikov, 1992a). Hepatocytes showed increased functional activity, but exposures for 25 and 40 days induced irreversible changes. Changes were more pronounced at 8 and 16Hz than at 2 and 4Hz. Exposures impaired cell organoids and nuclear chromatin. Single exposures did not induce any changes in the hepatocytes and small blood vessels.

c) Metabolism

(Shvaiko et al., 1984) found that rats exposed to 8Hz at 90, 115, or 135dB exhibited statistically significant changes in copper, molybdenum, iron, and/or manganese concentrations in liver, spleen, brain, skeletal muscle, and/or femur compared to concentrations in the tissues of controls. Practically all tissues showed significant changes in all the elements for exposures at 135dB. Changes included elevations and depressions in concentrations. The trends were consistent with increasing sound pressure except for some tissue copper values.

d) Auditory

(Nekhoroshev, 1985) exposed rats to noise of frequencies 4, 31.5, or 53Hz at 110dB for 0.5 h, 3 h, or 3 h/day for 40 days. Infrasound exposure caused graver changes than exposure to sound at 31.5 or 53Hz. Changes observed after exposure to this acoustic factor included reduced activity of alkaline phosphotase in the stria vascularis vessels and their impaired permeability. Impaired labyrinthine hemodynamics led to neurosensory hearing impairment.

(Bohne and Harding, 2000) sought to determine if noise damage in the organ of Corti was different in the low- and high-frequency regions of the cochlea. Chinchillas were exposed for 2 to 432 days to a 0.5 (low-frequency) or 4kHz (high-frequency) octave band noise at 47 to 95dB sound pressure level. Auditory thresholds were determined before, during and after noise exposure. The cochlea's were examined microscopically, missing cells were counted, and the sequence of degeneration was determined as a function of recovery time (0 – 30 days). With high-frequency noise, primary damage began as small focal losses of outer hair cells in the 4-8kHz region. With continued exposure, damage progressed to involve loss of an entire segment of the organ of Corti, along with adjacent myelinated nerve fibres. With low-frequency noise, primary damage appeared as outer high cell loss scattered over a broad area in the apex. With continued exposure, additional apical hair cells degenerated, while supporting cells, inner hair cells, and nerve fibres remained intact. Continued exposure to low-frequency noise also resulted in focal lesions in the basal cochlea that were indistinguishable from those resulting from high-frequency noise.

In guinea pigs, low-frequency pressure changes have been shown to cause head and eye movements (nystagmus) of the animals for square wave pulses with pressure above 150 dB (Parker et al., 1968).

e) Brain

(Nishimura et al., 1987) suggested from experiments on animals that infrasound influences the rat's pituitary adreno-cortical system as a stressor, and that the effects begin at sound pressure levels between 100 and 120 dB at 16Hz. The concentration of hormones shows a slight increase with exposure to infrasound. In the task performance a reduction was seen in the rate of working. It seems probable that concentration was impaired by infrasound exposure.

(Nekhoroshev and Glinchikov, 1992b) exposed rats and guinea pigs (3 per sex per dose level) to 8Hz at 120 and 140dB for 3 hours or 3 h/day for 5, 10, 15, 25, or 40 days and they showed changes in the heart, neurons, and the auditory cortex increasing in severity with increasing length of exposure. The presence of hemorrhagic changes are attributed mostly to the mechanical action rather than to the acoustic action of infrasound. They suggested that the changes in the brain may be more important than in the ears.

f) Lung

Histopathological and histomorphological changes were determined in the lungs of male albino mice exposed to infrasound (2, 4, 8, or 16Hz) at 90 to 120dB for 3 h/day for up to 40 days (Svidovyi and Glinchikov, 1987). After prolonged exposure to 8 Hz at 120 dB sectioned lungs revealed filling of acini with erythrocytes and thickening of inter-alveolar septa; after prolonged exposure to 8 and 16Hz at 140dB sectioned lungs revealed ruptured blood vessel walls, partially destroyed acini, and induced hypertrophy of type-II cells.

13.5 **Discussion.** No medical condition has been reported in the literature (Tierney Jr et al., 2003) to be associated with the perception of infrasound or its enhancement, but many of the symptoms reported by complainants with perceived or actual infrasound exposure are associated with human disease.

Sleep disorders – getting to or staying asleep, intermittent wakefulness, early morning awakening or combinations of these are common in depression and psychiatric disorders, particularly manic. And they are associated with abuse of alcohol, heavy smoking, stress, caffeine, physical discomfort, daytime napping, and early bedtime.

Headache – chronic headaches are commonly due to migraine, tension or depression but may be related to intracranial lesions, head injury, cervical spondylosis, dental or ocular disease (glaucoma), temporo-mandibular joint dysfunction, sinusitis, hypertension and a wide variety of general medical disorders. By enquiry of precipitating factors, timing of symptoms, and progression most may be distinguished. Those associated with neurological symptoms need a cranial MRI or CT scan, however, about one third of brain tumours present with a primary complaint of headache. With brain tumours and abscesses the clinical presentation is variable and is primarily determined by anatomical location, proximity to the ventricles, and major alterations in the intracranial pressure dynamics secondary to the mass.

Vertigo – is the cardinal symptom of vestibular (ear) disease. Local causes include perilymphatic fistula, endolymphatic hydrops (Meniere's disease), labrynthitis, acoustic neuroma, ototoxicity, vestibular neuronitis, and vestibular migraine. Central causes include brainstem vascular disease, tumours of the brain stem and cerebellum, multiple sclerosis and vertebrobasilar migraine.

Nystagmus – common causes include Meniere's disease, labrynthitis (with hearing loss and tinnitus), transient following changes in head position, vertigo syndrome due to central lesions e.g. brainstem vascular disease, arteriovenous malfunctions, tumour of the brainstem and cerebellum, multiple sclerosis, and vertebrobasilar migraine.

Nausea and vomiting – this may be caused by a) visceral efferent stimulation – mechanical e.g. gastric outlet obstruction, peptic ulcer, malignancy, small intestine obstruction, adhesions, Crohn's disease, carcinomatosis etc.; dysmotility by medications, small intestine scleroderma, amyloidosis; peritoneal irritation; infections; hepatic disorders; cardiac and urinary disease. b) CNS disorders – vestibular; tumours; infection; and psychogenic (bulimia). c) irritation of chemoreceptor – antitumor chemotherapy; drugs; radiotherapy; pregnancy; hypothyroid and parathyroid disease.

Mental changes – nervousness, excitability, etc., which may be caused by underlying endocrine disorders e.g. hyperthyroidism, menopause, and vitamin deficiencies.

Hallucinations (usually auditory) – may be persistent or recurrent without other symptoms and are usually associated with delirium or dementia. Alcohol or hallucinogens are often the cause.

Hence in the evaluation of subjects with symptoms, which may be attributable to infrasound exposure, a full clinical examination and assessment needs to be undertaken to exclude any other primary or secondary cause.

13.6 **Conclusion.** There is no doubt that some humans exposed to infrasound experience abnormal ear, CNS, and resonance induced symptoms that are real and stressful. If this is not recognised by investigators or their treating physicians, and properly addressed with understanding and sympathy, a psychological reaction will follow and the patient's problems will be compounded. Most subjects may be reassured that there will be no serious consequences to their health from infrasound exposure and if further exposure is avoided they may expect to become symptom free.

14. Complaint procedures

Complaints of low frequency noise must be handled with sincerity and compassion, recognising that low frequency noise is an area of complex subjective diversity. An unsympathetic approach compounds the problems of the complainant, who may already be feeling distressed, disbelieved and isolated. This is especially so when complainants are the only one in their homes who hear the noise.

14.1 **UK advice.** Advice on how to approach investigation of a complaint is as follows. (Casella-Stanger, 2002).

The investigator's first visit should be handled with particular care and the complainant must be shown respect. The situation should be approached with an open mind in order to avoid any entrenched reaction to the complainant.

Continue to keep an open mind during the investigation. Discuss the problem with the complainant and obtain a history and background to it. The history should include the following.

- *When the noise was first heard*
- *Type of noise heard*
- *Duration and frequency of occurrence of the noise*
- *Complainant's belief about the source*
- *Effects of noise on the complainant*
- *Whether other family members hear the noise*
- *Whether the complainant believes he/she is particularly sensitive to other sources of noise.*

14.1.1 **Investigation procedure.** A flow chart of a typical investigation is given in Figure 21. One unfortunate outcome of unsympathetic handling may be that the complainant is transferred from noise specialist to medical specialist and back to noise specialist, whilst both maintain that they can find no basis for the complaint.

At the present time, some complainants of low frequency noise in the UK consider that they are inadequately served by Environmental Health Officers (Benton and Yehuda-Abramson, 2002; Guest, 2002). This is because of a perception of inadequate training in low frequency noise problems, inadequate equipment and a reliance on A-weighting for assessment, leading to frequent conclusions of "not a Statutory Nuisance". This is not the fault of the EHO's who have to work within the current legislation and with the equipment with which they are provided. These problems produce a sense of isolation in the complainant, with attendant elevation of anxiety. The authorities might view the resulting behaviour as inappropriate, but from the complainant's view it is the most rational and best they can achieve.

Decision Flow Chart

To assist in Low Frequency Noise Investigation

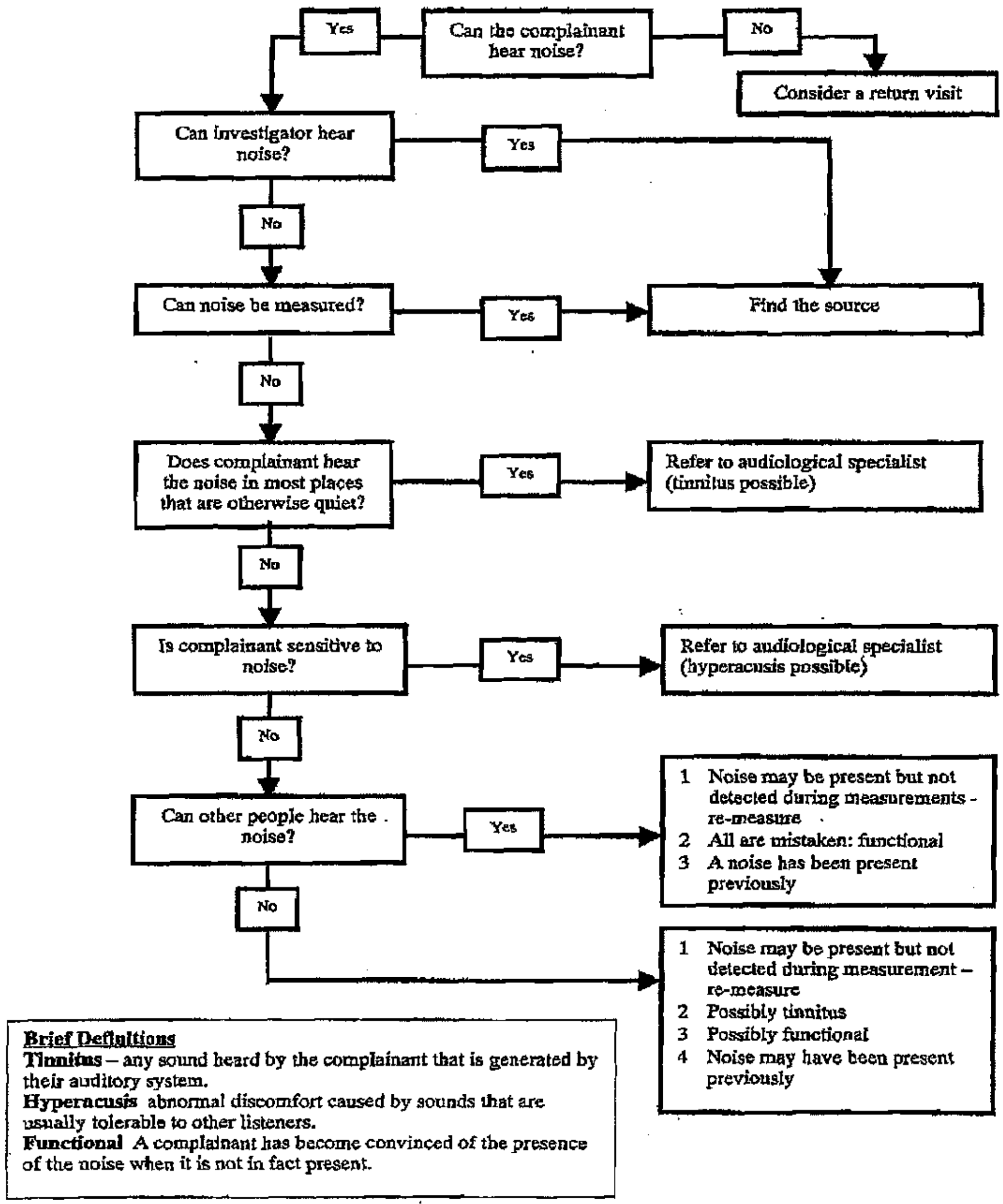


Figure 21. Flow chart of low frequency noise investigation.

14.2 Dutch advice. In the Netherlands, the Environmental Protection Agency of the Rotterdam region has adopted a structured approach to low frequency noise problems (Sloven, 2001). Support is provided for those who are called in to investigate low frequency noise, since the sporadic nature of the complaints means that there are few specialists.

Depending on how the complaint comes in, a typical procedure may be as follows. An inspector from the Environmental Protection Agency (technical aspects and management) contacts the appropriate Municipal Health Service (psychological and social aspects). They work together through a protocol similar to that in Figure 20 to determine whether the problem is "source orientated" or "person orientated".

The investigation is terminated when either the source is located and the problem solved, or if it is decided that the complainant is confused and needs alternative help. Termination may also occur for the following reasons:

- *Levels are very low and the source not determinable without excessive effort*
- *The source is known, but not controllable e.g. traffic*
- *Experience is that similar cases have not been solvable*
- *The complainant has multiple problems, others more severe than the low frequency noise*
- *The complainant refuses co-operation or decides to move house.*

The Dutch approach is interesting, as it makes use of both technical and social specialists, working together to obtain a rounded picture of the problem.

Technical assessment is based on the hearing level exceeded by 5% of the Dutch 55 year old population. Sloven notes that the average age of complainants of low frequency noise is 55, with two thirds female. This is similar to the experience of other countries, but Sloven adds that, for all environmental complainants in the Netherlands (20,000 a year), 70% are women with an average age of about 55, so that the pattern of low frequency noise complaints is not unusual. He also notes that, in about the year 2015, half of the Dutch population will be over 55 years of age.

15. Limits and Criteria

In setting criterion limits it is implicit that these are at levels which protect a certain percentage of the population. Noise levels at which protection is offered typically leave 10-20% of the population annoyed by a noise, since the desire to improve the environment is moderated by technical and economic factors. However, as there is a weak relation between the annoyance of low frequency noise in the home and its level, there may be an argument for more protective criteria for low frequency noise than those which are recommended for other noises (Benton, 1997a).

15.1 **Development of criteria.** Detailed criteria for environmental low frequency noise have developed over the past 25 years, driven by specific problems, particularly gas turbine installations, which radiate high levels of low frequency noise from their discharge. (Challis and Challis, 1978). Existing criteria from that time are reviewed by Challis and Challis. All criteria for low frequency noise seek to limit the low frequencies to a greater extent than would be permitted by general environmental noise criteria such as Noise Rating (NR), (Kosten and van Os, 1962), which is shown in Figure 22.

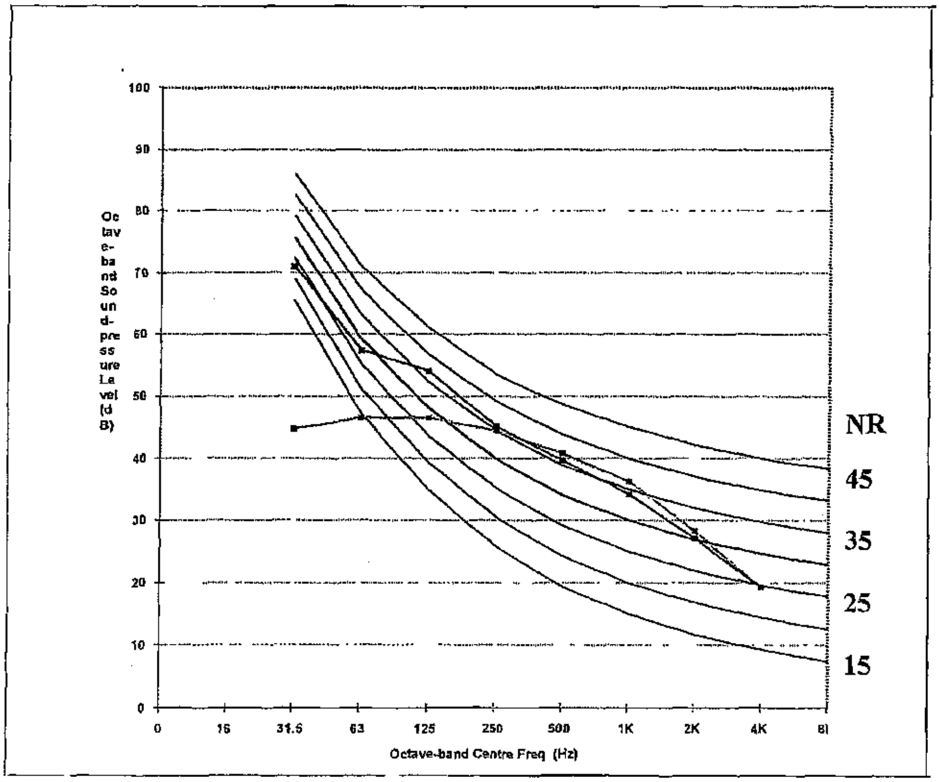


Figure 22. Noise Rating Curves. The two spectra of Figure 18 are plotted, showing how spectra with different subjective effects may have a similar NR number, in this case a little more than NR35.

For example, at low levels of mid-frequency noise, typical low frequency criteria permit a rise in noise levels of about 40dB between 8kHz and 31.5Hz, compared with about 60dB rise for NR 15. Most of the additional reduction is in the low frequency bands. Challis and Challis proposed a set of modified NR curves (NRM) following this pattern and extended down to 16Hz. Noise Rating is not suitable for use with those spectra which have high levels of low frequency noise. In fact, the spectra on which it was tested by Kosten and van Os were deficient in low frequency noise.

15.2 **Sound level meter weighting.** A sound level meter weighting curve was developed for low frequency noise assessment, as in Figure 23. (Inukai et al., 1990) The weighting curves pass more low frequencies through the sound level meter than the A-weighting does, giving them a greater influence on the overall sound level meter reading.

Both the LF curve and the LF2 curve rise in the region of 40Hz. In the LF2 curve, this is by about 10dB, which represents a selective penalty in the region of 40Hz.

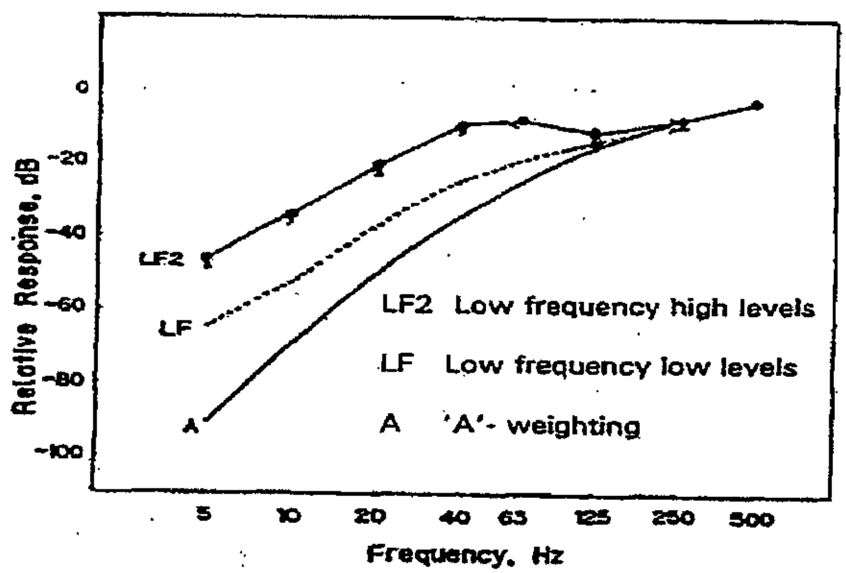


Figure 23. Sound level meter low frequency weighting networks.

15.3 **LFNR Curves.** Similar results had been found by Broner and Leventhall (1983) in work which was based on experiments with subjects judging annoyance of 10Hz wide bands of low frequency noise from 25Hz to 85Hz centre frequencies. It was found that there was a peak in annoyance in the bands with centre frequencies 35Hz and 45 Hz, showing that these bands were more annoying than the lower or higher frequency bands. A similar result had been obtained earlier (Kraemer, 1973). Broner and Leventhall used their results to modify the NR curves in the low frequency region, leading to the LFNR curves, which impose low frequency penalties as shown in Figure. 24. The curves are similar to NR curves down to 125Hz, but are more restrictive at lower frequencies. The curves are used in the following way.

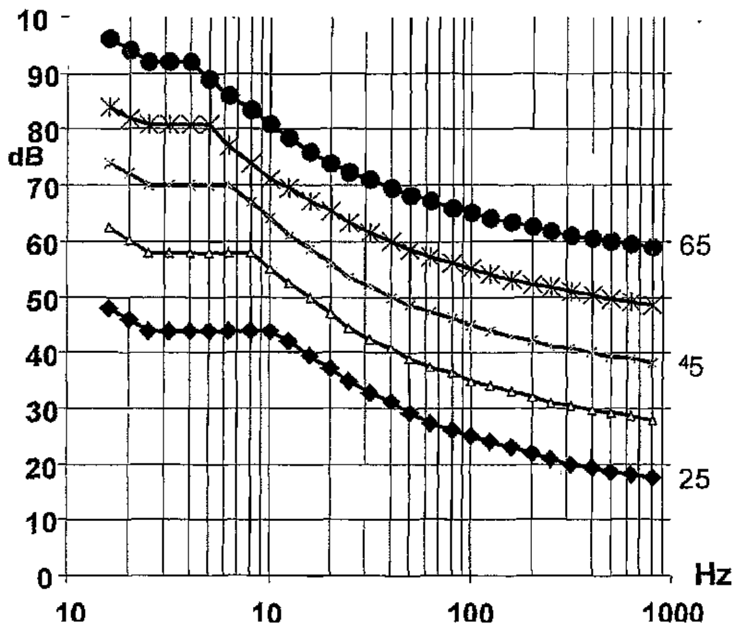


Figure 24. Low frequency noise rating curves LFNR. Each point is at a third octave frequency.

Plot the noise spectrum on the curves and, for frequencies above 125Hz, determine the appropriate rating curve in the normal way. If the spectrum of frequencies below 125Hz exceeds this rating curve, there is the potential for a low frequency problem. The curves assess not only the level of the noise, but also its spectrum balance. A penalty of 3dB was suggested for a noise which was fluctuating. The LFNR curves have not been widely adopted, but it is known that they have been used by some UK local authorities.

15.4 **Low frequency A-weighting.** Another approach to low frequency limits (Vercammen, 1989; Vercammen, 1992) uses a reference curve related to the average threshold minus two standard deviations. Vercammen also suggests using the G-weighting for infrasound, an A-weighting of the range 10Hz to 160Hz (LF_A) for low frequencies and the normal A-weighting for higher frequencies. The following are proposed as typical interior criterion levels.

Measurement	Day	Evening	Night
L_A	35	30	25 dBA
L_G	86	86	86 dBG
LF_A	30	25	20 dBA

It is not possible to make a direct measurement of LF_A by filtering the input to a sound level meter, as the specification of low frequency A-weighting permits wide tolerances. Consequently, third octave band levels are taken from 10Hz to 160Hz and summed for their A-weighting. Vercammen also notes the problems of assessing fluctuations in noise level.

15.5 **National Criteria.** The interest in criteria for low frequency noise and pressure from complainants, who have felt badly served by the regulatory authorities, has led to a number of countries developing criteria for assessment of low frequency noise problems. The criteria are summarised below:

15.5.1 **Sweden.** Recommendations for assessment of indoor low frequency noise (Socialstyrelsen-Sweden, 1996) are shown in the Criterion column of Table 6, which also includes the ISO 226 threshold. It is clearly the intention that the lowest frequencies shall not be audible to the average person. However, measurements are of the equivalent noise level (averaged over time) in the third octave band, so missing some of the annoying characteristics of a noise – fluctuations, rumble etc. The averaged level is appropriate to a steady tone, but has limitations for other noises. In the application of this method, the noise may be considered a nuisance if its level exceeds the criterion curve in any third octave band.

Frequency 1/3 octave band Hz	Criterion dB	ISO 226 threshold dB
31.5	56	56.3
40	49	48.4
50	43	41.7
63	41.5	35.5
80	40	29.8
100	38	25.1
125	36	20.7
160	34	16.8
200	32	13.8

Table 6. Swedish limits for low frequency noise

15.5.2 **Netherlands.** This method, which is intended to determine audibility is based on the average low frequency hearing thresholds for an otologically unselected population aged 50 – 60 years, where the reference levels are the binaural hearing threshold for 10% of the population. That is, the 10% most sensitive. The age range of 50 - 60 years was chosen as typical of the age of complainants. (N S G, 1999; van den Berg and Passchier-Vermeer, 1999a). Comparing 50% levels for 50 – 60 year olds with those of young persons, Table 7 shows that the older people are taken as 7dB less sensitive, on average, than the younger ones. At the 10% level they are 3dB less sensitive. Information is not given on whether, at lower percentage levels e.g. 5% or 1%, this difference reduces further. The 10% curve is used by considering noise levels exceeding those in the NSG reference curve in the range 20Hz to 100Hz, in order to draw conclusions on their audibility.

The above method is for audibility, not annoyance. A Dutch proposal for annoyance (Sloven, 2001) uses a criterion curve which is close to the German threshold below 40Hz and then corresponds with the Swedish method.

Low frequency hearing threshold for levels for 50% and 10% of the population.
(NSG reference curve in bold)

Freq Hz	Otologically Unselected Population 50 – 60 years 50% dB	10% dB	Otologically Selected Young adults (ISO 226) 50% dB	10% dB
10	103	92	96	89
12.5	99	88	92	85
16	95	84	88	81
20	85	**74**	78	71
25	75	**64**	66	59
31.5	66	**55**	59	52
40	58	**46**	51	43
50	51	**39**	44	36
63	45	**33**	38	30.
80	39	**27**	32	24
100	34	**22**	27	19
125	29	18	22	15
160	25	14	18	11
200	22	10	15	7

Table 7. NSG reference curve

15.5.3 Denmark. This method is similar to a proposal of Vercammen, above, in that the G-weighted levels, the A-weighted levels in the 10Hz to 160Hz third octave bands and the normal A-weighting are used (Jakobsen, 2001). Criteria are then as in Table 8 for internal noise levels.

	Infrasound L_{pG}	Low frequency noise $L_{pA,LF}$	Normal noise limit L_{pA}
Dwelling, evening and night	85dB	20dB	30dB / 25dB
Dwelling, day	85dB	25dB	30dB – day and evening
Classroom, office etc	85dB	30dB	40dB .
Other rooms in enterprises	90dB	35dB	50dB

Table 8. Danish recommendations

The levels in Table 8 for infrasound are intended to make the G-weighted noise inaudible, being set at 10dB below the G-weighting for the average threshold. There is conjunction at about 16Hz between 85dBG and 20dBA, as shown in Figure. 6 (Section 4.1.1). In the operation of the limits, the noise is measured over a 10 minute period and a 5dB penalty added for impulsive noise e.g. single blows from a press or drop forge hammer. Rumble or similar fluctuation characteristics are not considered and will be averaged out in the 10 minute measurement period.

15.5.4 Germany. This method (DIN:45680, 1997), is based on investigations in the region of industrial installations (Piorr and Wietlake, 1990). Hearing threshold levels used in DIN 45680 are given in Table 9, showing that the thresholds are close to those of ISO 226. The difference (dBC - dBA) > 20dB is used as an initial indication of the presence of low frequency noise. The noise is then measured in third octaves over specified time periods and compared with the threshold curve in Table 9. The main frequency range is from 10Hz to 80Hz. Frequencies of 8Hz and 100Hz are used only if the noise has many components within the range 10Hz to 80Hz. However, there is an assumption in DIN 45680 that the great majority of low frequency noise problems from industrial sources are tonal and that 8Hz and 100Hz third octave bands will be used only rarely. If the level in a particular third octave band is 5 dB or more above the level in the two neighbouring bands, the noise is described as tonal. For tonal noises, the level of the tone above the hearing threshold is found. The day time limit for exceedance of the threshold curve is 5dB in the 8Hz – 63Hz bands, 10dB in the 80Hz band, and 15dB in the100Hz band. In the night period all the limits are reduced by 5dB.

Third octave band frequency Hz	Hearing threshold dB	ISO 226 threshold dB
(8)	(103)	--
10	95	--
12.5	87	--
16	79	--
20	71	74.3
25	63	65.0
31.5	55.5	56.3
40	48	48.4
50	40.5	41.7
63	33.5	35.5
80	28	29.8
(100)	(23.5)	25.1

Table 9. Hearing threshold DIN 45680

For non-tonal noises, the limit for the A-weighted equivalent level (10 Hz – 80 Hz) is 35 dB during daytime and 25 dB during the night, where the A-weighting is obtained by using only the third octave bands which exceed the hearing threshold. Contributions from levels below the threshold are disregarded.

15.5.5 Poland. This method (Mirowska, 2001) uses the frequency range 10Hz to 250Hz. The sound pressure levels of the third octave bands of the noise are compared with a reference curve L_{A10}, derived from $L_{A10} = 10 - k_A$, where k_A is the value of the A-weighting for the centre frequencies of the third octave bands and is negative over the low frequency region. Thus, the L_{A10} curve is 10dB greater than the absolute value of the A-weighting corrections and any single frequency which met the curve will have a level of 10dBA. The curve is shown in Table 10 where it is compared with the ISO 226 threshold. The reference curve is below the ISO 226 threshold at the lower frequencies.

Frequency Hz	L_{A10} dB	ISO 226 dB
10	80.4	
12.5	83.4	
16	66.7	
20	60.5	74.3
25	54.7	65.0
31.5	49.3	56.3
40	44.6	48.4
50	40.2	41.7
63	36.2	35.5
80	32.5	29.8
100	29.1	25.1
125	26.1	20.7
160	23.4	16.8
200	20.9	13.8
250	18.6	11.2

Table 10. Polish reference levels L_{A10}.

The Polish method also takes background noise into account by determining the difference between the sound pressure levels of the noise and the background noise. Consequently there are two components in the assessment:

ΔL_1 - the difference between the measured sound pressure level and the L_{A10} curve.
ΔL_2 - the difference between the sound pressure levels of the noise and the background noise.

The noise is considered to be annoying when:
$\Delta L_1 > 0$
$\Delta L_2 >$ 10dB for tonal noise or 6dB for broadband noise

15.6 Comparison of methods.

15.6.1 Criterion curves. The National assessment methods compare the low frequency hearing threshold, or a function related to it, with the problem noise. Where A-weighting is used, there is an assumption that this weighting reflects hearing sensitivity at low frequencies. However, as the A-weighting is loosely based on what was considered to be the 40 phon loudness contour in the mid 1930's, it has a lower slope than the threshold. Figure 6 shows how the 20dBA curve crosses the threshold at about 30Hz, where the 20dBA curve denotes the levels of tones which will individually register as 20dBA. The reference curves are compared in Table 11. Poland requires the lowest levels and is 10dB lower than Denmark, since one is based on 10dBA and the other on 20dBA. The Netherlands and Germany use an assumed hearing threshold as their reference. Sweden describes a limiting noise curve, which should not be exceeded in any band. This curve is similar to ISO 226 between 31.5Hz and 50Hz, beyond which it tends towards 20dBA.

None of the methods assesses fluctuations, although Denmark imposes a penalty for impulses. The methods are generally designed for assessment of steady tones, but will underrate the subjective consequences of fluctuations, which are the main complaint of many sufferers.

	Poland	**Germany**	**Netherlands**	**Denmark Night**	**Sweden**	**ISO 226**
Frequency Hz	**L_{A10} dB**	**DIN 45680 dB**	**NSG dB**	**20dBA**	**dB**	**dB**
8		103				
10	80.4	95		90.4		
12.5	83.4	87		93.4		
16	66.7	79		76.7		
20	60.5	71	74	70.5		74.3
25	54.7	63	64	64.7		65.0
31.5	49.3	55.5	55	59.4	56	56.3
40	44.6	48	46	54.6	49	48.4
50	40.2	40.5	39	50.2	43	41.7
63	36.2	33.5	33	46.2	41.5	35.5
80	32.5	28	27	42.5	40	29.8
100	29.1	23.5	22	39.1	38	25.1
125	26.1			36.1	36	20.7
160	23.4			33.4	34	16.8
200	20.9				32	13.8
250	18.6					11.2

Table 11. Comparison of reference curves.

15.6.2 Measurement positions. A-weighted levels for assessment of environmental noise are normally taken outside a residential property. The complexities of low frequency noise, including uncertainties in the transmission loss of the structure and resonances within rooms, require low frequency noise to be assessed by internal measurements. This is recognised in the assessment procedures.

There is a measurement uncertainty, which is inversely proportional to both the bandwidth of the analysis and to the duration of the measurement (i.e. the integration time). As a result, the measurement period using a given third octave filter is related to the required accuracy. If the standard deviation of repeated measurements shall be less then 0.2 dB an integration time of almost five minutes is needed at 10 Hz. At 40 Hz a one-minute integration time is necessary and at 1000 Hz two seconds are needed. The noise signal is assumed to be stable over the measurement time, but this is not always so in practise.

16. Validation of the Methods

Piorr and Wietlake (1990) used a night reference curve identical to DIN 45680 up to 63Hz. They reported that 90% of complainants were satisfied with the implementation of the limits. Subsequently, Piorr and Wietlake's night criterion was applied to investigations in the UK (Rushforth et al., 2002) and found to be a "reasonably good predictor of annoyance".

Laboratory measurements using recordings of actual noises (Poulsen, 2002; Poulsen and Mortensen, 2002) have been used to compare the effectiveness of proposed national assessment methods for low frequency noise limits. The noise examples are shown in Table 12.

No.	Name	Description	Tones, characteristics
1	Traffic	Road traffic noise from a highway	None – broadband, continuous
2	Drop forge	Isolated blows from a drop forge transmitted through the ground	None – deep, impulsive sound
3	Gas turbine	Gas motor in a CHP plant	25 Hz, continuous
4	Fast ferry	High speed ferry; pulsating tonal noise	57 Hz, pass-by
5	Steel factory	Distant noise from a steel rolling plant	62 Hz, continuous
6	Generator	Generator	75 Hz, continuous
7	Cooling	Cooling compressor	(48 Hz, 95 Hz) 98 Hz, continuous
8	Discotheque	Music, transmitted through a building	None, fluctuating, loud drums

Table 12. Comparison of test noises.

Noise no. 1 is from a busy six-lane highway and it is almost continuous. Noise no. 2 consists of a series of very deep, rumbling single blows from a drop forge. Noises 3, 4, 5, and 6 each have one tonal component. Noise no. 7 has three tones but two of them are at a low level, and noise no. 8 has a characteristic rhythmical pulsating sound. The noises were selected to represent typical low frequency noise known to cause complaints. All noises had a clear low frequency character.

The noises were presented to 18 otologically normal young listeners in two minute durations and at levels of 20 dB, 27.5 dB, and 35 dB L_{Aeq}, in simulated indoor conditions. A special group of four older people (41 – 57 years old), who were known to be disturbed by low frequency noise, were also tested with the same noises. The subjects made annoyance judgements depending on assumed circumstances, such as day, evening and night. For example, Table 13 gives the night annoyance for the main group on a numerical scale, where 0 is not annoying and 10 is very annoying.

Nominal presentation level	20 dB	27.5 dB	35 dB
Noise example	Subjective annoyance Night	Subjective annoyance Night	Subjective annoyance Night
Traffic noise	1.6	3.4	5.2
Drop forge	4.3	5.9	6.9
Gas turbine	0.9	2.5	5.2
Fast ferry	0.9	3.2	5.4
Steel factory	1.0	2.7	4.9
Generator	1.7	3.2	5.0
Cooling compressor	2.7	4.4	6.0
Discotheque	3.0	5.4	6.7

Table 13. Subjective assessment of the annoyance, main group - if the noise was heard at night.

The special group were more annoyed by the noise as shown in Table 14.

Nominal presentation level	20 dB	27.5 dB	35 dB
Noise example	Subjective annoyance Night	Subjective annoyance Night	Subjective annoyance Night
Traffic noise	4.7	7.2	8.5
Drop forge	7.5	8.3	8.9
Gas turbine	5.0	8.1	9.8
Fast ferry	6.6	8.8	9.3
Steel factory	5.8	8.2	9.3
Generator	8.4	8.3	9.0
Cooling compressor	7.4	8.5	9.1
Discotheque	6.0	7.9	8.6

Table 14. Subjective assessment of the annoyance, sensitive group - if the noise was heard at night.

The special group judged noises differently from the main group, as shown in Table 15. Here it is seen that the special group found all noises more annoying than the main group did, but that they were most annoyed by the type of noises they complained about, perhaps indicating conditioning.

Ref Group order	Average scaling	Special group order	Average scaling
Drop forge	5.1	Generator	7.3
Discotheque	4.6	Cooling compressor	7.2
Cooling compressor	4.1	Drop forge	7.0
Generator	3.1	Gas turbine	6.9
Traffic noise	3.0	Fast ferry	6.9
Fast ferry	2.9	Steel factory	6.8
Steel factory	2.7	Discotheque	6.2
Gas turbine	2.7	Traffic noise	5.6
Average	**3.5**	**Average**	**6.7**

Table 15. Comparison of group noise ordering.

These subjective evaluations were then compared with the objective methods in the National procedures as shown in Table 16. It is seen that the Danish method gives best correlation with subjective evaluation, but this depends on the 5dB penalty for impulsive sounds. Without this penalty, it is similar to the German and Swedish methods.

Assessment method	Correlation coefficient, ρ
Danish	0.94
German non-tonal	0.73
German tonal	0.72
Swedish	0.76
Polish	0.71
Dutch proposal	0.64
C-level	0.66

Table 16 . Overview of the results from regression analysis of the relation between the subjective evaluations and the different objective assessment methods.

For the noises used, which are typical of low frequency noises, the infringement of the criterion curves is by a single frequency band. Only the band where the maximum excess occurs is taken into account and the excess at other frequency bands is neglected. It is seen from the comparison of the criteria in Table 11 that the curves diverge above about 40Hz, with the result that, at 100Hz, the German limit is about 15dB below the Swedish and Danish limits. Thus the different criteria will give different outcomes if the infringement is at frequencies above 40Hz.

17. Further Research

The preceding sections have shown that there are a number of gaps in our knowledge of low frequency noise. We do know that problems arise fairly widely, and on an international scale. A great deal of distress is caused to a limited number of people, who are unfortunate to be classified as "sufferers", although suffering is an apt description of the effects on them. It is no longer necessary to "make a case" for work on low frequency noise, but the direction of the work should be chosen to maximise benefit to the sufferers. There are two main areas to be addressed:

- *Assessment of the noise*
- *Development of personal coping strategies.*

Assessment assumes that there is a measurable noise.

Enhanced coping strategies are required:

- *During the time delay between occurrence of a noise and its control*
- *If the noise cannot be located.*
- *If the noise cannot be measured*

17.1 **Assessment.** A not uncommon occurrence is that there is clearly a low frequency noise present at a complaint location, but existing UK assessment methods are not able to determine its nuisance value, leading to the conclusion of "Not a Statutory Nuisance". Section 15 has outlined the assessment methods of other countries, which are able to draw positive conclusions on noises that would fail an A-weighting test. Further work should be carried out on assessment of low frequency noises, building on what is already known.

17.1.1 **Noises.** A number of noises, which are known to be causing low frequency problems, could be analysed and assessed by existing low frequency noise assessment methods. Calibrated tape recordings would be made of the noises, so that time variations could be evaluated. An attempt would also be made to determine an "annoyance rating" for the complainant. This would be through questioning and discussion in order to evaluate both the level of annoyance and the personality of the complainant.

The interdependence of spectra, fluctuations and complainant characteristics would be used to develop an assessment method that is more reliable than existing methods.

17.1.2 **Benefits.** The work would provide a means of assessing low frequency noises, for piloting by Environmental Health Officers and ultimately included in national recommendations.

17.2 Coping strategies. Some Hum sufferers report that they have been able to adopt strategies which ease the effects on them of their noise of unknown origin. In a few cases a complete "cure" has been achieved. An element of the strategy is to stop fighting the noise and relax one's physical and mental responses to it. There is a great deal to be learned from the methods of tinnitus management, which have developed over the past 20 years. This is not to imply that those low frequency noises which cannot be sourced are actually tinnitus, but that the experiences are similar; the complainant hears a noise that elicits a negative reaction. The research on coping strategies could evolve in the following way:

- *Consult with former sufferers who have accommodated to their noise, in order to learn from their strategies*
- *In parallel with this consult with tinnitus management specialists on their techniques.*
- *Recommend strategies for management of low frequency noise problems.*
- *Carry out field studies of management of low frequency noise. Where necessary co-operate with social services and GP.*
- *Follow up later to assess the results.*
- *Develop a training programme for EHO's and personal advice for sufferers.*

17.2.2 Benefits. The work has the potential to improve the quality of life of complainants, reduce the level of complaints of noise and also reduce the demands on environmental, social and health services. It will reduce the extent to which low frequency noise complaints become stuck in the system, as many do at present, with costly and damaging results.

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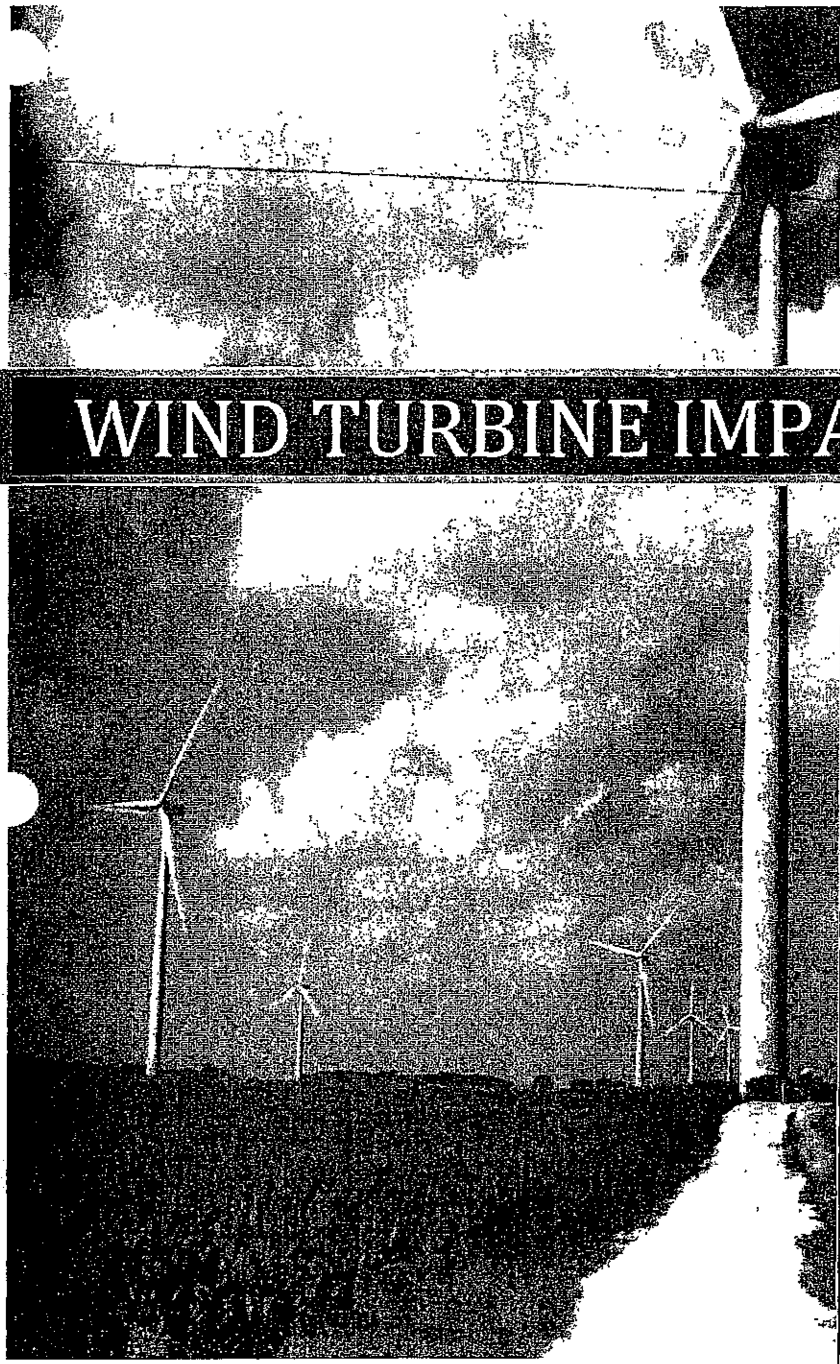
2009

WIND TURBINE IMPACT STUDY



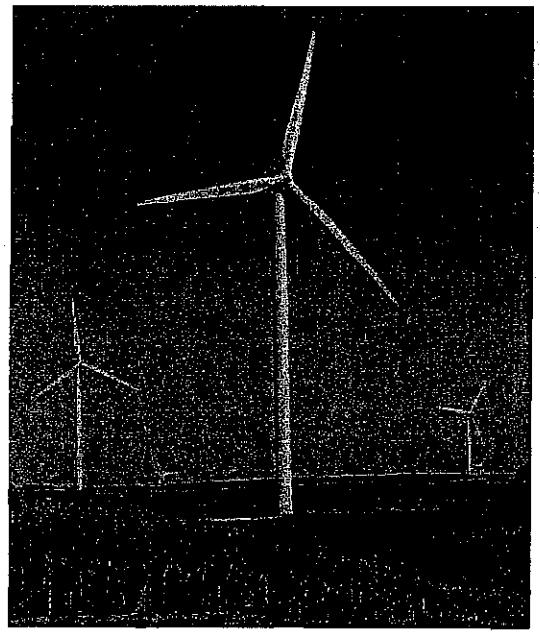
APPRAISAL GROUP ONE

9/9/2009

WIND TURBINE IMPACT STUDY

DODGE & FOND DU LAC COUNTIES – WISCONSIN

Preliminary Draft - September 2009



This is a study of the impact that wind turbines have on residential property value. The wind turbines that are the focus of this study are the larger turbines being approximately 389ft tall and producing 1.0+ megawatts each, similar to the one pictured to the right.

The study has been broken into three component parts, each looking at the value impact of the wind turbines from a different perspective. The three parts are: (1) a literature study, which reviews and summarizes what has been published on this matter found in the general media; (2) an opinion survey, which was given to area Realtors to learn their opinions on the impact of wind turbines in their area; and, 3) sales studies, which compared vacant residential lot sales within the wind turbine farm area to comparable sales located outside of the turbine influence.

The sponsor for this study was the Calumet County Citizens for Responsible Energy (CCCRE) (Calumet County, Wisconsin), which contracted our firm, Appraisal Group One, to research the value impact that wind turbines have on property value. Appraisal Group One (AGO) protected against outside influence from CCCRE by having complete independence to the gathering of facts, data and other related material and the interpretation of this data to the purpose of this study. AGO chose the location of the study, the search parameters, the methodology used and the three-step approach to the study. AGO does not enter into any contract that would espouse any preconceived notion or have a bias as to the direction of the study and its findings. The purpose of the study was to investigate the value impacts of large wind turbines, the issues influencing these impacts and to report these findings on an impartial basis.

AGO is an appraisal company specializing in forensic appraisal, eminent domain, stigmatized properties and valuation research. This company is located in Oshkosh, Wisconsin, and provides appraisal services throughout the State of Wisconsin. In addition, AGO provides forensic appraisal services, valuation consulting and research outside of the state. Recent projects were completed in Ohio, Indiana, Illinois and Michigan.

The geographic area of this study was focused in Dodge and Fond du Lac Counties. These two counties have three large wind farms. They are:

WE Energies - Blue Sky Green Field wind farm which has approximately 88 wind turbines and is located in the northeast section of Fond du Lac County, bordering Calumet County to the north.

Invenergy - Forward wind farm which has approximately 86 wind turbines and is located in southwest Fond du Lac County and northeast Dodge County.

Alliant - Cedar Ridge wind farm which has approximately 41 wind turbines and is located in the southeastern part of Fond du Lac County.

Of these three wind farms, only the WE Energies and Invenergy wind farms were used in the sales study since the Alliant – Cedar Ridge wind farm did not have enough viable sales within the turbine influence area to use as a base of comparison. The Realtor survey was limited to Fond du Lac and Dodge Counties, that being the area which had the three wind farms. The literature study was not limited geographically.

The balance of this report follows this introduction. The conclusions drawn at the end of each section are based on the data we collected and analyzed and are the sole possession of Appraisal Group One.

Submitted on September 9th, 2009, by:

Kurt C. Kielisch, ASA, IFAS, SR/WA, R/W-AC

President/ Senior Appraiser

Appraisal Group One

www.forensic-appraisal.com

WIND TURBINE IMPACT – REALTOR SURVEY

The purpose of the Realtor survey was to learn from the people who are on the first tier of the buying and selling of real estate what they thought of wind turbines and their impact to residential property value. This survey was designed to measure what type of impact (positive, negative or no impact) that wind turbines have on vacant residential land and improved property. The questions were designed to measure three different visual field proximity situations to wind turbines. These three were **bordering** proximity (defined as 600ft from the turbine), **close** proximity (defined as 1,000ft from the turbine) and **near** proximity (defined as ½ mile from the wind turbines). In all situations the wind turbines were visible from the property. Graphics and photographs were utilized to illustrate each question so the survey taker would have the same or similar understanding as others on each question. In addition to asking the Realtor about the type of impact they expected in each situation, the survey then asked them to estimate the percentage of the impact. Though it is understood that Realtors are salespeople and not appraisers, it is also true that they often have to estimate asking prices for their clients or act in the capacity of a buying agent for a client. Both situations demand an estimate of value and recognition of those factors that both benefit and detract from value.

The geographic area for selection of the survey participants was defined by the wind farm projects. These projects were in Fond du Lac and Dodge Counties, Wisconsin.

The Scope of Work (SOW) that was followed in the development, implementation and recording of this survey was as follows:

1. Outline the purpose of the questions and determine what is to be measured and what information is needed to have an informative survey free of any suggested bias.
2. Create a Beta version of the survey and have it tested by ten Realtors outside of the projected survey area.
3. Once the Beta testing and revisions were completed, then print the final version of the survey.
4. Realtor offices were presented with the survey and participants were offered a fee for taking the survey. (interestingly, some declined the fee.)
5. All surveys were given in person. No surveys were giving orally nor via the Internet.
6. Once the surveys were completed the survey presenter signed and dated the survey.
7. All surveys were reviewed for errors and those that were found in error, e.g. giving multiple answers to a question when only one was allowed, were then rejected and saved with the reason for its rejection.
8. The survey results were tabulated and presented in a spreadsheet format.

9. From the spreadsheet the results were presented graphically for ease of understanding.
10. A summary of the findings and a conclusion was then completed and included in this report.

Following is: (a) a copy of the survey that was hand delivered to each survey participant and (b) graphic presentation of the tabulated results from the survey.

Summary of Findings & Conclusion of Impact

The survey indicated that in all but two scenarios (those being Questions #8 and #9), over 60% the participants thought that the presence of the wind turbines had a negative impact on property value. This was true with vacant land and improved land. Where the group diverted from that opinion is when they were presented with a 10-20 acre hobby farm being in *close* and *near* proximity. In these cases 47% (close proximity) and 44% (near proximity) of the participants felt that the wind turbines caused a negative impact in property value.

The answers showed that *bordering* proximity showed the greatest loss of value at -43% for 1-5 acre vacant land and -39% for improved properties. Next in line was the *close* proximity showing a -36% value loss for 1-5 acre vacant land and -33% for improved property. Last in line was the *near* proximity, showing a -29% loss of value for a 1-5 acre vacant parcel and -24% loss in value for improved parcels. These losses show a close relationship between vacant land and improved land. This pattern was replicated regarding the *bordering* proximity for a hobby farm, whereas 70% believed it would be negatively impacted. Lastly, the opinions regarding the impact of the wind turbines due to placement, that being in front of the residence or behind the residence, showed that in both situations most participants believed there would a negative impact (74% said negative to the front placement and 71% said negative to the rear placement).

In conclusion, it can be observed that: (a) in all cases with a 1-5 acre residential property, whether vacant or improved, there will be a negative impact in property value; (b) with 1-5 acre properties the negative impact in property value in *bordering* proximity ranged from -39% to -43%; (c) with 1-5 acre properties the negative impact in property value in *close* proximity ranged from -33% to -36%; (d) with 1-5 acre properties the negative impact in property value in *near* proximity ranged from -24% to -29%; (e) in all cases the estimated loss of value between the vacant land and improved property was close, however the vacant land estimates were always higher by a few percentage points; (f) it appears that hobby farm use on larger parcels would have lesser sensitivity to the proximity of wind turbines than single family land use; and (g) placement either in front or at the rear of a residence has similar negative impacts.

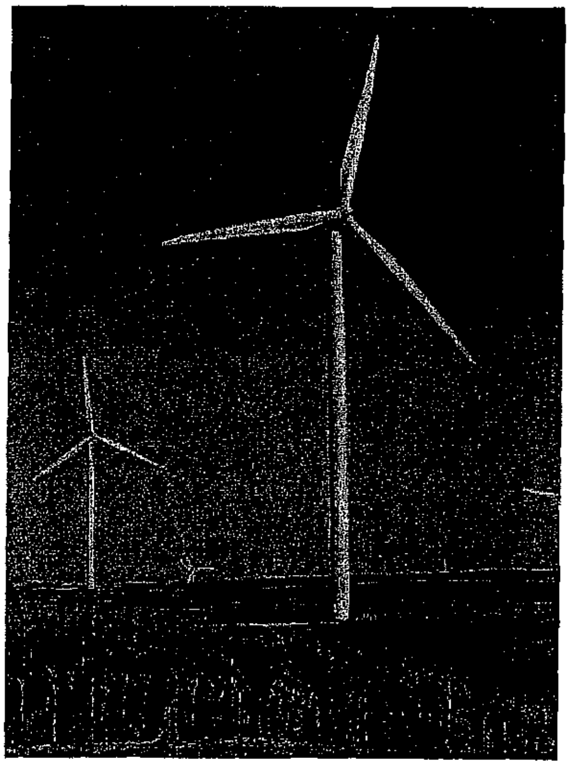
SAMPLE OF THE SURVEY
FOUND ON THE FOLLOWING PAGES

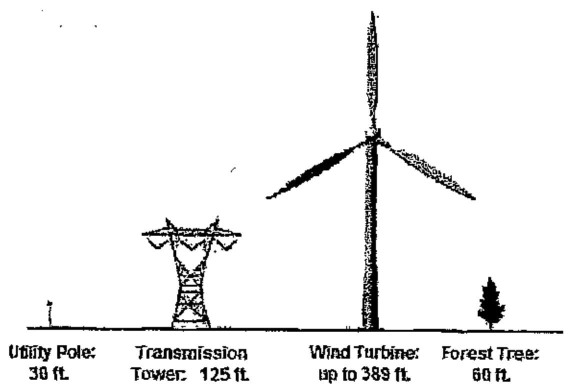
Wind Turbine Realtor Opinion Questionnaire

A. Purpose of the questionnaire

This questionnaire seeks to find the opinion of real estate sales professionals on whether an industrial-scale wind turbine near a residential property has an impact on its property value. The questionnaire specifically defines terms such as "wind turbine," "close proximity," "near proximity" and "outlying proximity."

Wind Turbine – for this questionnaire, a wind turbine is defined as a 1.5 MW industrial-scale wind turbine, approximately 389 feet tall from base to blade tip, at its highest point, with a blade diameter of approximately 252 feet. Such a wind turbine is pictured below, left. A comparison of the maximum height of industrial-scale turbines compared to other utilities and natural features is seen below, right.





Graphic: Impact of Wind Turbines on Market Value of Texas Rural Land. Derry T. Gardner of Gardner Appraisal Group, Inc. February 13, 2009. Original height of turbine altered for specific case

All dimensions to scale: 1 inch = 200 feet

Visual Field Proximity – for this questionnaire, "bordering proximity" is defined as 600 feet from turbine to residence, and easily seen from the subject property. "Close proximity" is defined as 1000 feet from turbine to residence, and readily seen. "Near proximity" is defined as ½ mile from turbine to residence, and seen in the distance. In the questionnaire you will see examples of each.

B. Please tell us about your real estate background: **(check all that apply)**

- Are you a Wisconsin licensed real estate sales person? ___ yes ___ no If yes, how long? ___yrs.
- Are you a Wisconsin licensed real estate broker? ___ yes ___ no If yes, how long? ___yrs.
- Are you a Wisconsin licensed/certified/general appraiser? ___ yes ___ no If yes, how long? ___yrs.
- Are you a Wisconsin assessor? ___ yes ___ no If yes, how long? ___yrs.
- Are you a land developer? ___ yes ___ no

C. What type of property have you listed or sold in the past? **(check all that apply)**

___ vacant land for residential use
___ vacant land for agricultural use
___ vacant land for recreational use
___ vacant land for commercial use
___ single-family residential
___ vacant land for residential developments
___ operative farm
___ hobby farm
___ recreational land
___ large tract rural land for any purpose
___ improved commercial

- In the last 5 years, have you listed a property from which one or more wind turbines were visible?

  ___ yes ___ no

  If yes, then please check the type of property **(check all that apply)**

  ___ residential improved
  ___ farm
  ___ residential development
  ___ large tract rural land for any purpose
  ___ vacant
  ___ recreational land
  ___ hobby farm
  ___ agricultural

- In the last 5 years, have you sold a property from which one or more wind turbines were visible?

  ___ yes ___ no

  If yes, then please check the type of property **(check all that apply)**

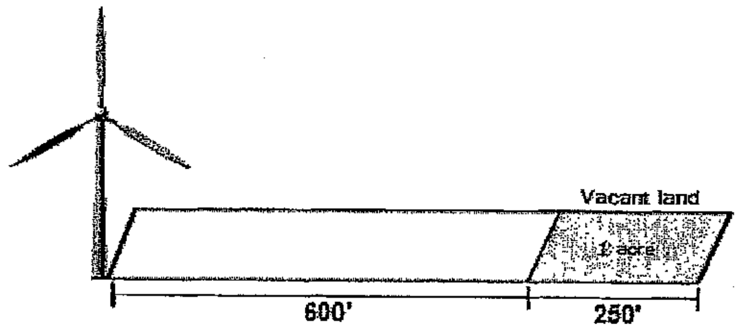
  ___ residential improved
  ___ farm
  ___ residential development
  ___ large tract rural land for any purpose
  ___ vacant
  ___ recreational land
  ___ hobby farm
  ___ agricultural

- Where do you reside?

  ___ City
  ___ Suburb
  ___ Rural

For this next set of questions, we are focusing on vacant residential land.

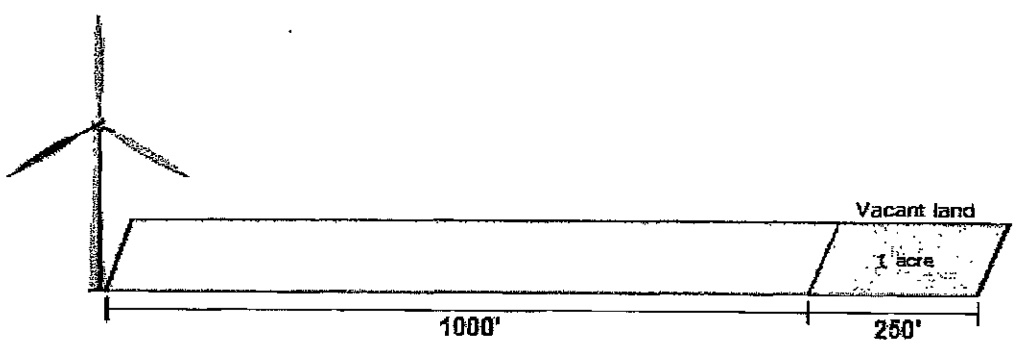
1. What is your opinion of the property value impact of wind turbines in **bordering proximity** to a 1-5 acre vacant residential lot? (see figure)
   i. Do you believe the property value of the parcel in this example would be:
      ____ Positively impacted
      ____ Negatively impacted
      ____ No impact



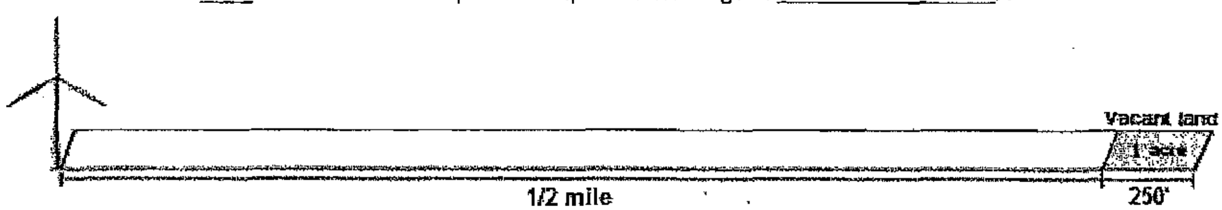
   ii. In your opinion, what would be the percentage of impact?
      ____ I would not know.
      ____ I would estimate a negative impact in the range of ______________%
      ____ I would estimate a positive impact in the range of ______________%

---

2. What is your opinion of the property value impact of wind turbines in **close proximity** to a 1-5 acre vacant residential lot? (see figure)
   i. Do you believe the property value of the parcel in this example would be:
      ____ Positively impacted
      ____ Negatively impacted
      ____ No impact
   ii. In your opinion, what would be the percentage of impact?
      ____ I would not know.
      ____ I would estimate a negative impact in the range of ______________%
      ____ I would estimate a positive impact in the range of ______________%

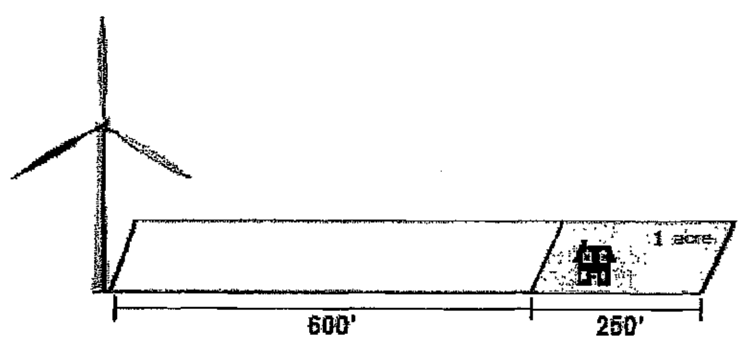


3. What is your opinion of the property value impact of wind turbines in **near proximity** to a 1-5 acre vacant residential lot? (see figure)
    i. Do you believe the property value of the parcel in this example would be
        _____ Positively impacted
        _____ Negatively impacted
        _____ No impact
    ii. In your opinion, what would be the percentage of impact?
        _____ I would not know.
        _____ I would estimate a negative impact in the range of ________________%
        _____ I would estimate a positive impact in the range of ________________%

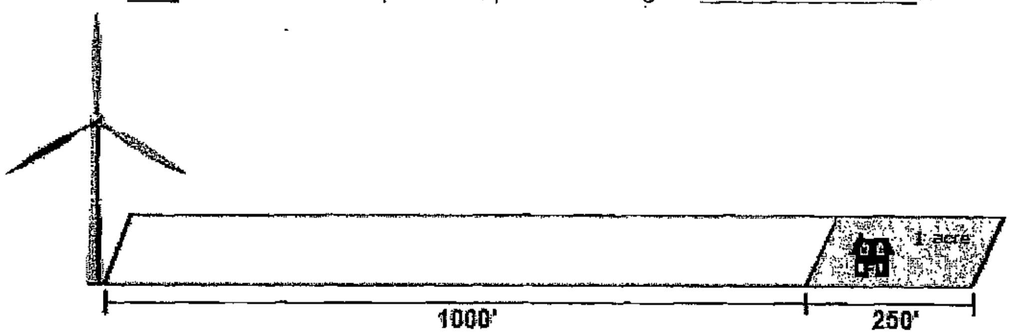


For this next set of questions, we are focusing on **improved** residential land. "Improved" means there is a residence on the property.

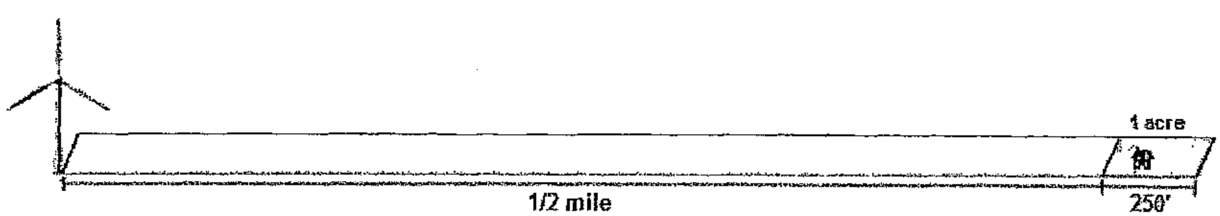
4. What is your opinion of the property value impact of wind turbines in **bordering proximity** to a 1-5 acre improved residential property? (see figure)
    i. Do you believe the property value of the parcel in this example would be
        _____ Positively impacted
        _____ Negatively impacted
        _____ No impact
    ii. In your opinion, what would be the percentage of impact?
        _____ I would not know.
        _____ I would estimate a negative impact in the range of ________________%
        _____ I would estimate a positive impact in the range of ________________%



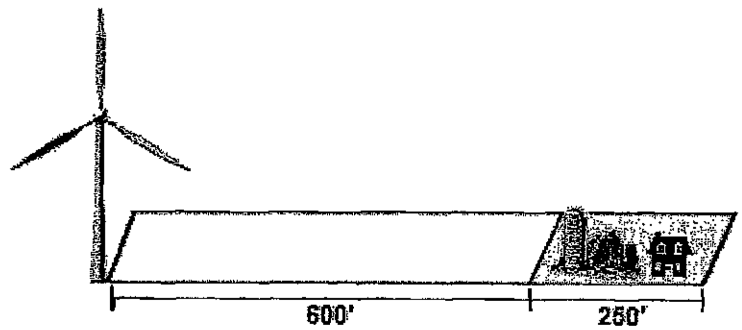
5. What is your opinion of the property value impact of wind turbines in **close proximity** to a 1-5 acre of <u>improved residential</u> property? (see figure)
    i. Do you believe the property value of the parcel in this example would be
        ____ Positively impacted
        ____ Negatively impacted
        ____ No impact
    ii. In your opinion, what would be the percentage of impact?
        ____ I would not know.
        ____ I would estimate a negative impact in the range of ________________%
        ____ I would estimate a positive impact in the range of ________________%



6. What is your opinion of the property value impact of wind turbines in **near proximity** to a 1-5 acre <u>improved residential</u> property? (see figure)
    i. Do you believe the property value of the parcel in this example would be
        ____ Positively impacted
        ____ Negatively impacted
        ____ No impact
    ii. In your opinion, what would be the percentage of impact?
        ____ I would not know.
        ____ I would estimate a negative impact in the range of ________________%
        ____ I would estimate a positive impact in the range of ________________%



7. Envision a hobby farm improved with a residence. It's 10-20 acres in size and has a wind turbine in **bordering proximity**. (see figure)
   i. Do you believe the property value of the parcel in this example would be
      ____ Positively impacted
      ____ Negatively impacted
      ____ No impact



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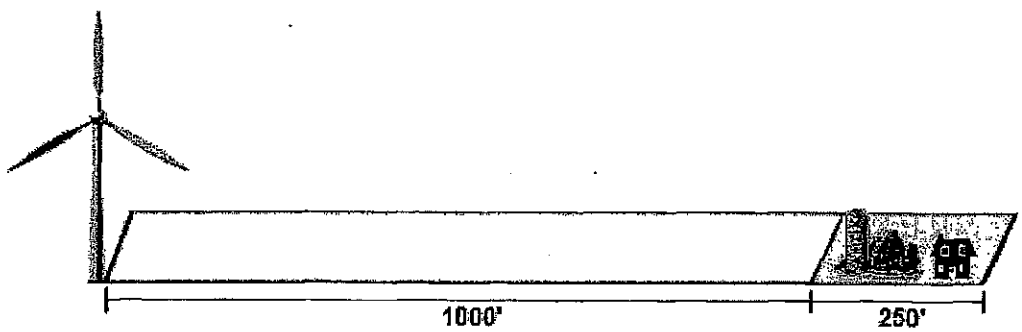
8. Envision a hobby farm improved with a residence. It's 10-20 acres in size and has a wind turbine in **close proximity**. (see figure)
   i. Do you believe the property value of the parcel in this example would be
      ____ Positively impacted
      ____ Negatively impacted
      ____ No impact



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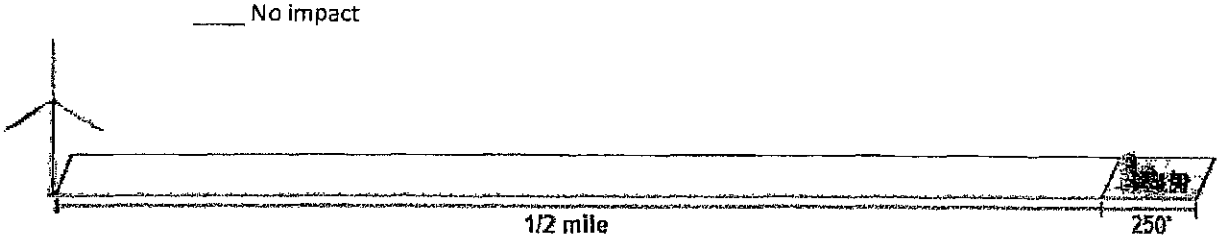
9. Envision a hobby farm improved with a residence. It's 10-20 acres in size and has a wind turbine in **near proximity**. (see example on next page)
   i. Do you believe the property value of the parcel in this example would be
      ____ Positively impacted
      ____ Negatively impacted
      ____ No impact



10. Assume that the wind turbine can be seen from the *front yard* of a 1-to-5 acre improved residential property as pictured below. Based on your professional experience would you say that this turbine would have:
    ___ A positive impact on the property value
    ___ A negative impact on the property value
    ___ No impact on the property value

11. Assume that the wind turbine can be seen from the *back yard* of a 1-to-5 acre improved residential property as pictured below. Based on your professional experience would you say that this turbine would have:
    ___ A positive impact on the property value
    ___ A negative impact on the property value
    ___ No impact on the property value.

Please feel free to include your own issues, comments or experiences (positive or negative) pertaining to wind turbines below:

____
____
____
____
____
____
____
____
____
____
____

Thank you for your help! Please date and sign below.

I have completed this questionnaire on ____/____/_______ signed ____________________________

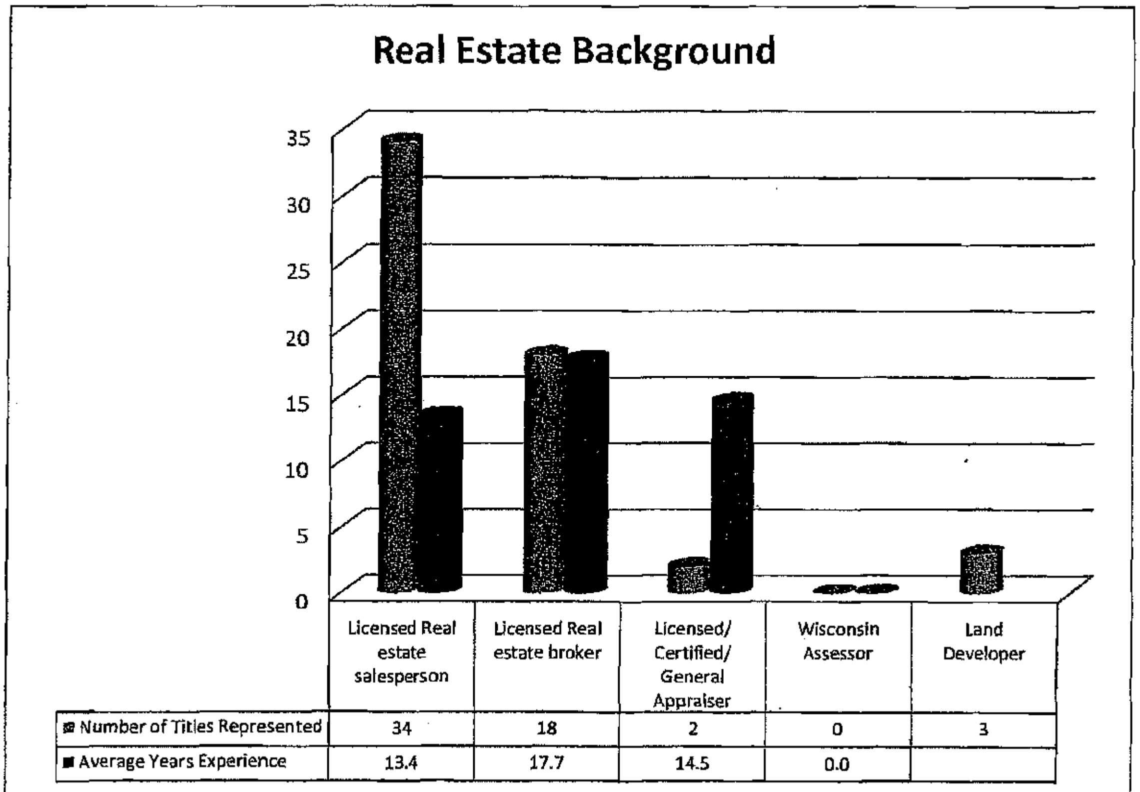
Name: ____
Company: ____
Address of company: ____
Contact phone number: ____

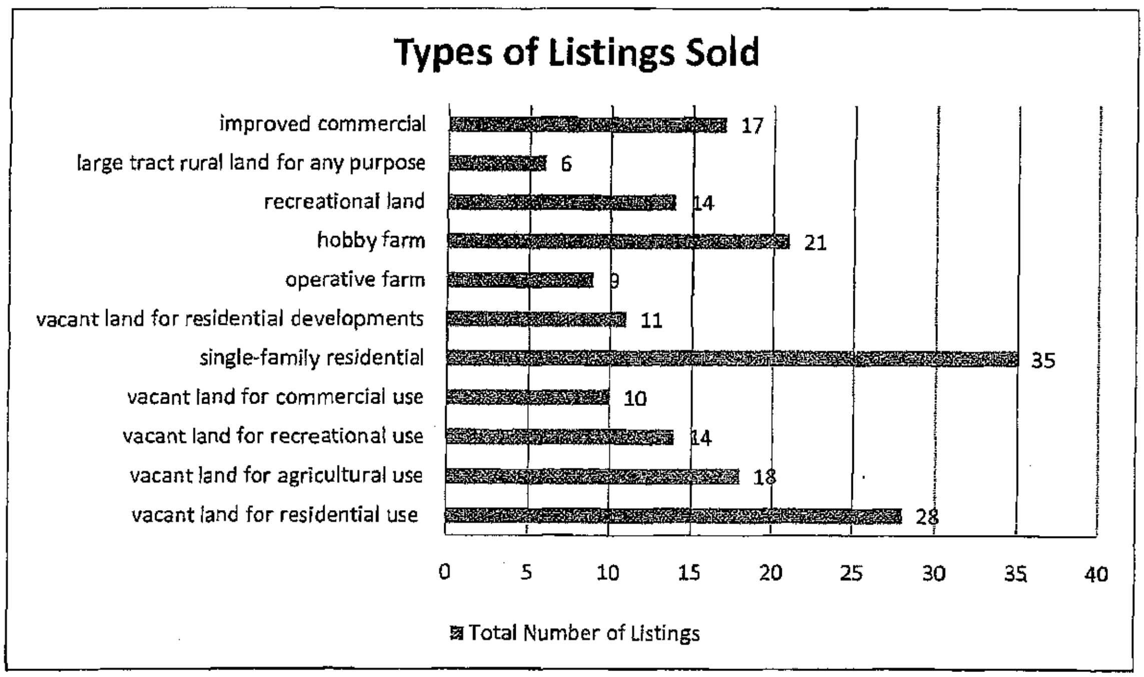
(To be filled out by interviewer)

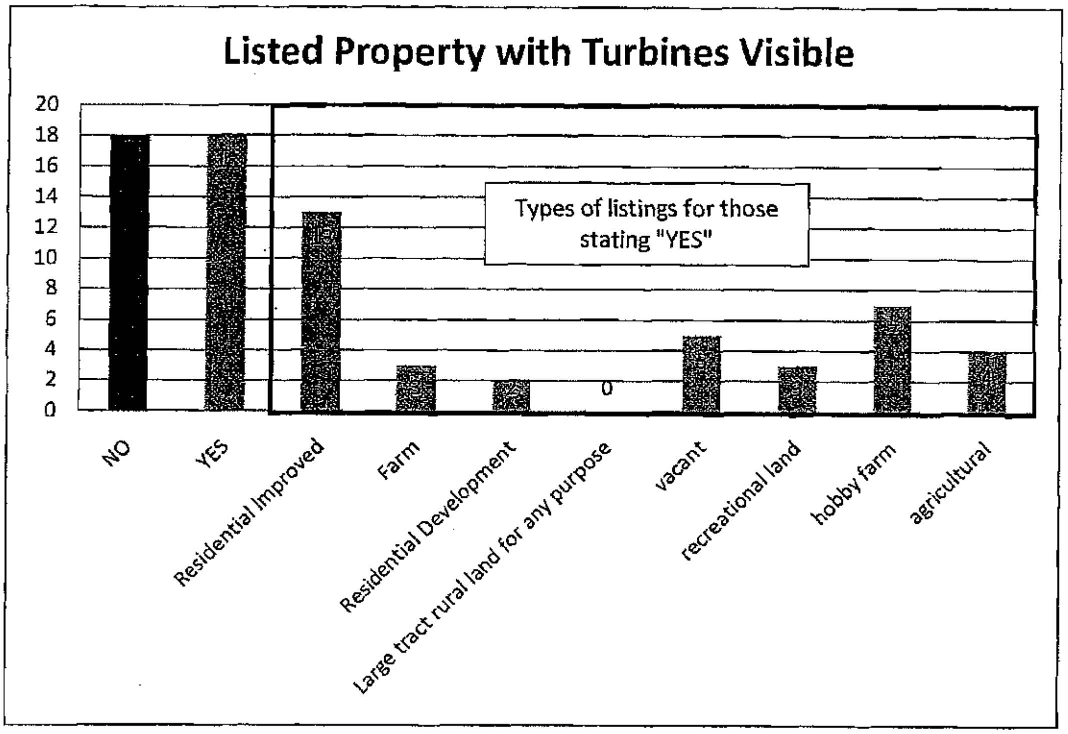
This questionnaire was given by ____
on ____/____/_________
This questionnaire was given: ___ in person ___ by fax ___ by e-mail ___ by letter
If this questionnaire was given in person, at what location?

____

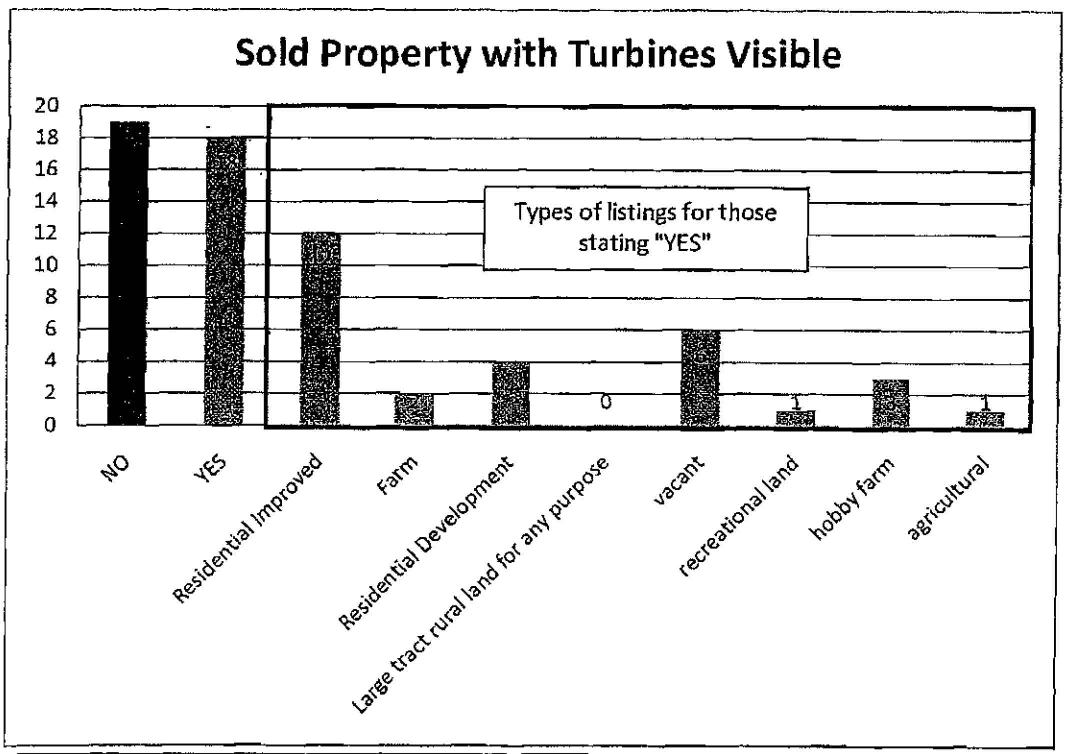
RESULTS FROM THE SURVEY IN GRAPHIC PRESENTATION
FOUND ON THE FOLLOWING PAGES


Real Estate Background
35
30
25
20
15
10
5
0
Licensed Real estate salesperson
Licensed Real estate broker
Licensed/ Certified/ General Appraiser
Wisconsin Assessor
Land Developer
Number of Titles Represented
34
18
2
0
3
Average Years Experience
13.4
17.7
14.5
0.0

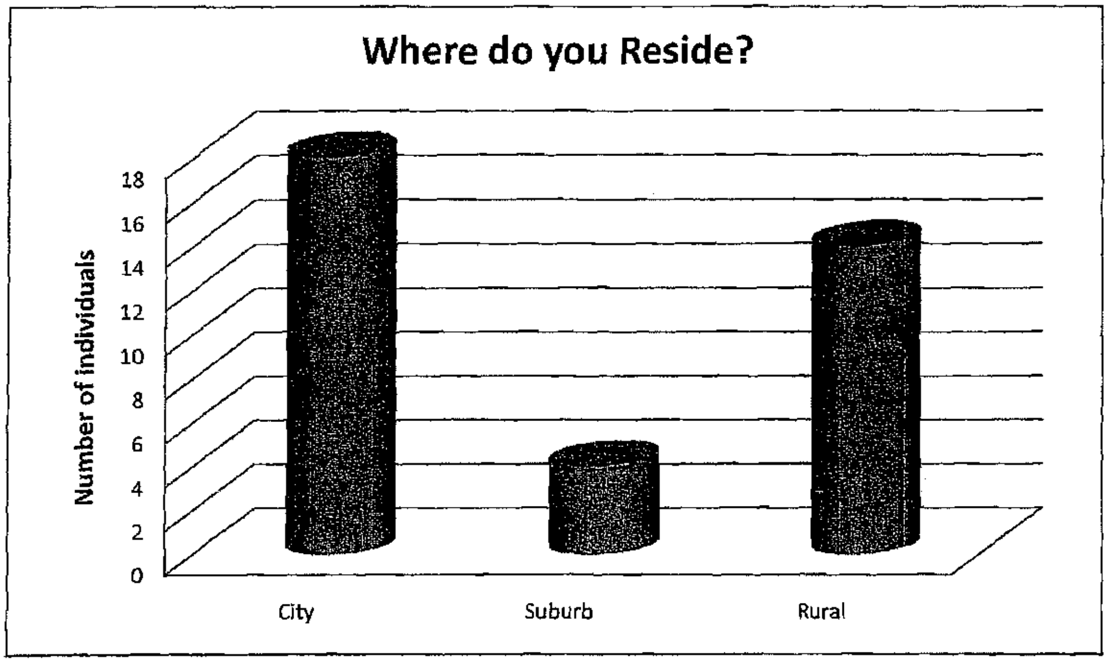

Types of Listings Sold
improved commercial
large tract rural land for any purpose
recreational land
hobby farm
operative farm
vacant land for residential developments
single-family residential
vacant land for commercial use
vacant land for recreational use
vacant land for agricultural use
vacant land for residential use
17
6
14
21
9
11
35
10
14
18
28
0
5
10
15
20
25
30
35
40
Total Number of Listings

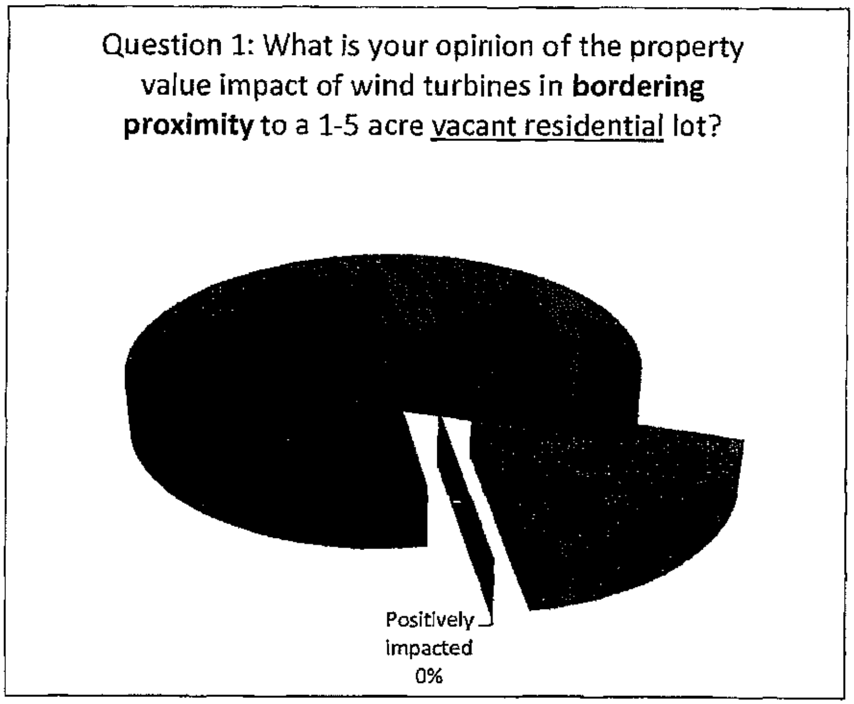


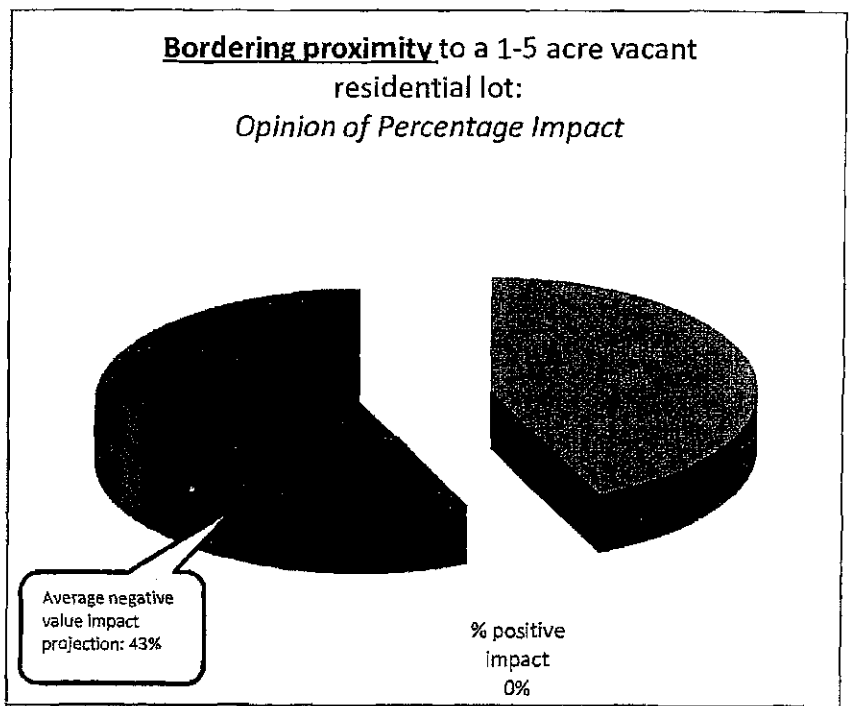
Listed Property with Turbines Visible
20
18
16
14
12
10
8
6
4
2
0
Types of listings for those stating "YES"
0
NO
YES
Residential Improved
Farm
Residential Development
Large tract rural land for any purpose
vacant
recreational land
hobby farm
agricultural



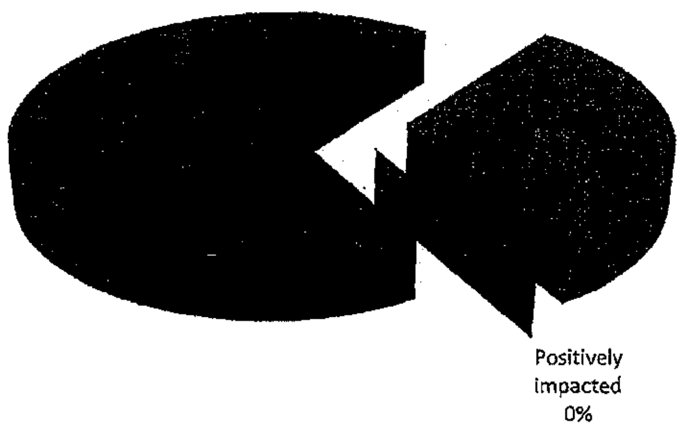
Sold Property with Turbines Visible
20
18
16
14
12
10
8
6
4
2
0
Types of listings for those stating "YES"
0
1
1
NO
YES
Residential Improved
Farm
Residential Development
Large tract rural land for any purpose
vacant
recreational land
hobby farm
agricultural


Where do you Reside?
Number of individuals
18
16
14
12
10
8
6
4
2
0
City
Suburb
Rural


Question 1: What is your opinion of the property value impact of wind turbines in **bordering proximity** to a 1-5 acre vacant residential lot?
Positively impacted 0%

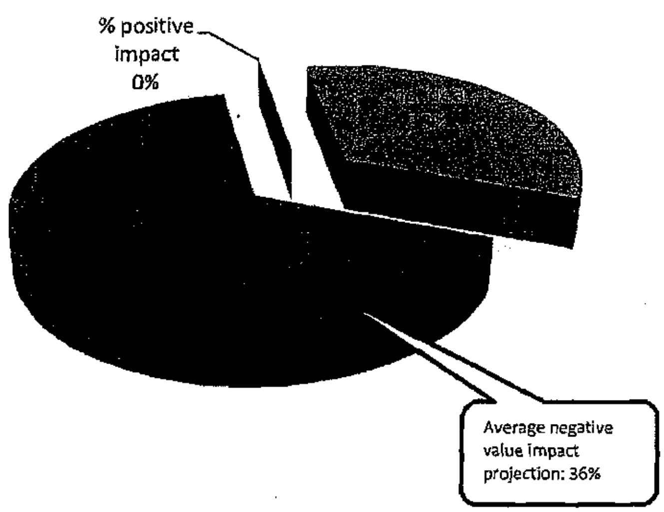

Bordering proximity to a 1-5 acre vacant residential lot:
Opinion of Percentage Impact
Average negative value impact projection: 43%
% positive impact 0%

Question 2: What is your opinion of the property value impact of wind turbines in **close proximity** to a 1-5 acre vacant residential lot?

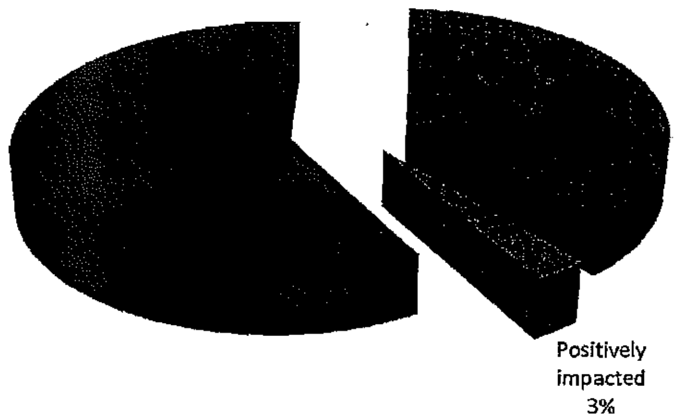


Close proximity to a 1-5 acre vacant residential lot:

Opinion of Percentage Impact

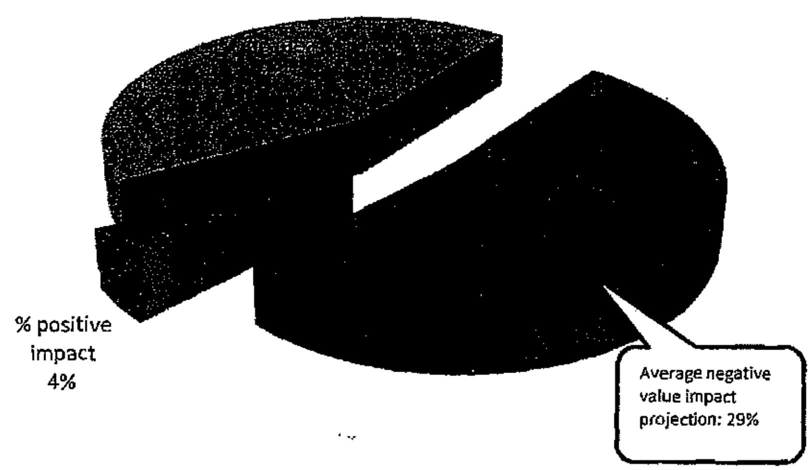


Question 3: What is your opinion of the property value impact of wind turbines in **near proximity** to a 1-5 acre <u>vacant residential</u> lot?

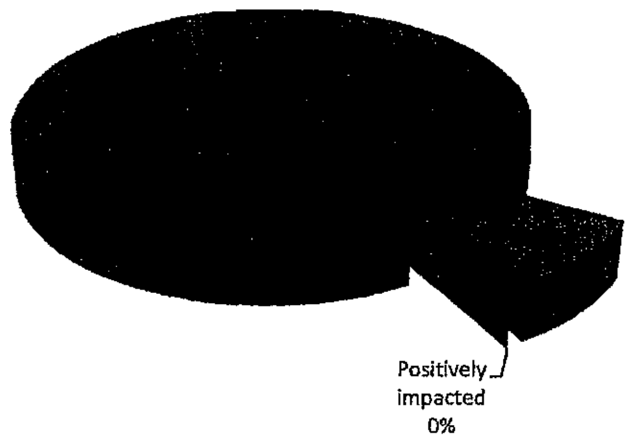


<u>Near proximity</u> to a 1-5 acre vacant residential lot:

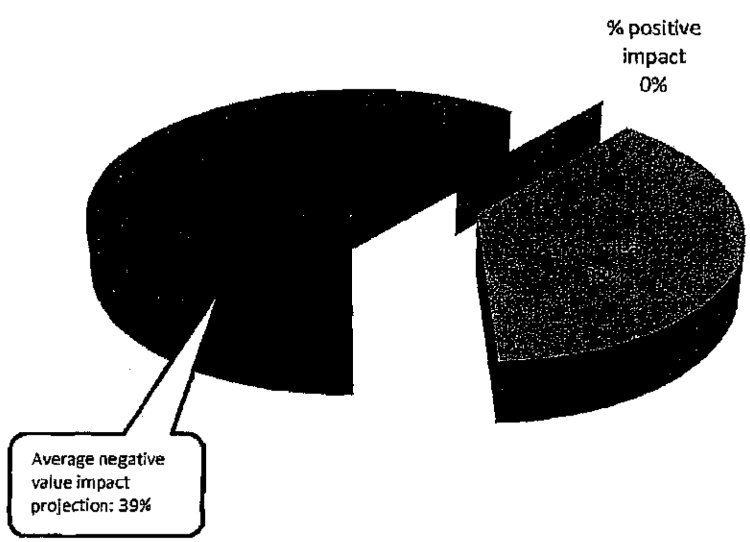
Opinion of Percentage Impact



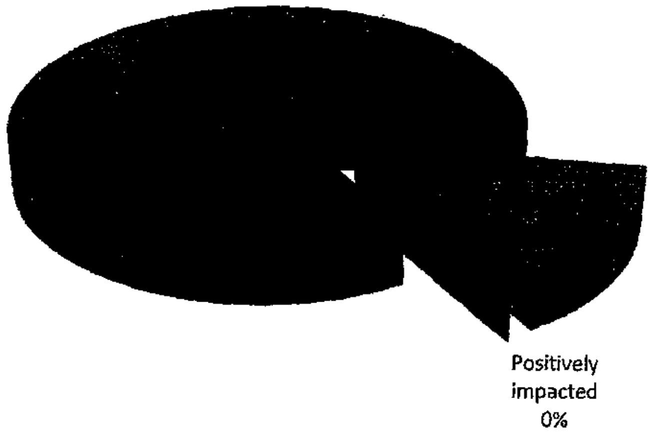
Question 4: What is your opinion of the property value impact of wind turbines in **bordering proximity** to a 1-5 acre improved residential lot?



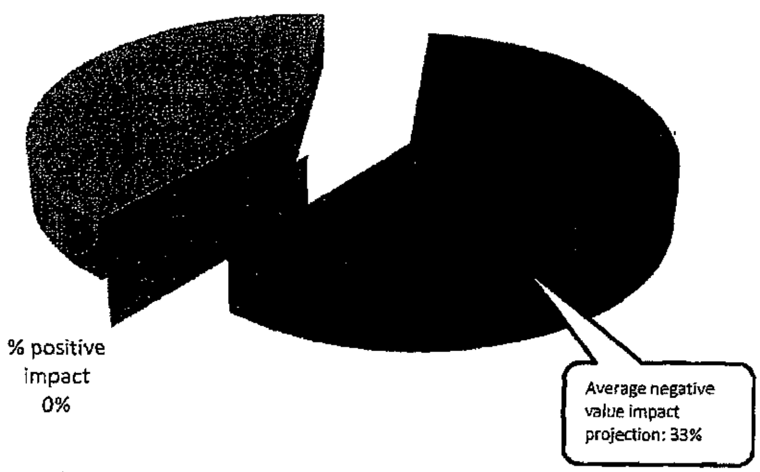
Bordering proximity to a 1-5 acre improved residential lot:
Opinion of Percentage Impact

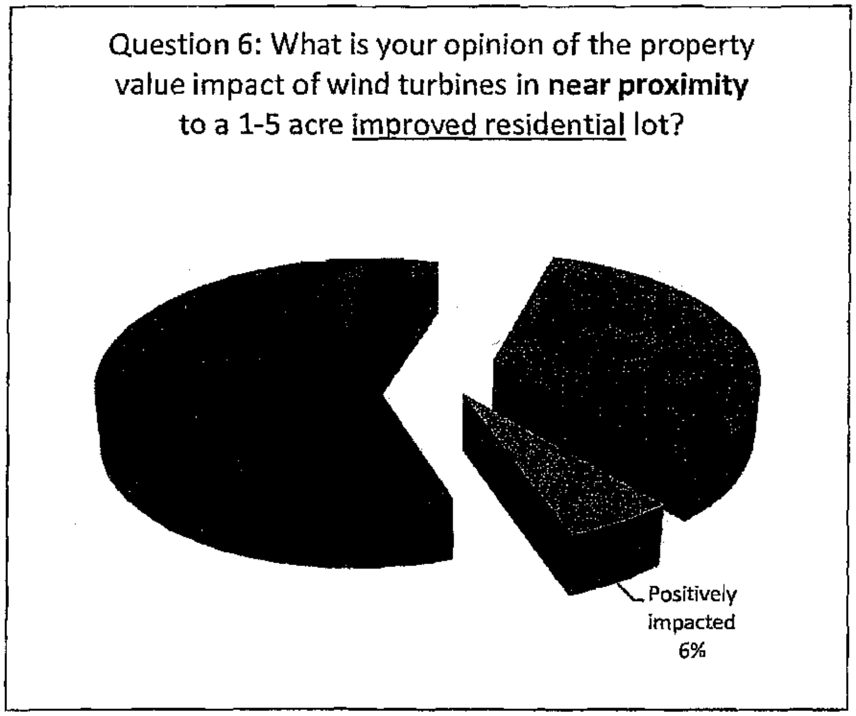


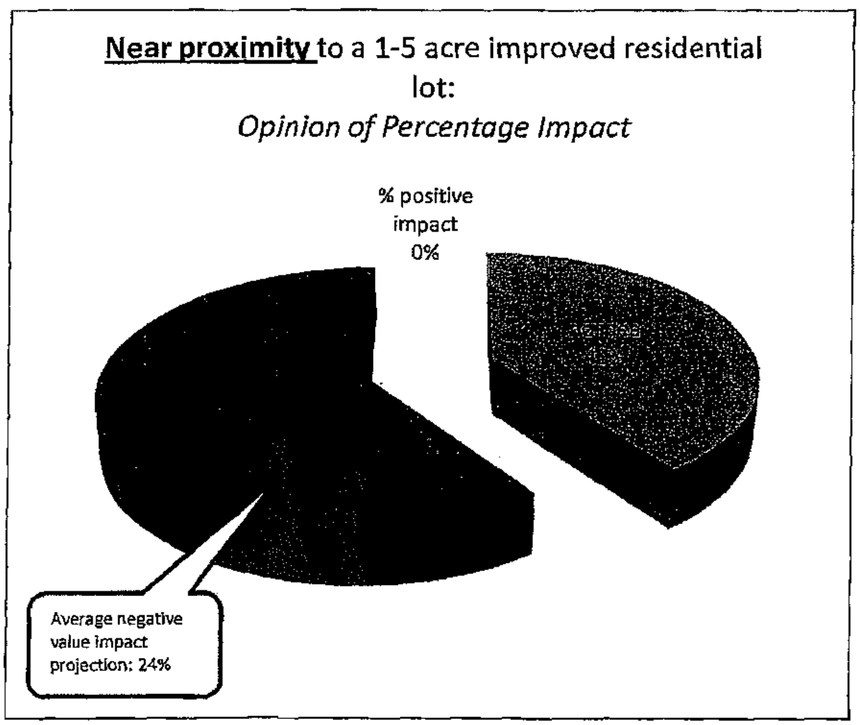
Question 5: What is your opinion of the property value impact of wind turbines in **close proximity** to a 1-5 acre <u>improved residential</u> lot?

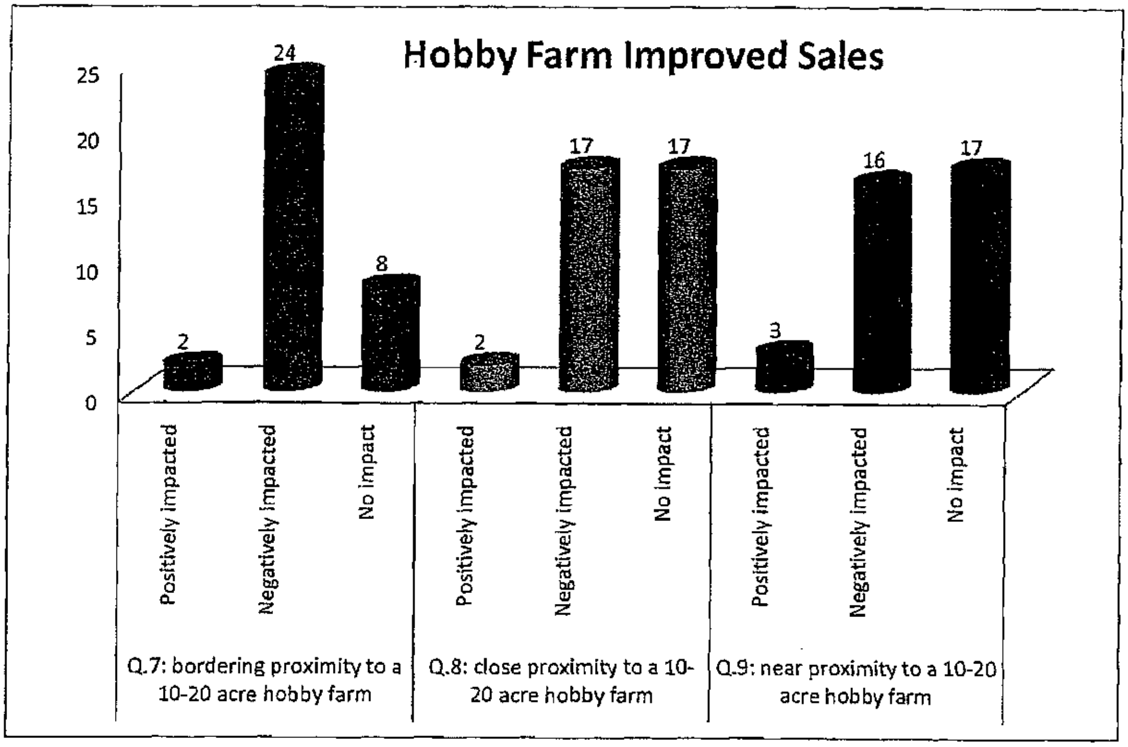


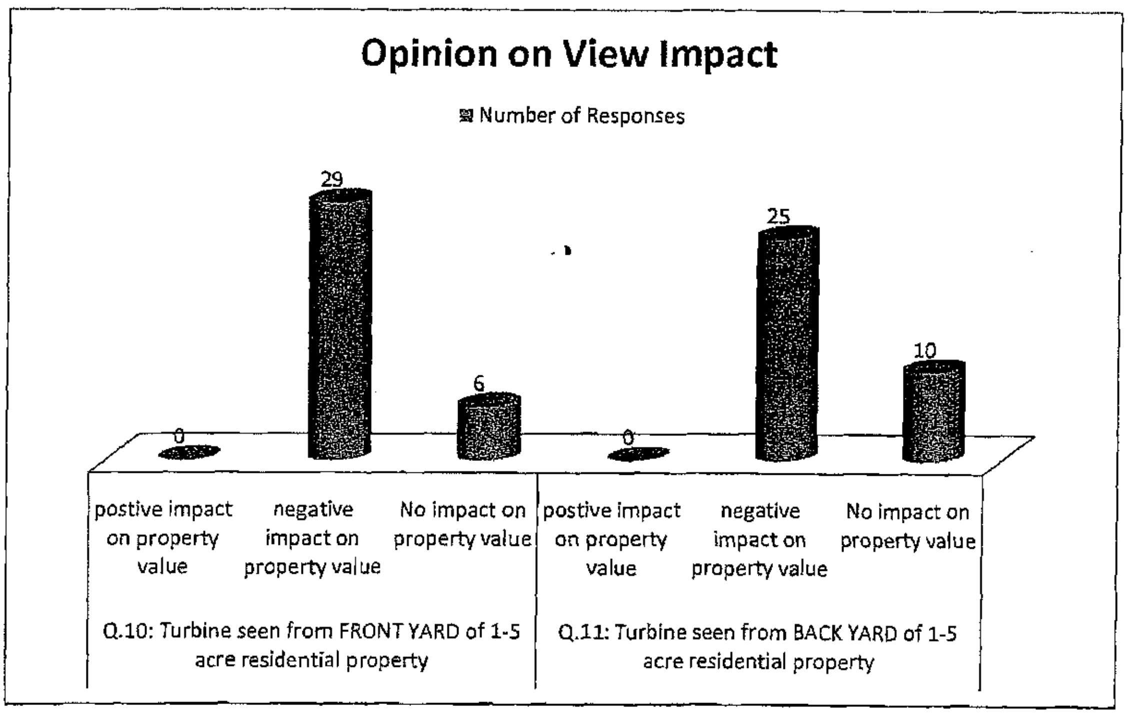
<u>Close proximity</u> to a 1-5 acre improved residential lot:
Opinion of Percentage Impact




Question 6: What is your opinion of the property value impact of wind turbines in **near proximity** to a 1-5 acre improved residential lot?
Positively impacted 6%


Near proximity to a 1-5 acre improved residential lot:
Opinion of Percentage Impact
% positive impact 0%
Average negative value impact projection: 24%


Hobby Farm Improved Sales
25
20
15
10
5
0
24
8
2
2
17
17
3
16
17
Positively impacted
Negatively impacted
No impact
Positively impacted
Negatively impacted
No impact
Positively impacted
Negatively impacted
No impact
Q.7: bordering proximity to a 10-20 acre hobby farm
Q.8: close proximity to a 10-20 acre hobby farm
Q.9: near proximity to a 10-20 acre hobby farm


Opinion on View Impact
Number of Responses
0
29
6
0
25
10
postive impact on property value
negative impact on property value
No impact on property value
postive impact on property value
negative impact on property value
No impact on property value
Q.10: Turbine seen from FRONT YARD of 1-5 acre residential property
Q.11: Turbine seen from BACK YARD of 1-5 acre residential property

WIND TURBINE IMPACT - SALES STUDIES

The purpose of the wind turbine impact sales studies was to compare the residential land sales of properties located within the wind turbine farm area to comparable land sales located outside of the influence of the wind turbines. Being located outside of the influence meant that the wind turbines could not be seen from the property.

The Scope of Work (SOW) for this assignment was as follows:

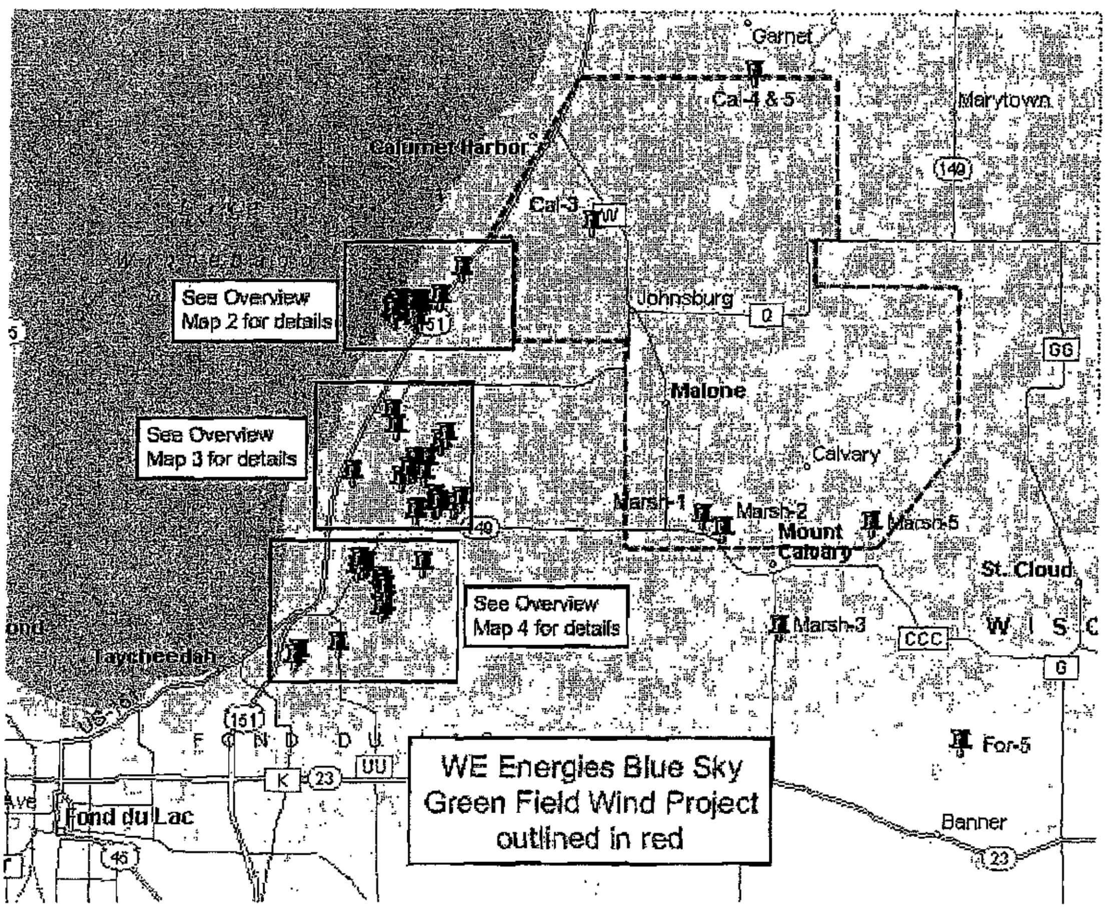
1) Obtain the wind farm maps from the wind farm developer.
2) Identify the wind turbine influence area using the wind farm maps, township maps, plat books and county maps.
3) Physically inspect the wind farm influence area.
4) Search for all residential vacant land sales in the wind farm influence area using the following parameters:
   a) 1-10 acre land size.
   b) January 1^{st}, 2005 to May 31^{st}, 2009, to keep the sales in the influence of the wind turbines either present or planned.
   c) Vacant land sales only.
   d) Residential land use only.
   e) Arm's length transactions that meet the legal definition of a Market Value transaction.
   f) Utilize REDI, MLS, court records, assessor records, county maps, Google maps, FEMA maps, and other sources as needed for property data of each sale.
5) Research and confirm all sales within the wind turbine influence and physically inspect all sales and locate the proximity of all nearby wind turbines.
6) Complete a sales info sheet on each sale.
7) Using the sales in #5, set forth the parameters for the comparable land sales located outside of the sphere of influence and follow steps #4 through #6.
8) Once all the sales are confirmed and the sales info sheets completed, complete a spreadsheet listing all land sales data.
9) Complete a market appreciation/depreciation time study for time adjustments.
10) Complete a "x, y" scatter chart plotting the land sales within the influence of the wind turbines vs. those outside of the influence after time adjustments are applied.
11) Plot regression lines of the two values using logarithmic functions.

12) Compare the values projected by the charts to identify and define any value difference between the land sales within vs. outside of the influence of the wind turbines.
13) Summarize and conclude the impact of wind turbines to property value.

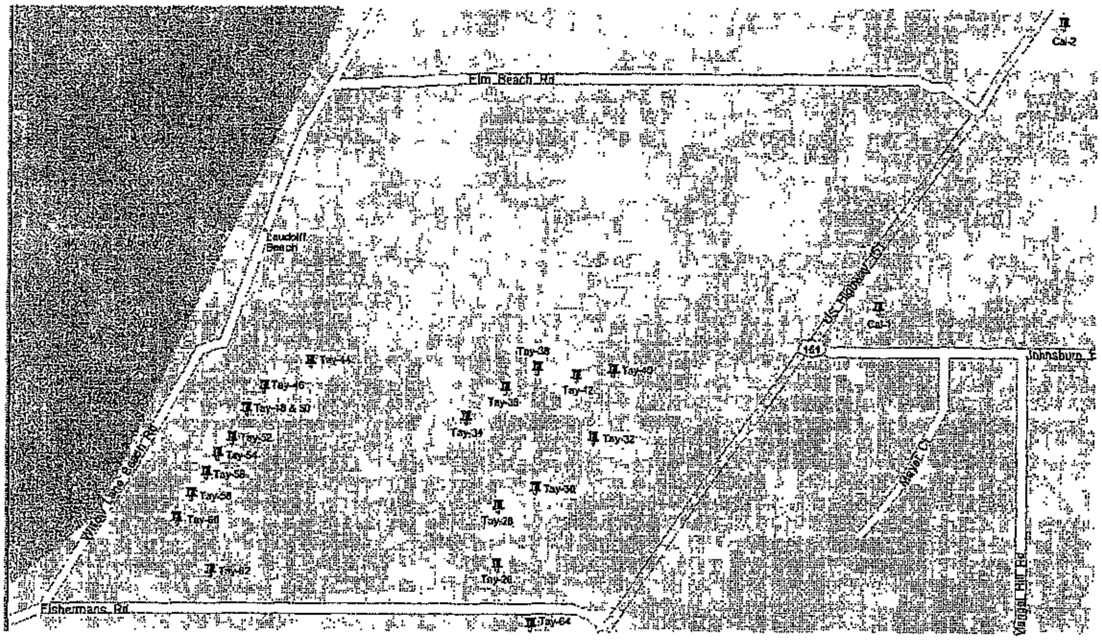
The areas of study include the WE Energies - Blue Sky Green Field wind farm located in the northeast section of Fond du Lac County and the Invenergy - Forward wind farm located in southwest Fond du Lac County and northeast Dodge County. The sales studies and their conclusions follow.

WE Energies - Blue Sky Green Field Wind Farm Sales Study

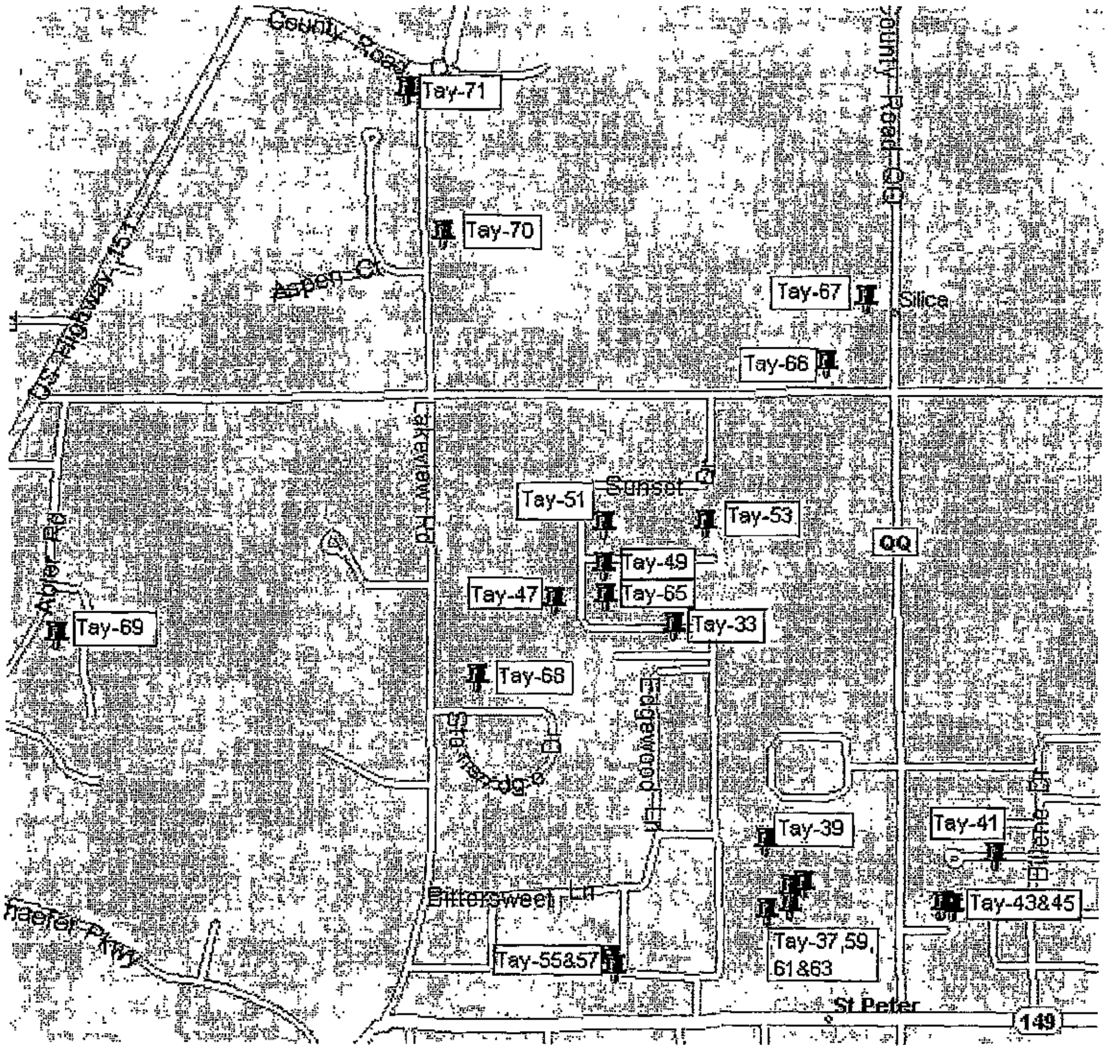
The area of study was the northeast section of Fond du Lac County bordered by Calumet County to the north, Lake Winnebago to the west and Sheboygan County to the east. The study included the townships of Calumet, Taycheedah and Marshfield. A total of 68 vacant residential land sales were utilized for this study. From that total, 6 land sales were in the influence of the wind turbines (within the wind farm parameters), and 62 sales were located outside of that sphere of influence. The sales map for this study is pictured below:



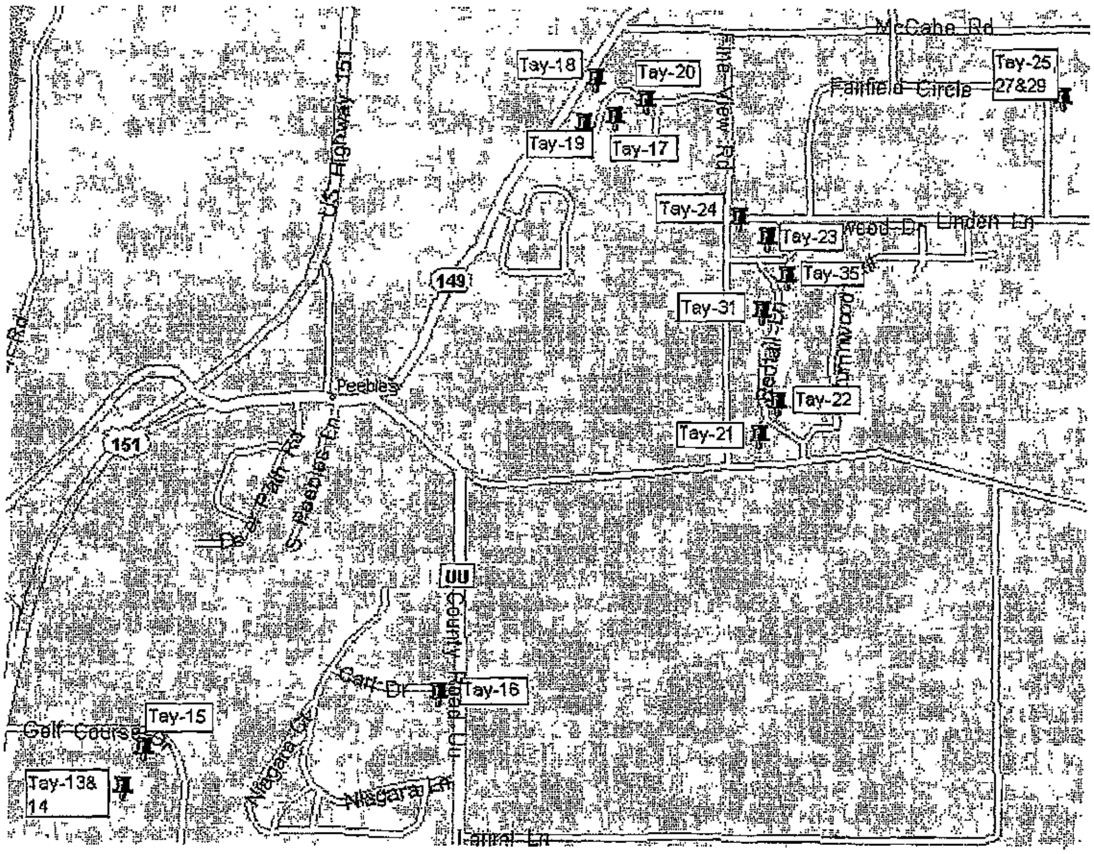
Overview Map #2



Overview Map #3



Overview Map #4



All of these sales were the placed in a spread sheet that appears on the next pages.

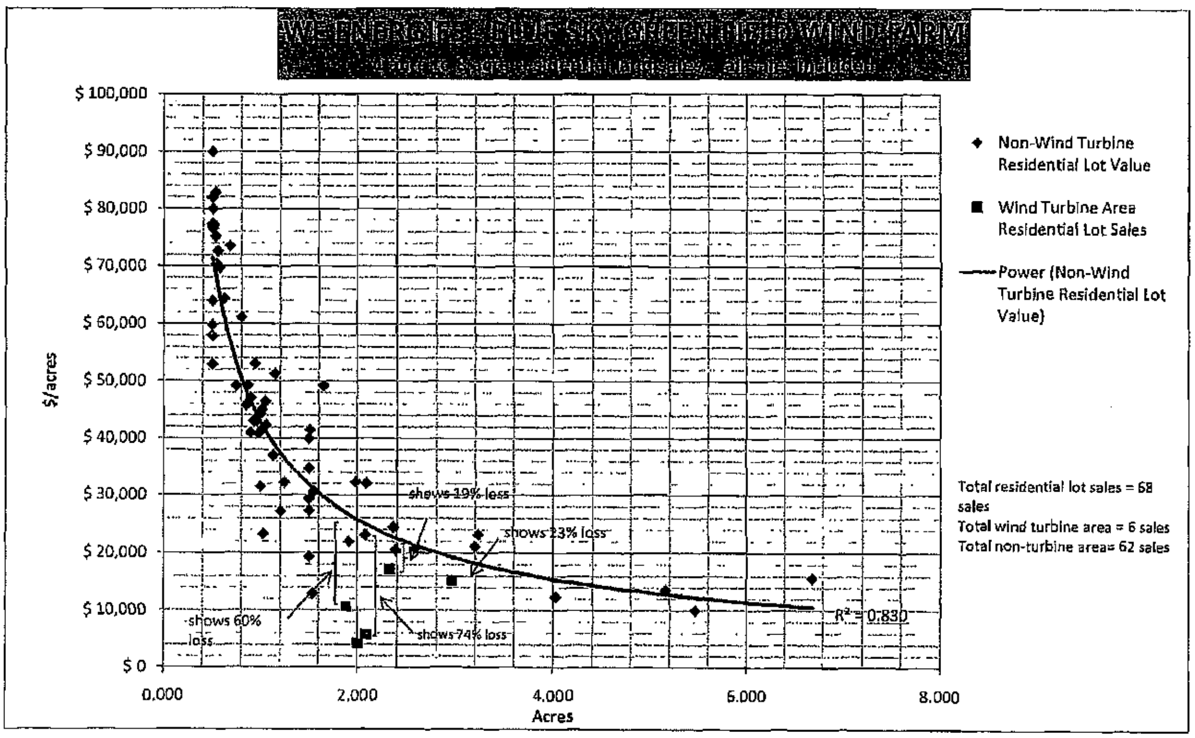
WE-ENERGIES BLUE SKY GREEN FIELD SPREADSHEET

Identifier	Subdv	Lot	Street #	Street name	resale?	Sale Amt	Sale Date	Doc #	lot size acres	[redacted]	adj Sale after time adj	$/ac
Cal-5	Rural	turbine	W2073	Cty Rd HHH	N	$ 8,500	3/31/2006	868997	2.000		$ 8,500	$ 4,250
Cal-4	Rural	turbine	W2079	Cty Rd HHH	N	$ 8,500	3/31/2006	868996	2.000		$ 8,500	$ 4,250
Cal-3	Rural			Schumacher Rd.	N	$ 12,000	2/12/2009	931211	2.088		$ 12,000	$ 5,747
Marsh-5	Rural	turbine	W1362	Basswood Rd.	N	$ 45,000	12/27/2007	908549	2.960		$ 45,000	$ 15,203
Marsh-2	Rural	turbine	W2209	Cty Rd W	N	$ 40,000	5/1/2009	871059	2.330		$ 40,000	$ 17,167
Marsh-1	Rural	turbine		Cty Rd W	N	$ 20,000	1/16/2008	909043	1.880		$ 20,000	$ 10,638
	Rural			Johnsburg Rd.	N	$ 53,500	6/10/2009	940604	2.578		$ 53,500	$ 20,753
Cal-2	Rural			State Hwy 151	N	$ 105,000	10/30/2006	883092	6.689		$ 105,000	$ 15,697
For-5	Rural		W879	Pleasant View Ct.	N	$ 24,000	2/4/2008	910007	1.030		$ 24,000	$ 23,301
Marsh-3	Rural			Cty Rd W	N	$ 19,900	10/20/2006	882217	1.540		$ 19,900	$ 12,922
Tay-13	Winward Estates	Lot 44	W4562	Aeolus Way	Y	$ 40,000	5/14/2009	938265	0.500		$ 40,000	$ 80,000
Tay-14	Winward Estates	Lot 44	W4562	Aeolus Way	N	$ 45,000	5/31/2007	895585	0.500		$ 45,000	$ 90,000
Tay-15	Winward Estates	Lot 68	N7346	Easterlies Dr.	N	$ 42,900	11/19/2008	926853	0.870		$ 42,900	$ 49,310
Tay-16	Niagara Estates	Lot 25		Carl Dr.	N	$ 70,000	9/15/2008	923533	5.160		$ 70,000	$ 13,566
Tay-17	Glacier Ridge	Lot 8		Jennie Lee Ct.	N	$ 64,000	5/1/2009	937263	1.980		$ 64,000	$ 32,323
Tay-18	Glacier Ridge	Lot 10 & 11		Jennie Lee Ct.	N	$ 75,000	9/6/2006	879445	3.230		$ 75,000	$ 23,220
Tay-19	Glacier Ridge	Lot 9	W4209	Jennie Lee Ct.	N	$ 67,000	6/12/2006	880888	2.090		$ 67,000	$ 32,057
Tay-20	Glacier Ridge	Lot 5		Jennie Lee Ct.	N	$ 81,250	10/4/2006	881308	1.650		$ 81,250	$ 49,242
Tay-21	Hawk's Landing	Lot 3	W4084	Redtail Ct.	N	$ 41,900	9/1/2006	879320	1.132		$ 41,900	$ 37,014
Tay-22	Hawk's Landing	Lot 88	N7611	Redtail Ln.	N	$ 40,400	5/1/2006	871526	0.556		$ 40,400	$ 72,662
Tay-23	Hawk's Landing	Lot 24		Thornwood Dr.	N	$ 39,900	5/9/2006	872462	0.620		$ 39,900	$ 64,355
Tay-24	Rural			Linden Dr.	N	$ 62,500	8/8/2008	920377	1.508		$ 62,500	$ 41,446
Tay-25	Rural			Fairlane Circle	Y	$ 52,000	5/7/2009	937834	1.501		$ 52,000	$ 34,644
Tay-26	Fisherman's Estates	Lot 32		Sturgeon St.	N	$ 40,000	8/30/2006	881378	0.930		$ 40,000	$ 43,011
Tay-27	Rural			Fairlane Circle	Y	$ 41,000	4/12/2007	892630	1.501		$ 41,000	$ 27,315

Tay-28	Fisherman's Estates	Lot 26		Sturgeon St.	N	$ 48,900	5/19/2006	872415	0.800	$ 48,900	$ 61,125
Tay-29	Rural			Fairlane Circle	N	$ 29,000	4/12/2007	892629	1.501	$ 29,000	$ 19,320
Tay-30	Fisherman's Estates	Lot 27		Sturgeon St.	N	$ 45,500	3/27/2006	869335	1.010	$ 45,500	$ 45,050
Tay-31	Hawk's Landing	Lot 14	N7694	Redtail Ln.	N	$ 43,900	8/24/2007	901256	0.993	$ 43,900	$ 44,209
Tay-32	Fisherman's Estates	Lot 28	W3867	Sturgeon St.	N	$ 50,000	11/26/2007	906314	4.030	$ 50,000	$ 12,407
Tay-33	Rural			Sunset Dr.	N	$ 44,900	4/20/2007	893004	1.060	$ 44,900	$ 42,358
Tay-34	Fisherman's Estates	Lot 23		Minnow Ln.	N	$ 41,272	5/11/2006	871911	0.960	$ 41,272	$ 42,992
Tay-35	Hawk's Landing	Lot 99	N7715	Redtail Ln.	N	$ 44,000	5/1/2006	883441	0.531	$ 44,000	$ 82,863
Tay-36	Fisherman's Estates	Lot 21		Minnow Ln.	N	$ 50,000	11/7/2006	884123	0.680	$ 50,000	$ 73,529
Tay-37	Sand Hill Ridge	Lot 23	W3766	Heron Ct.	N	$ 39,900	3/16/2006	868646	0.530	$ 39,900	$ 75,283
Tay-38	Fisherman's Estates	Lot 17		Perch Ln.	N	$ 48,800	3/15/2006	868611	1.050	$ 48,800	$ 46,476
Tay-39	Sand Hill Ridge	Outlot 2	N8192	Sand Hill Dr.	N	$ 49,900	3/27/2006	869045	0.940	$ 49,900	$ 53,085
Tay-40	Fisherman's Estates	Lot 16		Perch Ln.	N	$ 67,400	6/1/2007	895781	3.190	$ 67,400	$ 21,129
Tay-41	Rural		W3632	Schuster Ln.	N	$ 40,000	4/13/2006	869751	0.980	$ 40,000	$ 40,816
Tay-42	Fisherman's Estates	Lot 17	N9309	Perch Ln.	N	$ 47,500	4/18/2008	915162	1.550	$ 47,500	$ 30,645
Tay-43	Rural		W3677	Rosenthal Ct.	N	$ 32,900	6/28/2007	897596	1.206	$ 32,900	$ 27,280
Tay-44	Fisherman's Estates	Lot 10		Perch Ln.	N	$ 39,710	4/3/2006	869336	0.570	$ 39,710	$ 69,667
Tay-45	Rural		N3673	Rosenthal Ct.	N	$ 31,500	4/23/2007	893867	1.000	$ 31,500	$ 31,500
Tay-46	Fisherman's Estates	Lot 9	N9256	Perch Ln.	N	$ 41,000	5/15/2006	872274	0.500	$ 41,000	$ 82,000
Tay-47	Rural		N8424	Sunset Dr.	N	$ 41,900	4/6/2007	892075	1.010	$ 41,900	$ 41,485
Tay-48	Fisherman's Estates	Lot 7		Perch Ln.	N	$ 38,500	1/13/2006	934159	0.500	$ 38,500	$ 77,000
Tay-49	Rural			Sunset Dr.	N	$ 42,400	3/29/2007	893091	0.900	$ 42,400	$ 47,111
Tay-50	Fisherman's Estates	Lot 7	N9242	Perch Ln.	Y	$ 26,500	3/25/2009	934159	0.500	$ 26,500	$ 53,000
Tay-51	Rural		W3879	Somerset Ct.	N	$ 36,900	2/15/2007	889033	0.900	$ 36,900	$ 41,000
Tay-52	Fisherman's	Lot 5		Perch Ln.	N	$ 38,700	2/28/2006	867683	0.500	$ 38,700	$ 77,400

	Estates											
Tay-53	Rural		W3833	Somerset Ct.	N	$ 36,900	5/15/2006	872951	0.750	[redacted]	$ 36,900	$ 49,200
Tay-54	Fisherman's Estates	Lot 4		Perch Ln.	N	$ 38,610	3/28/2006	869334	0.500	[redacted]	$ 38,610	$ 77,220
Tay-55	Rural			Highland Dr.	N	$ 49,000	4/30/2007	893642	2.386	[redacted]	$ 49,000	$ 20,536
Tay-56	Fisherman's Estates	Lot 3		Perch Ln.	N	$ 38,500	1/13/2006	864806	0.500	[redacted]	$ 38,500	$ 77,000
Tay-57	Rural		N8168	Highland Dr.	N	$ 44,000	4/6/2007	892278	1.500	[redacted]	$ 44,000	$ 29,333
Tay-58	Fisherman's Estates	Lot 2		Perch Ln.	N	$ 38,300	4/28/2006	871249	0.500	[redacted]	$ 38,300	$ 76,600
Tay-59	Sand Hill Ridge	Lot 12	N8168	Sand Hill Dr.	N	$ 32,000	4/25/2008	915763	0.500	[redacted]	$ 32,000	$ 64,000
Tay-60	Fisherman's Estates	Lot 1		Perch Ln.	N	$ 38,000	4/25/2006	871250	0.540	[redacted]	$ 38,000	$ 70,370
Tay-61	Sand Hill Ridge	Lot 18	N8169	Sand Hill Dr.	N	$ 29,900	2/5/2008	910111	0.500	[redacted]	$ 29,900	$ 59,800
Tay-62	Fisherman's Estates	Lot 41		Sturgeon St.	N	$ 38,000	11/7/2006	884125	0.540	[redacted]	$ 38,000	$ 70,370
Tay-63	Sand Hill Ridge	Lot 17	N8179	Sand Hill Dr.	N	$ 29,000	11/30/2007	906665	0.500	[redacted]	$ 29,000	$ 58,000
Tay-64	Rural			Fisherman's Road	N	$ 42,000	6/3/2009	939982	1.907	[redacted]	$ 42,000	$ 22,024
Tay-65	Rural			Sunset Dr.	N	$ 38,900	6/2/2006	873344	0.850	[redacted]	$ 38,900	$ 45,765
Tay-66	Rural			Silica Rd.	N	$ 48,000	11/1/2007	905011	2.080	[redacted]	$ 48,000	$ 23,077
Tay-67	Rural		N8566	Cty Rd QQ	N	$ 55,000	1/22/2007	887591	5.461	[redacted]	$ 55,000	$ 10,071
Tay-68	Rural			Stoneridge Dr.	N	$ 60,000	5/15/2006	874032	1.501	[redacted]	$ 60,000	$ 39,973
Tay-69	Park Ridge	Lot 11		Park Ridge Dr.	N	$ 58,900	2/10/2006	865888	1.148	[redacted]	$ 58,900	$ 51,307
Tay-70	Rural		N8593	Lakeview Rd.	N	$ 58,000	8/15/2007	900674	2.370	[redacted]	$ 58,000	$ 24,473
Tay-71	Rural			Lakeview Rd.	N	$ 40,000	5/16/2007	894831	1.240	[redacted]	$ 40,000	$ 32,258

The spread sheet from above has been translated into a chart on the next page. This chart plots the land sales within the influence of the wind turbines in red and those sales outside of this influence in blue. The blue regression line plots the best fit of predicted values of the land value outside of the influenced area and then this line is compared to the six land sales lying within the wind farm. The difference in value is plotted and referenced in the graph.



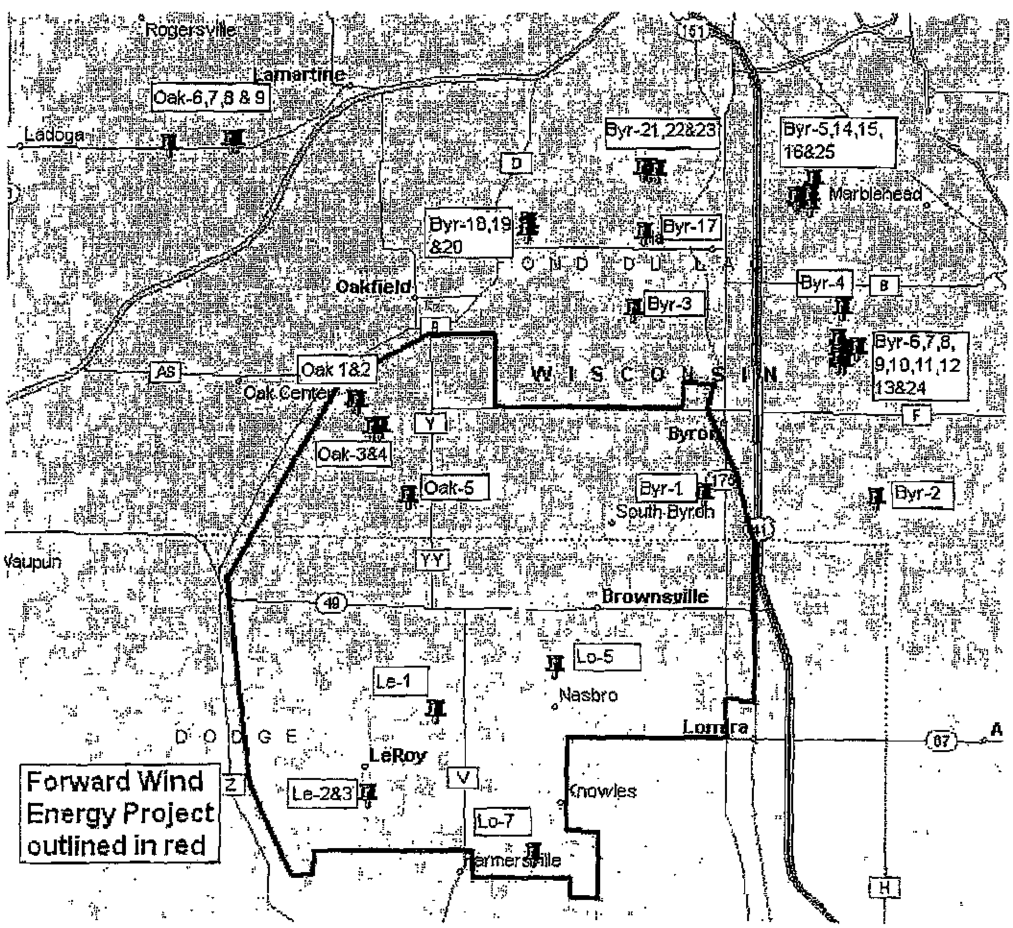
$ 100,000
$ 90,000
$ 80,000
$ 70,000
$ 60,000
$ 50,000
$ 40,000
$ 30,000
$ 20,000
$ 10,000
$ 0
$/acres
0.000
2.000
4.000
6.000
8.000
Acres
shows 19% less
shows 23% loss
shows 60% loss
shows 74% loss
R² = 0.830
Non-Wind Turbine Residential Lot Value
Wind Turbine Area Residential Lot Sales
Power (Non-Wind Turbine Residential Lot Value)
Total residential lot sales = 68 sales
Total wind turbine area = 6 sales
Total non-turbine area= 62 sales

SUMMARY & CONCLUSION

The sales study indicated three factors: (1) sales within the wind turbine influence area sold for less than those outside of this area; (2) there were substantially less sales available within the turbine influence area as compared to those sales outside of the influence area; and, (3) the impact of the wind turbines decreased the land values from -19% to -74%, with an average of -40%. Additionally, it can be said with a high rate of confidence that the impact of wind turbines on residential land sales is negative and creates a loss greater than -19% averaging -40%. It is logical to conclude that the factors that created the negative influence on vacant land are the same factors that will impact the improved property values. Therefore, it is not a leap of logic to conclude that the impact of wind turbines to improved property value would also be negative, most likely following the same pattern as the vacant land sales, that being greater than -19% averaging -40%.

Invenergy – Forward Wind Farm Sales Study

The area of study was the southwest section of Fond du Lac County and the northeast section of Dodge County being bordered by US Highway 41 to the east and Horicon Marsh to the west. The study included the townships of Oakfield and Byron in Fond du Lac County and Leroy and Lomira in Dodge County. A total of 34 vacant residential land sales were utilized for this study. From that total, 6 land sales were in the influence of the wind turbines (within the wind farm parameters) and 28 sales were located outside of that sphere of influence. The sales map for this study is pictured below:



All of these sales were the placed in a spread sheet that appears on the next pages.

INVENERGY – FORWARD WIND FARM SPREADSHEET

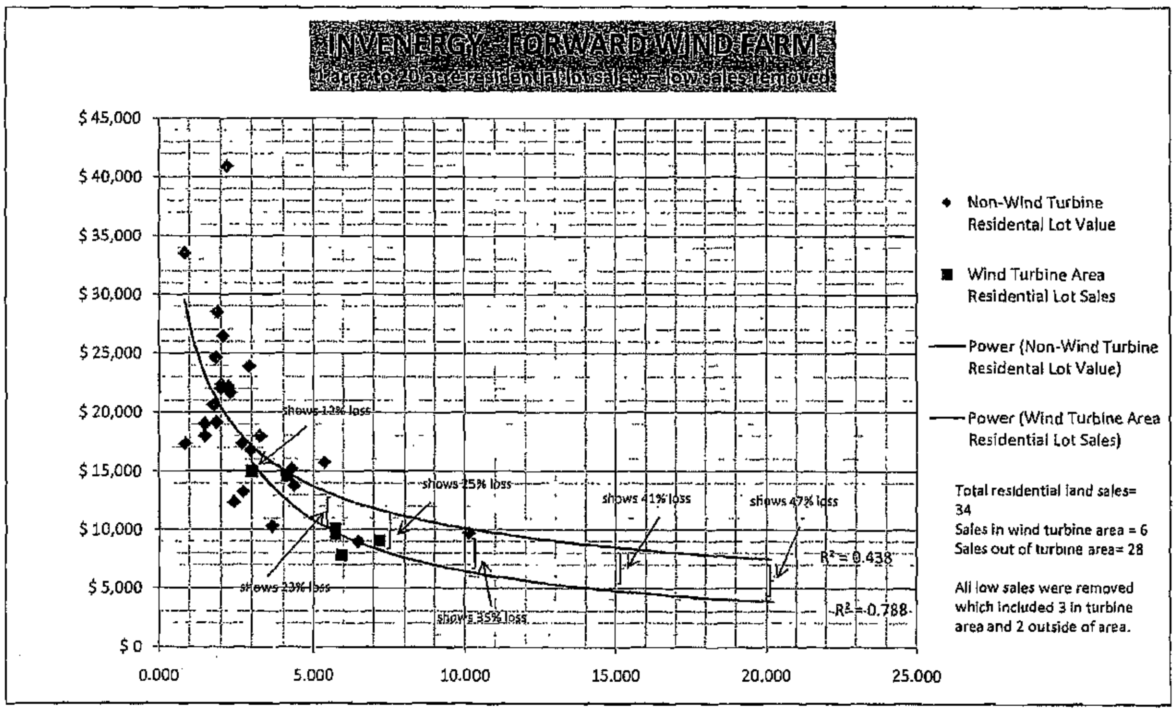
Salmon colored sales are within the wind turbine influence

Yellow colored sales are low sales both in and out of the turbine influence area removed from the chart analysis.

Identifier	Subdv	Lot	Street #	Street name	resale?	Sale Amt	Sale Date	Doc #	lot size in acres	adj Sale	$/ac
Byr-1	Rural			Cty Hwy Y	N	$ 46,500	5/29/2009	939508	5.947	$ 46,500	$ 7,819
Oak-2	Rural		W6162	Schoepke Rd.	N	$ 57,900	5/27/2005	848184	5.725	$ 57,900	$ 10,114
Lo-7	Rural		W2368	Farmersville Rd.	N	$ 60,000	8/5/2005	1051944	4.113	$ 60,000	$ 14,588
Oak-1	Rural		W6186	Schoepke Rd.	N	$ 55,000	6/15/2005	849179	5.724	$ 55,000	$ 9,609
Oak-5	Rural		W7610	Kinwood Rd.	N	$ 45,000	11/7/2005	860118	3.000	$ 45,000	$ 15,000
Lo-5	Rural			Rustic Rd.	N	$ 65,000	10/2/2007	1098197	7.188	$ 65,000	$ 9,043
Le-1	Rural		N11014	Dairy Rd.	N	$ 16,000	3/1/2005	1041761	4.000	$ 16,000	$ 4,000
Oak-3	Rural			Highland Rd.	N	$ 40,000	4/18/2006	870251	20.000	$ 40,000	$ 2,000
Oak-4	Rural			Highland Rd.	N	$ 30,000	4/18/2006	870206	15.000	$ 30,000	$ 2,000
Oak-6	Rural			Dehring Rd.	N	$ 30,000	8/14/2007	900404	5.000	$ 30,000	$ 6,000
Byr-17	Rural			Cty Hwy B	N	$ 38,700	1/18/2006	934701	5.719	$ 38,700	$ 6,767
Byr-10	Yellowstone Glen	Lot 10		Maple Ridge Dr.	N	$ 49,900	1/11/2008	909184	2.970	$ 49,900	$ 16,801
Byr-11	Yellowstone Glen	Lot 12		Maple Ridge Dr.	N	$ 49,900	9/7/2007	901728	2.250	$ 49,900	$ 22,178
Byr-12	Yellowstone Glen	Lot 9		Church Rd.	N	$ 64,900	12/19/2006	885873	4.270	$ 64,900	$ 15,199
Byr-13	Rural			Maple Lane	N	$ 35,500	12/3/2007	906831	1.855	$ 35,500	$ 19,137
Byr-14	Whispering Wind Estates	Lot 3	W5363	Abel Dr.	N	$ 36,500	12/20/2006	944576	1.770	$ 36,500	$ 20,621
Byr-15	Whispering Wind Estates	Lot 13		Abel Dr.	N	$ 89,900	4/20/2007	894055	2.197	$ 89,900	$ 40,919
Byr-16	Whispering Wind Estates	Lot 14		Bowe Ln.	N	$ 84,500	4/13/2007	892992	5.369	$ 84,500	$ 15,738
Byr-18	Rural		W7113	Briar Ct.	N	$ 50,000	1/3/2006	863679	2.306	$ 50,000	$ 21,683
Byr-19	Rural	Lot 4		Briar Ct.	N	$ 55,000	1/24/2007	887690	2.077	$ 55,000	$ 26,481

Byr-2	Rural		W5135	Cty. Rd. Y	N	$ 27,000	5/4/2006	871853	1.500	$ 27,000	$ 18,000
Byr-20	Rural	Lot 3		Briar Ct.	N	$ 58,500	6/28/2006	875130	3.260	$ 58,500	$ 17,945
Byr-21	Boda	Outlot 1		Lost Arrow Rd.	N	$ 58,500	11/23/2007	905816	6.492	$ 58,500	$ 9,011
Byr-22	Boda	Lot 3		Boda Lane	N	$ 30,000	8/31/2006	879134	2.420	$ 30,000	$ 12,397
Byr-23	Boda	Lot 6		Boda Lane	N	$ 28,500	3/14/2008	913416	1.500	$ 28,500	$ 19,000
Byr-24	Yellowstone Glen	Lot 18	W5143	Maple Ridge Dr.	N	$ 46,500	2/28/2006	867569	2.680	$ 46,500	$ 17,351
Byr-25	Whispering Wind Estates	Lot 19	W5384	Bowe Ln.	N	$ 70,000	12/28/2007	908457	2.927	$ 70,000	$ 23,915
Byr-3	Rural		N3866	Hickory Rd.	N	$ 36,000	7/11/2007	897417	2.717	$ 36,000	$ 13,250
Byr-4	Lonesome Oak		N3787	Shamrock Ct.	N	$ 37,500	6/28/2007	897801	3.636	$ 37,500	$ 10,314
Byr-5	Rural		W5326	Lost Arrow Rd.	N	$ 98,500	8/1/2008	920831	10.130	$ 98,500	$ 9,724
Byr-6	Yellowstone Glen	Lot 2	W5110	Maple Ridge Dr.	N	$ 44,900	3/29/2006	868808	1.820	$ 44,900	$ 24,670
Byr-7	Yellowstone Glen	Lot 17	W5133	Maple Ridge Dr.	N	$ 44,900	6/7/2006	873673	2.010	$ 44,900	$ 22,338
Byr-8	Yellowstone Glen	Lot 3		Maple Ridge Dr.	N	$ 53,900	11/12/2007	905595	1.890	$ 53,900	$ 28,519
Byr-9	Yellowstone Glen	Lot 8		Maple Ridge Dr.	N	$ 59,900	10/31/2007	907222	4.350	$ 59,900	$ 13,770
Le-2	Town		N10456	Cty. Rd. Y	N	$ 15,000	1/10/2005	1038920	0.865	$ 15,000	$ 17,341
Le-3	Town		N10456	Cty. Rd. Y	Y	$ 29,000	2/25/2005	1041336	0.865	$ 29,000	$ 33,526
Oak-7	Rural		W8870	Cty Hwy TC	N	$ 44,000	12/28/2007	908830	2.000	$ 44,000	$ 22,000
Oak-8	Rural			Cty Hwy TC	Y	$ 44,000	5/30/2008	917939	2.000	$ 44,000	$ 22,000
Oak-9	Rural			Cty Hwy TC	N	$ 44,000	5/29/2007	895852	2.000	$ 44,000	$ 22,000

The spreadsheet from above has been translated into a chart on the next page. This chart plots the land sales within the influence of the wind turbines in red and those sales outside of this influence in blue. The blue regression line plots the best fit of predicted values of the land value outside of the influenced area. The red regression line plots the best fit of predicted values of the land inside of the wind turbine influence. The difference in value between the two is plotted and referenced in the graph.


INVENERGY - FORWARD WIND FARM
1 acre to 20 acre residential lot sales - low sales removed
$ 45,000
$ 40,000
$ 35,000
$ 30,000
$ 25,000
$ 20,000
$ 15,000
$ 10,000
$ 5,000
$ 0
0.000
5.000
10.000
15.000
20.000
25.000
shows 12% loss
shows 25% loss
shows 41% loss
shows 47% loss
shows 23% loss
shows 35% loss
$R^2 = 0.438$
$R^2 = 0.788$
Non-Wind Turbine Residental Lot Value
Wind Turbine Area Residential Lot Sales
Power (Non-Wind Turbine Residental Lot Value)
Power (Wind Turbine Area Residential Lot Sales)
Total residential land sales= 34
Sales in wind turbine area = 6
Sales out of turbine area= 28
All low sales were removed which included 3 in turbine area and 2 outside of area.

SUMMARY & CONCLUSION

The sales study indicated three factors: (1) sales within the wind turbine influence area sold for less than those outside of this area; (2) there were substantially fewer sales available within the turbine influence area as compared to those sales outside of the influence area; and, (3) the impact of the wind turbines decreased the land values from -12% to -47% with the average being -30%. Additionally, it can be said with a high rate of confidence that the impact of wind turbines on residential land sales is negative and creates a loss greater than -12%, averaging -30%. It is logical to conclude that the factors that created the negative influence on vacant land are the same factors that will impact the improved property values. Therefore, it is not a leap of logic to conclude that the impact of wind turbines on improved property value would also be negative, most likely following the same pattern as the vacant land sales, that being greater than -12% averaging -30%.

WIND TURBINE IMPACT – LITERATURE REVIEW

By Erik Kielisch

Introduction

The push for renewable energy is a global phenomenon. "Green" energy has swept the public consciousness, and wind farms are being promoted as a clean-air alternative to traditional energy sources.[1] The prevalent opinion is, "Wind is free. Why not harness it?" The wind industry claims wind turbines emit no greenhouse gases and produce electricity without using fossil fuels.[2] They also claim that the free nature of wind eliminates fuel cost uncertainty and stabilizes the overall price of electricity as compared to fossil-fueled power plants,[3] and thusly national security can be enhanced by diversifying and distributing such electricity generation resources.[4] Industry advocates claim wind energy development can create jobs, income and tax revenues – especially in rural communities where farmers can benefit from income opportunities through leasing.[5]

On the surface, it's an attractive option, but the reality is far less encouraging. Each industry claim has been widely contested by many, including several European countries the wind energy industry holds in high regard.

The focus on the ideals personified by wind power and the willful ignorance of its true costs and inefficiency has fast become a case of "symbolism over substance."[6] Though wind is free, harnessing it is not. Nor are wind farms benign, and the converting of blowing wind into electricity is anything but "green." As the following literature review summary will show, wind energy has many unresolved issues that warrant further investigation before committing the country's resources to its further development.

The Setting

When most Americans hear of wind farms, they think of the rustic water-pumping windmills found on turn-of-the-century farms or reruns of "Little House on the Prairie." These windmills are dwarfed by the turbines proposed and built worldwide. The most common height of a modern industrial-grade wind turbine used in wind farms is nearly 400 feet from base to blade tip. That's taller than the Statue of Liberty.[7] And the spinning diameter of the blades is wide enough to comfortably fit a Boeing 747.[8]

Though fossil fuels are a limited resource, the benefits of wind energy are equally limited. In their haste to promote renewable energy, many counties and states are approving wind farms with little research into how industrial-grade wind turbines impact the health of nearby residents, property values and the local economy.[9]

Health Issues

Many people living near operating wind turbines are reporting neurological and physiological disorders that are only resolved when the turbines are off or when the people leave the area. Common symptoms include sleeplessness, headaches, dizziness, unsteadiness and nausea, exhaustion, anxiety, anger, irritability and depression, problems concentrating and learning, and Tinnitus (ringing in the ears).[10] Symptoms can be experienced up to 1.2 miles away in rolling terrain; 1.5 miles away in valleys; and 1.9 miles away in mountainous regions.[11] These symptoms are being referred to as "Wind Tower Syndrome"[12] in the U.S., but they are the same symptoms of a proven ailment, Vibroacoustic Disease (VAD).[13]

In 2007, two Portuguese scientists found that the amount of infrasound and low frequency noise (LFN) generated by wind turbines is conducive to VAD.[14] Symptoms include: slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis, chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, and parasitic), inflammation of stomach lining, pain and blood in urine, conjunctivitis, allergies, psychiatric disturbances, hemorrhages (nasal, digestive, conjunctive mucosa) varicose veins, hemorrhoids, duodenal ulcers, spastic colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, and neurological disturbances.[15]

Though some may claim high frequency noise has no health effects, a study of before-and-after sound waveforms shows how overexposure to high frequencies can cause similar symptoms including: Tinnitus, headaches, sleeplessness, dangerously high blood pressure, heart palpitations, itching in the ears, eye watering, earaches and chest pressure.[16]

These symptoms can become so overwhelming that landowners have to leave their home to recover. In a case in Canada, four families had to abandon their homes near the wind farms – prompting the wind company to bury the turbines' collector line near the worst-hit homes. A collector line transports wind-generated electricity below ground within the turbine rows and above ground from the rows to the main substation.[17] The operator also installed an insulator between the neutral line and the grounding grid. It reduced the high frequencies, but didn't completely cure the situation.[18]

Most studies on the health impacts of wind turbines have been conducted in Canada and Europe – where turbines have long been operating. But in 2009, Minnesota's Department of Health released a study on the public health impact of wind turbines. They also found that wind turbines generate a broad spectrum of low-intensity (frequency) noise,[19] and houses do little to weaken LFNs.[20] Sleeplessness and headaches are the most common health and annoyance complaints associated with proximity to turbines.[21] LFN is typically a non-issue at more than a half mile, but differences in terrain or different wind conditions could cause the sound to reach further. Unlike LFN, shadow flicker can affect people outdoors and indoors. Minnesota's Department of Health recommended further testing to determine the LFN impact; evaluate potential impacts from shadow flicker and visibility; and estimate the cumulative noise impacts of all wind turbines.[22]

The noise produced from wind turbines is extremely complex, and it is the complexity of the noise and vibration which causes the disturbance.[23] A 2007 British study surveyed 39 residents already known to be suffering from problems they felt were due to their close proximity to the turbines. On average, 75% of them reported fatigue, lack of sleep and headaches. Half reported stress and anxiety. And a quarter reported migraines, depression and Tinnitus.[24]

To counter health claims, the wind industry has quoted the World Health Organization's Community Noise Paper of 1995 which says, "There is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects." However, the final WHO document of 1999 reversed that statement: "The evidence on low frequency noise is sufficiently strong to warrant immediate concern."[25]

According to Dr. Amanda Harry's 2007 study, "Wind Turbines, Noise and Health," people are affected by LFN because the human body is "in an extremely delicate state of equilibrium with the sonic environment and any profound disturbance of this system will have profound ramification to the individual."[26]

LFNs are mainly the result of the displacement of air by a blade and of turbulence at the blade surface.[27] LFN intensity changes with the wind and it can amplify audible, higher frequency sounds to create periodic sound. The effect is stronger at night – sometimes up to 15-18dBs higher – because of atmospheric differences. Multiple turbines can interact with each other to multiply the effect which will be greater for larger, more modern turbines.[28] LFNs contribute to the overall audible noise but they're mainly seismic – which is why people say they can "feel" the noise.[29]

Body vibration exposure at seemingly low frequencies from 1-20 Hz can have the following effects:[30]

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

Over time, symptoms from LFN can have serious adverse physiological effects:[31]

- After 1-4 years: slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis.
- After 4-10 years: chest pain, definite mood swings, back pain, fatigue, skin infections, inflammation of stomach lining, pain and blood in urine, conjunctivitis, allergies.
- After 10 years: psychiatric disturbances, hemorrhages, varicose veins, hemorrhoids, duodenal ulcers, spastic colitis, blindness, headaches, severe joint pain, intense muscular pain, neurological disturbances.

One particular case in Nova Scotia, Canada has generated substantial press. The d'Entermont family home sits in the midst of a 17-turbine wind farm. Soon after the turbines began operating, the parents saw a noticeable shift in their six children's behavior. They started becoming more irritable, hearing ringing in the ears, lost concentration and developed high blood pressure. They had to move 30 miles away to resolve the health issues, and no one will buy their home.[32]

However, these symptoms don't affect everyone. Because wind is inconsistent, so too will be the noise (and thus health effects) caused by wind turbines.[33] As a result, the wind industry counters such health claims by relying on engineers and acoustics consultants who base their conclusions on engineering principles instead of on physiology like opposing audiologists and physicians who study the effect of sound and vibration on people.[34,35] Likewise, many environmentalists dismiss any health effects – claiming they're fictions fueled by not-in-my-backyard-ism.[36] However, experts in biomedical research have drawn different conclusions.[37]

The French National Academy of Medicine has warned that the harmful effects of sound related to wind turbines are insufficiently assessed. They consider wind turbines to be industrial installations and expect turbine operators to comply with specific regulations that address the harmful effects of sound particularly produced by these structures.[38]

This year, two families in Ontario, Canada had to move due to adverse health effects from nearby wind turbines. One of the displaced landowners said he started suffering from very high blood pressure, sore feet and irritability once the wind farm was online. Once he leaves the area, he quickly recovers. The wind company is paying for one of them to stay in a hotel while tests are being done on their property.[39]

In July of 2009, Sean Whittaker, vice president of policy for the Canadian Wind Energy Association said such health complaints are few. "There's no cause and effect relationship between audible sound produced by turbines and adverse health effects," Whittaker said. "...all research to date indicates that turbines do not produce infrasound at levels near enough to have impacts on humans."[40]

Elizabeth May, the former Executive Director of Sierra Club of Canada, vehemently defends wind energy but admits that literature studies show wind towers negatively affect human health. She makes a concession for better project siting – away from impacted citizens.[41]

But why do some suffer and others do not? Everyone's body is different. Some can be exposed to the flu and never catch it, while others succumb. Of three siblings with identical parentage, two may always be healthy and the third may suffer from extreme arthritis. The human body is complex and some are more resilient than others to outside influences.

Health Solutions

The international community recommends generous setbacks from wind farms in order to mitigate any potential health effects and loss to property values. The setbacks range from a minimal 1,500 foot setback[42] to 1½ miles away from any home, school or business.[43] Because symptoms can be suffered up to a mile from a wind farm, one study suggests that turbines should be no closer than 1½ miles from a residence.[44] Others recommend an immediate and mandatory minimum buffer of 1¼ miles between a dwelling and an industrial wind turbine, and even more of a buffer between a dwelling and a wind turbine with greater than 2MW installed capacity.[45]

Other solutions include: filtering inverters at each turbine, burying all collector lines, filtering the power at the substation before going to the grid, and installing a proper neutral system to handle the high frequency return current.[46]

Wind Turbine Hazards

Wind turbines, like all machines, have weaknesses and are subject to accidents and failure. Inclement weather and strong gusts can snap off wind tower blades;[47] ice can build up on the blades, break and throw large ice chunks[48] and fling ice shards onto nearby homes[49,50] - potentially harming nearby residents;[51] turbulent wind can accelerate a blade's deterioration, weakening it to the point of breaking off and crashing into nearby homes;[52] high winds can also overpower its automatic braking system and result in structural failure;[53] automatic shut-down systems can malfunction, damaging the turbine to the point of collapse;[54] and gale force winds can shut down turbines and make them a safety concern. In one such case, British police cordoned off a 1,500 foot area around the wind farm for "safety precautions."[55] Other common problems include fires and blade disintegration caused by mechanical failures and lightning.[56]

In Europe, which has long had wind farms, they have seen an increase in turbine accidents, defects and needed repairs. A turbine's gearbox is expected to last 5 years and often quits before then. Due to the huge demand for turbines, manufacturers have no time to test their product before sending it into the field. And the demand has so strained manufacturing capabilities that the waiting list for replacement parts can sometimes top 18 months – leaving the turbine motionless in the meantime.[57]

Wind farms interfere with weather radar by sending false storm signals,[58] thus limiting the ability of people in surrounding areas to know if they should seek shelter or not. They also interfere with military radar, affecting military readiness.[59] And they may interfere with civilian radar,[60] making it dangerous to site turbines near airports or military installations.[61]

Despite the constant warning lights on top of each turbine, wind farms are dangerous to planes. A distance of 1,200 feet is still too close to an airport or landing strip because aircraft cannot turn fast enough to avoid the turbines. Also, turbines create a down draft – additional turbulence that pilots have to overcome in take offs and landing.[62]

In the 2007 *Burch v. Nedpower Mount Storm, LLC* decision, a West Virginia court found that wind farms can constitute a nuisance to nearby landowners. Even though the state's Public Service Commission approved the facility, the court ruled that such approval does not overrule the common law of nuisance.[63] Accepted causes of nuisance included noise, eyesore, flicker and strobe effect of light reflecting from blades, potential danger from broken blades, ice throws, and reduced property values.[64]

Conservation Concerns

Wind turbines have been found to adversely affect a wide variety of environmental, ecological, and scenic values.[65] Poor turbine sitings have led to bird and bat fatalities.[66] According to the American Bird Conservancy, wind towers kill 10,000 to 40,000 birds every year. However, this is still much lower than the 100 million window-related bird deaths each year.[67] Bat deaths, however, are killed three times as much as birds by wind turbines.[68] And many bats killed by turbines are most likely migrating for mating rituals. If such bats are killed then certain bat species are in danger of failing to repopulate.[69]

Aside from wildlife concerns, conservation groups are divided on wind energy. In North Carolina, environmentalists are fighting over siting issues. Some side with the wind companies and want to place wind turbines on mountain ridges for optimal winds. But other environmentalists want to keep them off the ridges in order to protect the mountains' natural beauty.[70]

According to the wind industry, the most damage to wildlife and plant-life happens during construction. After that, they say collision deaths are insignificant compared to the effects of other man-made structures, vehicles and pollution.[71] Turbine installation can also significantly affect natural drainage and ground water.[72]

The wind industry acknowledges is toxic or hazardous materials in the form of relatively small amounts of leaking lubricating oils, hydraulic and insulating fluids.[73] However, even small leakages of such materials can negatively impact ground water if left unchecked over time.[74] Fluid leaks not only drip directly downward, but they also fly off the tips of the spinning blades, thus spreading the contamination over a wider area.[75] On-site storage of new and used lubricants and cleaning fluids also constitutes a hazard.[76] To protect the public, the National Wind Coordinating Committee recommends setback requirements to provide "an adequate buffer" between wind generators and consistent public exposure and access.[77]

Property Values and Land Use

Wind industry advocates say little about a turbine's impact on property values. When they do address the issue, they deny that wind farms negatively impact property values. If they do admit impact, they say the only effect would be more time on the market.[78]

Mike Sagrillo, president of Sagrillo Power & Light Co. said that those who claim property value diminutions "pull myths out of thin air and persist in wild accusations despite being debunked."[79] To prove this point, wind industry advocates frequently refer to a 2004 study performed by the Renewable Energy Policy Project (REPP) – an organization dedicated to accelerating the use of renewable energy.

The REPP study, paid for by wind energy proponents, reviewed 25,000 assessment records of property sales within 5 miles of wind projects from 1998-2001 to determine if there was a negative effect on property values within the view shed of the wind farm projects. In 9 out of their 10 case studies, they found either no change in value or even an increase of value for those properties within the turbines' view shed.[80]

However, the conclusion that property values increased isn't verified.[81] They did not follow up with the property purchasers.[82] The REPP findings omit many necessary variables for analysis such as adjustments for a rising or falling market, number of days from listing to sale, residential property vs. rural property, effect of noise, flickering and shadows, distances of the homes from the turbines, and possible change in highest and best use due to the presence of the turbines.[83] By using assessment data, they measured mass property values, not individual property values, and assessments do not accurately reflect market value. The purpose of an assessment is to treat all property owners equally so the general tax burden is shared by all.

The REPP study also does not analyze whether or not the properties had a direct line of sight to the turbines, and the number of property transactions decreases the closer one approaches the wind farm. By only examining change in comparable property values over a three year period, the study weakens itself because, in most cases, the projects had been announced and debated long before the three-year window opened. As a result, any depressive effect on property values would have occurred prior to the start of the study.[84]

In contrast, others say close proximity to wind turbines can devalue a property 20-30%.[85] In analyzing potential impact to their township from a wind farm, the township of Centerville, Michigan disregarded the REPP study because of its flaws and bias in favor of wind energy.[86]

Industry advocates often liken wind turbines to other man-made structures like water towers.[87] But water towers don't move.[88] If they had no effect, then people would want to live near them. However, developers are balking at even building near wind turbines lest potential buyers of high-end homes be "spooked by the noise and visual distraction of the huge whirling fan blades."[89] In many cases there is a complete lack of interest in any homes near existing or planned wind farms. And when they do sell, they usually sell at less than current market value.[90]

At best, a wind turbine near a residential property can have no effect on the value and salability of the property. As one realtor explained, "Logically, as wind turbines produce constant audible noise over a large area, and as they intrude on the view shed, the only valid conclusion is that nearby residences are less valuable than they would be if there was no turbine nearby. Why would a buyer choose a house within sight and sound of a turbine, if a comparable house at the same price were available elsewhere, beyond the sight and sound of the turbine? It is totally counter-intuitive to suggest anything else."[91]

In the last couple years, Canadian assessors have begun to devalue homes that are at least 1,500 feet away from the nearest turbine. In Prince Edward Island, several residents near an industrial wind farm received up to a 10% lower property value due their proximity. The assessors considered the turbines as an industrial area and devalued nearby properties accordingly.[92]

As with other easements, some claim that the impact from windmills will diminish over time. However, studies from Europe show otherwise. In Germany, which has long had windmills, real estate agents report property value losses between 20-30% for properties in sight of wind farms.[93] And even though a minority may find windmills to be a nuisance, property values can still drop $2,900 per turbine up to $16,000 for a property abutting 12 turbines.[94] Likewise, Scottish real estate agents found that a 41-turbine wind farm would result in $1 million in property value losses.[95]

Properties within wind farm areas may experience longer days on market. In his study, "Living with the Impact of Windmills," Real Estate broker Chris Luxemburger studied 600 sales over 3 years within proximity of a wind mill (interchangeable with "turbine") found that the days on market were more than double for properties within the windmill zone. Selling price was an average of $48,000 lower inside the zone than outside. And 11% of homes within the zone did not sell vs. 3% of homes outside the zone.[96]

Wind farms are normally built in rural locations. Therefore, apart from size, the main influences on value will often be the view, peace and serenity, and a rural environment. In many rural locations a wind farm will reduce the value of properties located nearby.[97] However, it has been observed in some rural farming areas that prices remained steady or even increased for those properties benefitting from the associated income stream from the turbine leases.[98] Many factors contribute to a loss in value, including: loss of a quality view, environmental noise pollution and the consequent health impact, shadow flicker and strobing light (which can have health repercussions). The further a dwelling is from wind turbines, the less impact they will have on property values and health.

In 2004, the township of Lincoln in Kewaunee, Wisconsin performed its own study and found that sales within one mile of the wind farm prior to installation were 104% of the assessed values. Properties selling after the wind farm installation in the same area were at 78% of the assessed value.[99] The UK has reported similar impacts up to a 20% loss in value from the presence of four 360-foot tall turbines 550 yards from a new home.[100]

In most cases, environmental noise pollution will influence the bulk of the property damages. In a well-populated rural area, the total financial damage on the community will substantially exceed the public interest that will be served from the wind farm.[101]

To counter claims of property value loss, the wind industry cites a 2006 study which shows no impact on property values from visibility of a constructed 20-turbine wind farm. The author, an environmental scientist graduate student, analyzed 280 arms-length residential home sales within 5 miles of the wind farm occurring between 1996 and 2005. He concludes that the lack of impact was due to wind farms "fitting the community's 'sense of place;'" payments "balanced" any adverse impacts; a well-respected landowner / proponent swayed others; and "possibly residents swapped local impacts for global benefits." However, the study does not include sales less than 4,000 feet from the windmills. It does not include any data on whether there were homes closer that did not sell. And of his 280 sales, only 43 had sold after the project started.[102]

The wind industry has referenced a 2007 British study of 919 home sales within 5 miles of a wind farm that found no impact from wind turbines on property value.[103] However, the turbines' maximum height was just over a third (124ft) of turbines being currently built. Additionally, the study omitted whether any of the sales could see the turbines. All distance zones and rural and town properties were combined together without differentiation. There was no before-and-after analysis of sale prices.[104] When interviewing general land agents, the study found 60% said that nearby wind farms would decrease property values in the view shed.

And 67% believed property value depreciation starts at the planning stages and lessen with time.[105]

In Kewaunee, Wisconsin, a 2007 study paid for by Invenergy, LLC – a wind farm developer – found no measurable difference in home values in the target areas close to the wind farms and the control areas outside of the wind farm vicinity. It found the same for a case study in Mendota, Illinois.[106]

However, even the possibility of a wind farm may have a more significant impact than the actual presence of one. In Michigan, a real estate agent lost a large vineyard sale because a proposed wind farm was seen as a detriment to potential buyers.[107] Wind farms in the UK are purposely avoiding populated areas in order to mitigate property value-based opposition.[108]

In 2006, concerned about the impact wind turbines may have on local property values, two members of the Centerville Township in Michigan conducted their own literature review of four available studies on the subject. The township committee concluded that the presence of wind turbine generators near residential houses causes property values to decline.[109] They concluded that the amount of negative impact is as high as $25,000 per property. In their words, "This is common sense, and there are no serious scholarly studies that support an opposite conclusion."

They found that large wind turbines can affect neighboring property values due to noise, health effects and visual impacts on residents. Some homes have been reported as "not salable" because of their proximity to wind turbines. Further impact on property values depends on location. These adverse impacts on property values may not exist in agricultural areas that have huge farms. If land is being sold as fertile farmland, then the presence (or absence) of a nearby wind turbine is probably irrelevant. If there is a chance that a future wind turbine might be placed on the property, a potential buyer might think the land was slightly more valuable.[110]

Though having a wind turbine on a property may create an income stream and thus increase a property's production value, it does not necessarily result in increased market value.[111] The wind turbine lessee incurs a higher property tax and receives annual rent for signing the lease/easement. The other landholders find their property values decreased, and they receive nothing.[112] Real Estate brokers in rural areas confirm that property values in wind farm areas are 10-30% less than similar properties outside of wind farm areas.[113]

View adds value to rural property. Take away the view, and you take away the value.[114] Homes with a turbine within 300 feet can suffer reduced property values of up to 10%. Noise, blinking lights, glare from the blades and vibrations all play a role in devaluation.[115] The value of a farmhouse may be affected by as much as 30% if it is in close proximity to a wind turbine.[116] In 2001 a British judge found that the noise, visual intrusion and flickering of a turbine a little over 1,800 feet away from a property negatively impacted local properties by 20%. According to the judge, "It is an incursion into the countryside. It ruins the peace."[117] Agents in Britain, Australia and the U.S.A. agree. They have found it nearly impossible to sell properties next to wind farms unless they discount it 20-30%.[118] "To me, it is absolute common sense that if you put up huge industrial structures in an exceptionally beautiful area, property prices are going to suffer," said British real estate agent, Kyle Blue.[119]

A 2004 realtor study around Nantucket Sound found that 49% of realtors expect property values to fall in proximity to a wind farm.[120] Two studies conducted in Nantucket, Massachusetts found that a 130-turbine offshore wind farm would drive enough visitors away to see a loss of up to 2,500 tourism-related jobs. They also found that inland property values would decline 4.6% while the waterfront properties suffer nearly 11% diminution for a total loss of $8 million in yearly tax revenue.[121]

In 2005, a successful Maryland realtor named Russell Bounds testified before the Maryland Public Service Commission as to the effect wind farms have on property values. In his experience he found that combining an area of natural beauty with industrial development like a wind farm will negatively impact its desirability. "It is not only devalued," Bounds said, "but the property may also be rendered unsaleable."[122]

Bounds further testified that property values up to a mile from the turbines will be negatively impacted. Beyond a mile the visual impact may still diminish property value. Closer to the turbines, the visual and the noise impact will substantially diminish special attributes of a property including scenic view, natural setting and peace and quiet.[123]

The impact of a wind turbine close to a property "takes a property of substantial value and takes away all of the characteristics that are the strengths of that property," Bounds said. "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."[124]

In Maryland, a wind farm developer demonstrated the diminution of value when it bought two abutting properties to their wind farm and were unable to sell them for close to their purchase price. They bought one property for $104,447.50 and sold it for $65,000. They bought another property for $101,049.00 and shortly thereafter sold it for only $20,000.[125]

Studies have shown that fear of wind farms can negatively affect purchase prices. In his February 2009 study, "Impact of Wind Turbines on Market Value of Texas Rural Land," Appraiser Derry Gardner studied 350 acres of premium ranch land that were put on the market for $2.1 million. A prospective buyer agreed to the sale price but backed out when the seller disclosed a 27-turbine wind farm within a 1½ mile radius from the property. The seller discounted the land by 25%, but the buyer still declined to purchase. As of the study's publication, after two years on the market there has been little interest in the property despite its other positive characteristics.[126]

Independent studies have shown an average diminution of value up to -37% when the turbine is on the property; up to -26% average diminution for properties within 1,056 – 2,112 feet of a turbine; and up to -25% average diminution for properties within 1.8 miles of turbines. Properties can also suffer an additional 15-25% diminution in value due to infrastructure construction (clearing, blasting, digging, etc.), high voltage transmission power lines (HVTL) to transport generated electricity, substations, additional traffic for servicing turbines and HVTLs, and additional roads.[127]

Wind farms have the potential to impact local property values.[128] As the number of houses near to, or with a view of the installation increases, the likelihood of aesthetic or economic objections seems to increase.[129] To calm property owners, one township recommended that the wind farm developer provide property value assurances that are transferrable to subsequent owners of the wind facility.[130] Developers may wish to consider compensating the community in some fashion that benefits even non-participants, such as impact payments to the township. Resulting benefits, such as reduced property taxes, may help to address concerns about inequities.[131]

Noise

Turbines make noise. The amount of noise can change with atmospheric conditions, wind speed, temperature, and terrain. Noise, particularly low frequency noise, travels not only seismically but also airborne over terrain. Hills and valleys can create a megaphone effect that can directionalize, combine and intensify the sounds of multiple turbines.[132,133] It can be noticeable for long distances in more remote areas with existing low ambient levels.[134] At the turbine's hub, the noise ranges from 100-105 dBA. People can differentiate sounds up to 3 dBA above background levels.[135]

The wind industry has said that the windy nature of rural locations often masks the quiet nature of modern turbines, even for "the very few individuals" located close enough to hear it.[136] However, turbine noise greatly affects people even a mile away, and low frequency noise can make people irritable.[137] Industry advocates say little, if anything, about infrasound or low frequency noise.

The environmental noise pollution from wind turbines built too close to dwellings causes serious discomfort and often health injury. Oftentimes those affected did not object to the construction, accepting the developer's assurances that noise would not be a problem.[138]

A common argument in support of wind turbines is that their noise is at lower sound pressure levels than highways and roadways. In contrast, a 2007 study found that noise annoyance associated with wind turbines hasn't decreased because the absolute noise level they create is less important than the character of the noise produced.[139] In other words, annoyance doesn't depend so much on the volume of sound created, it depends on what it actually sounds like. Wind turbines produce no constant tonality, making the creation of a noise standard challenging.[140]

The main issue appears to be low frequency sound waves. Two to three Hz can cause vomiting and other serious health issues. Twelve Hz can cause hallucinations.[141] Because of the deep foundations necessary to stabilize large wind turbines, LFN is transmitted down and throughout the contours of the land, often follows bedrock and even accelerates to emerge randomly miles from its origin.[142] Audible noises and LFN vibrations should be considered in siting along with the potential additional noise caused by broken machinery such as a failed bearing.[143]

Quality Of Life

To many, turbines are visually distracting, out of place and threaten residents' peace and quality of life.[144] Strobing light and shadows affect feelings of peace and solitude.[145]

Turbines generate flicker and shadows that can distract nearby motorists.[146] They also interfere with television signals, thus affecting the quality of life for nearby residents.[147]

Turbine-generated noise has an adverse impact on quality of life and may adversely impact the health of those living nearby. Research links noise to adverse health effects such as sleep deprivation and headaches. Sleep deprivation may lead to physiological effects such as a rise in cortisol levels – a sign of physiologic stress – as well as headaches, 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.[148]

Even proximity to small wind farms can have a serious impact on nearby residents. Concerned about the potential effects of a 22-turbine wind farm near their town, the township of Lincoln, Illinois surveyed its residents in 2001 and found that, on average, 42% were bothered by blade flicker and noise, had been awakened by turbine sound, and had TV reception problems. Nearby property owners also cited increased lightning activity, increased traffic hazards, annoyance at the tower's blinking lights, emergence of strange symptoms, and fears of EMFs. These tangible and intangible issues had an impact on the market value of nearby real estate. Reluctance to live near the turbines dramatically increased with proximity. For example, 41% of residents would not build or buy a home within 2 miles of the turbines. Within a half mile, 61% would not build or buy a home. And a quarter mile away from the turbines, 74% would not build or buy a home.[149] Wind farm developers said property values wouldn't suffer. But the town zoning administrator did his own empirical research and found that sales within 1 mile of the windmills prior to their construction were 104% the assessed value, and properties selling in the same area after construction were at 78%. Sales more than a mile away were at 105% the assessed value before and 87% after. They also found several properties have taken much longer than normal to sell.[150]

In New York, a landowner with a turbine on his property 2,000 feet from his house says the turbine rattles his windows, and he can hear some turbines a mile away in his house. The wind company said the turbine noise wouldn't exceed the sound of a refrigerator 900 feet away. He was joined by two other neighbors with similar complaints. They added that fellow neighbors in proximity to the turbines started experiencing seizures, anxiety attacks, learning disorders and other ailments once the turbines started running. Neither he nor the other leaseholders nor the town has received any promised compensation because the turbines are not selling into the grid. They were told the lights would be the softest available but they were instead much brighter than anticipated.[151]

Several case studies conducted by the wind industry show that landowners care little about nearby wind farms. In Oregon's Stateline Project, a 127-turbine farm covering 15 square miles in 2001 only sparked concerns over wildlife protection.[152] Southwest Minnesota has been building wind farms since 1995 ranging from 17 turbines to 143. Very few issues were raised during the review and permitting process and only after being built have issues emerged regarding poor television reception in proximity to the farms, additional noise generated by loose pieces of material within the blade at low speeds; cleanup of materials associated with turbine or blade modifications; complaints about aesthetic detriment; and bird health issues.[153]

In Highland County, Virginia, members of the rural mountain community fears that a proposed 19-turbine, 400-feet-tall-each project will blight their rural landscape and destroy the area's scenic beauty. The wind farm developer claims the turbines can power 20k homes. Community response has been very negative. Residents are afraid the turbines will kill tourism – their only industry – and negatively impact property values.[154]

A proposed 67-tower wind farm near Delavan, Illinois sparked strong opinions among its affected community. Supporters say it will bring additional property tax revenue, jobs and clean energy. Its opponents say it will be an eyesore, a dangerous obstacle to crop dusters and would lower property values. An acoustical engineer from Michigan testified that the turbines would create noise that could affect nearby residents.[155]

In addition to landscape blight, many landowners are upset when the wind farms bring new transmission lines to transmit the wind energy to metro areas. But utilities are generally dismissive of such concerns. As the spokeswoman of Texas utility Oncor put it, "the importance of the transmission lines outweighs the aesthetic worries."[156]

In Europe, where wind farms have existed and operated for many years, many people do not want to be near them, especially in scenic areas.[157]

Wind Energy Production

Wind energy is gaining momentum in Wisconsin largely due to favorable geography, but it has its flaws. A typical coal-fired generating plant produces 500-600 megawatts of electricity per hour. Most wind turbines operate on average 30% of the time.[158] Invenergy, LLC forecast that their 133 turbines would generate 200 megawatts per hour.[159] However, the wind industry's average production percentages show that Invenergy's Forward Wind Farm in Fond du Lac and Dodge counties would generate 60 mWh (average).[160] In order to equal a fossil-fuel power plant, Invenergy would have to increase its farm 8 to 10 times its original size. A power plant typically covers a 40-acre footprint. Invenergy's wind farm covers a township. They would have to cover half a county to equal the output of one fossil-fueled power plant, and then only when the wind blows.

To make up the difference when the wind stops blowing, traditional power plants have to be constantly on (or "spinning") and generating reserve capacity equal to the maximum total power of wind turbines[161] – ready at any moment to be "ramped up" to stabilize the grid. This fluctuating backup system of spinning and ramping makes traditional power plants run inefficiently and increases fuel consumption (emissions). Keeping the necessary additional reserve capacity, and factoring in ramping up and down, will increase the fuel consumption (emissions) at least 8-10% compared with the steady operation of traditional power stations.[162]

Over 20 years of use in Europe, wind generated power has proven to be variable, unpredictable, uncontrollable and "routinely disappointing," according to UK energy expert, David White.[163]

In his 2007 study, "Calculating the Real Cost of Industrial Wind Power: An Information Update for Ontario Electricity Consumers," Keith Stirling, MA, summarized the Washington D.C.-based National Research Council of the National Academies 2007 report on the environmental impacts of wind energy projects. He summarizes their findings thusly, "Wind energy development will provide no reduction in emissions of sulfur and nitrogen oxides, the pollutants responsible for acid rain and ground-level ozone. Regarding carbon dioxide, industrial wind turbines will offset national emissions by only 1.2-4.5% from the levels that otherwise would occur from electricity generation. [Most expert estimates are much lower however, usually around .0003%]. Wind power will not reduce carbon emissions of the U.S., but merely will slow the increase by a small amount."[164]

Even with generous government subsidies, wind energy is the highest cost option of available renewable energy sources.[165] It becomes more expensive to consumers once required backup and additional infrastructure are factored in. The high cost is caused by: A) the need to maintain backup generating reserve to cover times when the wind does not blow, B) the need to stabilize the grid when wind produces power that is not needed by current demand, and C) Government subsidization and tax benefits for the wind industry.[166]

Wind-power increases the complexity of the transmission and distribution system, and it is therefore inevitable that transmission losses [often estimated at 10%] will increase because of the additional miles of power lines required, both factors increasing costs.[167]

To help fund a new wind farm in Minnesota that will send its energy to Wisconsin, Alliant Energy proposes to raise electric and natural gas rates by 2010 – resulting in citizens having to pay nearly $9 more per month per household on their electric bill and $2.40 more per month per household on their gas bill. The farm will include 122 turbines, 400-feet tall each with 130-foot blades. As of July of 2009, Wisconsin citizen watchdog groups were criticizing Wisconsin's Public Service Commission's minimal review and questioning the project's need.[168]

In his introduction to his Environmentally Responsible Wind Power Act of 2005, U.S. Senator Lamar Alexander stated, "Wind produces puny amounts of high-cost unreliable power...Congress should not subsidize the destruction of the American landscape."[169]

To promote wind energy, many government entities have not factored in the real emissions impact of matching both demand and wind output simultaneously. As a result, many current policies incorrectly assume that CO2 emissions savings are guaranteed by the introduction of wind-power, and ignore wind power's difficulties and costs.[170]

Ireland's Electricity Supply Board published evidence in 2004 showing that as the level of wind capacity increases, the CO2 emissions increase with the variation of wind-power output.[171] Unlike natural gas or coal, wind energy cannot be physically stored on an industrial scale. Consequently, generation and demand have to be continuously balanced on the grid. Fossil-fuelled capacity operating as reserve and backup is required to accompany wind generation and stabilize supplies to the consumer.[172]

Operating gas turbines by ramping up and down generates more CO2 per kWh of electrical generation than if the gas turbines were operated on the normal planned load. Dependent on the weather forecasts, it may be possible to shut down some capacity for brief periods, but this may frequently be for only a matter of hours. Fuel is then wastefully consumed and CO2 emitted as the plant is started up again, without any power being generated, before it is returned to load-bearing grid service. Gas turbines are not made to handle frequent ramping and start-ups. This not only increases the CO2 emissions, but also causes otherwise avoidable wear and tear, and so shortens the periods between overhauls, thereby adding to maintenance costs and eventually resulting in a 15% increase in electricity cost.[173]

Merging wind-generated power into the power system is more complex than simply shutting down traditional power plants whenever the wind blows. The feed-in capacity can change frequently within a few hours.[174,175] And half of the time, wind power in-feed is less than two-thirds of its annual average.[176,177] Starting up and shutting down power plants may take minutes or hours, depending on the type of plant, while power may be needed in seconds. Unlike a conventional plant, wind output is not related to customer demand. Maximum wind production may occur during low customer demand periods, or at times of peak demand there may be little or no wind-generated power.

Canada knows all too well the irregular nature of wind. In Ontario, Canada they found that wind output changes have shown one distinct pattern: winds tend to be calm when consumers need electricity most. Northerners use the most electricity in summer – their weakest season for wind. Although winter is the strongest season, on the coldest days, when people use the most power, wind output tends to be poorest. Over the typical day, wind output peaks around midnight and bottoms out around 8 a.m., contrary to daily consumption.[178]

While Ontario's new wind generation has reduced fossil fuel generation when wind output is available, the wind production pattern – output falls during the early morning – has offset this benefit by lowering the fuel efficiency of the flexible fossil generators used for ramping, increasing air emissions per unit of production, and increasing maintenance costs.[179]

Ontario's 2006 Energy Probe reviewed a 2004 German study of their grid reliability and found that the proposed tripling of wind capacity in Germany by 2020 is alone driving a need for quintupling generation reserve requirements.[180] Wind power construction must be accompanied by almost equal construction of new conventional power plants, which will be used very nearly as much as if the wind turbines were not there.[181,182]

Germany hosts approximately 11,000 turbines which provide 4.7% of Germany's gross demand. Even then the electricity is sporadic because the wind blows when it likes, as it likes, and where it likes – which, unfortunately, is rarely in places where large quantities of power are required.[183] Likewise, the Danes, long held as a prime example of wind energy in action, reported in 2004 that increased development of wind turbines did not reduce their CO2 emissions.[184]

The increased use of wind power in Germany has resulted in uncontrollable fluctuations in generation due to the random character of wind power feed-in. This significantly increases the demands placed on the control balancing process and increases grid costs. Their massive increase of new wind farms in recent years has greatly increased their need for fossil-fueled reserve capacity.[185,186]

As wind power generating capacity increases, its ability to displace conventional sources decreases. Wind power is essentially adding surplus capacity rather than replacing conventional plants. One-third of the time, widespread wind power facilities in the U.K. (which boasts the best wind resource in Europe) would be producing at less than 14% of the turbines' capacity.[187,188]

Wind farms only provide electricity when the wind is strong enough but not too strong. As they suddenly provide electricity when the wind changes, the grid operator must match this changed supply of electricity to the existing demand. This is achieved by switching a power station to spinning standby mode so it can provide electricity when the wind changes again.

Spinning reserves provide no useful electricity and do not reduce emissions from power generation.[189]

Promoters of wind energy routinely overstate environmental benefits. They advocate that each kilowatt-hour (kWh) of electricity produced by a wind turbine displaces the same amount of fuel-use and emissions associated with a kWh of electricity produced by a fossil-fuel generating unit. However, the saving of CO2 emissions is not proportional to the amount of fossil-fueled power that it displaces. Necessary spinning reserve fossil-fired capacity emits more CO2/kWh than if the plant were optimized, thus offsetting much of the benefit of wind.[190] In addition to the assumption of kWh-per-kWh offsets, wind energy advocates often use outdated information about emissions when making their claims, not taking into account the difference made by newer, cleaner burning fossil fueled plants.[191]

The more wind power capacity is in the grid, the lower percentage of traditional generation it can replace. A wind farm of 24,000 turbines with a generating capability of 48,000 MW would replace just 2,000 MW of conventional generation, the equivalent to two medium-sized coal stations.[192]

The greater the distance between the source of generation and center of demand, the greater the losses during transmission. Currently these losses are estimated at 10-15%.[193] This is a problem since most wind turbines are in rural locations and far from the need.

Even at 10,000 turbines across the country, the UK will still not be able to supply 15% of its energy through wind turbines by 2020. Environmentalists say it's necessary to stop Global Warming while others point out how thousands of more wind turbines will blight their land.[194]

The high cost and low return of wind farms is acknowledged by the U.S. National Association of Attorney Generals. In a 2008 presentation, they concluded that, despite being "green" wind farms are a high-cost alternative with a large footprint but small power output.[195]

As we have seen from empirical research gleaned from a worldwide search, wind turbines produce very little electricity.[196] They have a high capital cost,[197] and poor capacity utilization.[198] Why, then, is wind-power the beneficiary of such extensive support if it is incapable of providing consistent power to replace traditional power plants, does not achieve the CO2 reductions required, and causes cost increases in backup, maintenance and transmission, while at the same time discouraging investment in clean, firm generation capacity?[199]

Wind Farms = Tax Havens

In light of the technical limitations of wind turbines, it makes sense to ask why wind farms remain so popular. Two factors seem to take precedence. Firstly, the U.S. government is requiring states to provide a certain percentage of their energy with green energy solutions by 2020. Utilities have to find some alternative energy to invest in. The second reason appears to be that utilities receive generous subsidies and tax incentives to build wind farms. The tax breaks include federal and state accelerated depreciation, production tax credits, and reduced (or forgiven) property and sales taxes.[200]

Wind farms are very attractive to utilities looking to bury taxable income. For example: A company proposing a new 300 megawatt wind farm costing $300,000,000 would be able to:

1. Shelter approximately $132 million from federal income tax liability in the tax year when the project went into service, an additional $67.2 million in the second year, $40.3 million in the third year, and the remaining $60.5 million in the next 3 years because of generous accelerated depreciation allowed for wind farms.[201]
2. Deduct an additional $14,191,200 per year for 10 years from its federal tax liability because of federal Production Tax Credits of $0.018 per kWh for all electricity produced.[202]
3. Escape significant corporate income tax liability because the federal accelerated depreciation reduces taxable income.[203]
4. Avoid most normal liabilities associated with other taxes including Business and Occupation taxes and property taxes.[204]

The above federal and state tax breaks add up to a total of $325,434,600 for the first 10 years. The tax breaks for wind farm owners shift tax burdens to remaining taxpayers, further degrading expected local economic benefits. The value of the tax breaks to the wind plant owner could easily exceed the owner's income from the sale of electricity, particularly in the early years of the project.[205]

Wind farms are heavily dependent upon large ratepayer and taxpayer subsidies and mandates to compete against conventional electrical power generation sources.[206] Electricity sales contribute approximately 30% of a renewable station's income, while the remaining 70% comes from indirect subsidy paid for by the consumer, whether they have elected for 'green' energy or not.[207]

Since opposition to wind farms can lead to costly delays, some New York energy companies were found to be unethically influencing municipal officers to allow the development of develop wind farms. As a result, New York's Attorney General drafted a Wind Code of Ethics to publicize every aspect of future wind farms and restrict such companies from influencing officials. Since there were no exiting ethical laws concerning the municipal officers, the Attorney General sought to rectify it with this work-around.[208] However, the Code is voluntary, and signers are required to help fund a government agency whose job it is to regulate the signers. The effectiveness of such a code is symbolic at best.

Economic Impact

How do wind farms impact local economies? Industry advocates say wind farms will add jobs and tax revenues to local communities, while their opponents say their adverse impacts on property values, tourism and the environment effectively neutralize any perceived economic benefits. Champaign County of Ohio estimated that a 100MW wind farm would yearly generate the tax dollar equivalent of 449 homes; and they estimated a 300MW farm would generate the tax dollar equivalent of 1,347 homes. They anticipate significant positive local property tax impacts are possible – assuming they can tax and collect at local levels.[209]

Unfortunately, wind farms contribute little to county property taxes. In some states, wind energy producing equipment is exempt from property taxes, and taxable items may be limited to the foundation and tower structure. Some developers also apply for additional local tax relief.[210]

Additional tax revenues are frequently mentioned as a positive reason to build wind farms.[211] General Electric, a major wind turbine manufacturer, claims that over the long term wind farms will add $250 million to the US Treasury.[212] However, they acknowledge they will only begin to "pump money into the US Treasury" once the Production Tax Credits expire.[213] PTCs are good for the first 10 years of a wind farm's production. They project 10 million metric tons per year of CO_2 emissions avoided.[214] They project creating thousands of short-term construction jobs with a long-term employment of 1,600 over 20 years or more of operation.[215] In contrast, the Township of Bethany, New York, found in 2007 that, beyond the temporary construction phase, wind farm projects have little to no significant job impact.[216]

Despite potential benefits of wind farm projects, The Bacon Hill Institute – a public policy research group – studied a proposed wind farm in Nantucket Sound and found it failed the cost-benefit test recommended by the U.S. government for assessing large-scale projects. The wind farm developer stressed the value of wind power as a source of clean, renewable energy. But the study found that the overall economic costs of the project would exceed benefits by $211.8 million. Without $241 million from state and federal subsidies, the project would not be financially viable. And while the farm may generate some wind energy jobs, the impact on tourism would result in a net loss of 1,000 local jobs.[217]

Losing tourism is a major concern of any locale that depends on the allure of their land to attract visitors and support the economy. The success of rural enterprises is inextricably linked with the maintenance and conservation of a healthy, attractive and irreplaceable rural appeal.[218] Wind turbines are largely seen as a chief threat to such areas.

Rural tourism is big business in the UK (worth appx. $26.7 billion) and supports up to 800,000 jobs. In a 2006 study, the UK's Small Business Council examined the impact wind farms would have on small businesses – specifically those dependent on rural tourism. They found that 75% of visitors say the quality of the landscape and countryside is the most important factor in choosing a destination. Between 47% and 75% of visitors felt that wind turbines damage the landscape quality. Of the three areas they studied, they found that 11% of visitors would avoid the first area, resulting in a loss of $48.5 million and 800 jobs. Approximately 7% of visitors would not return to the second area, resulting in a loss of $117 million and 1,753 jobs. In the third area, just 5% would stay away, but its lost affluence would result in $668.5 million lost along with 15,000 jobs. In some areas, 49% of all sectors of rural businesses experienced a negative impact.[219]

In a separate tourist area of the UK, five wind farms are proposed totaling 71 turbines along 18 miles. In a pilot survey of 1,500 visitors, the Council found that approximately 95% of the visitors said wind turbines would spoil their enjoyment of the landscape. And this spoiling directly translates into less business from tourism and lost jobs.[220]

They studied another tourist area in the UK, and found that two-thirds of local businesses said turbines are visually intrusive. While 54% thought wind turbines would increase their 'green' credentials, 27% believed it would still have a negative impact on the tourism industry by reducing visitor numbers. After the details of the tower heights were revealed the next year, the 27% grew to 39% who felt the 400-foot-high turbines would make visitors stop visiting completely.[221]

In North Devon, an area renowned for its beauty, a before-and-after survey was conducted to gauge visitors' feelings toward possible wind farms. Before details of their 300' height were revealed, 34% were generally favorable and 66% unfavorable towards turbines. After the size and location of the turbine proposals was revealed, the number of 'unfavorable' visitors rose to 84%. When asked if wind farms would affect their choice of holiday destination, less than 50% claimed that they would still choose North Devon. A further 39% said they would choose North Devon but subject to the size and location of the wind farms. Eleven percent would completely avoid North Devon.

Scotland is also proposing wind farms, but a visitor survey found that 15% of visitors would not return if wind turbines are built – resulting in a potential loss of $133.7 million and 3,750 jobs.[222]

In Vermont, the state government wants green energy at the potential cost of impacting its natural beauty.[223] But even in a prime location like on the top of a windy ridge, wind turbines sit idle 40% of the time.[224,225]

Wind farms negatively impact pastoral beauty, thus severely damaging rural Vermont's main industry: tourism.[226] Tourists don't want to pay to look at wind turbines, but wind supporters claim the turbines themselves will become an attraction and boost tourism.[227] The wind industry tried making them attractions in the UK, and both failed. In 1999, a visitors' center was built in Norfolk, UK – then home to one of the largest turbines in the world. It ran out of money and closed in 2002. Then in 2001, a $9.1 million visitor center was built with hopes of attracting 150,000 annual visitors to its wind farm. Despite opening to much publicity it attracted less than a tenth of projected visitors, and it went bankrupt. Its CEO said, "Sadly, just like many eco-attractions, they're not sustainable; there's just not enough interest."[228]

Conclusion

After reviewing articles and studies on wind energy, wind turbines appear to have a negative impact on the property values, health, and quality of life of residents in close proximity. Of the studies that found no impact on property value, nearly all were funded by wind farm developers or renewable energy advocacy groups. Of the studies and reports showing property loss, the average negative effect is -20.7%.

It is equally reasonable to conclude that some residents in close proximity to wind turbines experience genuine negative health effects from Low Frequency Noise, infrasound and blade flicker. Of the studies and reports cited, an average setback of little over a mile should significantly lessen detrimental health effects. In addition to noise and flicker issues, disrupted TV and cell phone receptions contribute to negatively impact the quality of life for residents living in close proximity to wind turbines.

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McCann Appraisal, LLC

December 14, 2009

Mr. Ben Hoen
Ernest Orlando Lawrence
Berkeley National Laboratory

Re: The Impact of Wind Power Projects on Residential Property Values in the United States: A Multi-Site Hedonic Analysis

Dear Mr. Hoen:

I have prepared this follow up Certified Review letter after reading your group's published study (Report). Perhaps the LBNL research team will be doing supplemental or ongoing work that will incorporate corrections, additions and shift the focus to reflect proportionate relevance, and these review comments and concerns can be given due consideration.

With all due respect, the final Report falls short of being a truly objective and reliable real estate value study of the issue at hand, in my professional opinion, the reasons for which I will begin to describe in this follow up review.

Intended Users of Report
As I predicted in a prior communication with you, your final Report would get a lot of exposure and probably be cited as justification for zoning and land use application approval requests for wind energy projects, on a far reaching scale.

For that reason, an abundance of caution should have been utilized to emphasize any reasonable and logical interpretation of the "nearby property" study data, even when that is contrary to, or significantly differs from, the thrust of the general conclusion that is based on the 5-mile and beyond data.

In this day and age of questionable "science" being applied regarding predictions of global warming, any appearance of omitting relevant data or painting "targets around bullet holes" does little to solve controversies or facilitate sound, well informed planning and decision making. With that preface, my review comments are, as follows:

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PHONE: (312) 644-0621 FAX: (312) 644-9244

Turbine Height
First, I direct your attention to Report *Table* 2, which cites study locations and the "hub" height of turbines. This is misleading to a typical reader, as zoning standards usually include the height as fully extended by the turbine blades. The height of the structures does not peak at the "hub" and there is obviously a greater height, often approximately 400 feet and current projects proposed up to 500 feet; by any objective measure more significant than the lower hub height.

First McCann Review of LBNL Draft report
The Report omitted the fact that in the written review of the Draft Report, I cited to you in particular as my opinion basis for value impact <u>40 sales</u> that demonstrate on their face a 25% lower value of homes in close proximity to the Mendota Hills turbines.

The two (2) "sales" you DO attribute to McCann *(Report Table 1, page 9)* as my opinion basis are, in reality, (pre-draft Report) examples I provided of inordinately long and on-going marketing times, at otherwise market-based asking prices.

The deterrent to sale of the homes directly attributable to the wind farm project is well understood by the local Realtor who had the listings and who, at the time of my communication with you, had reported to me the consistent rejection rationale of over 100 otherwise interested would-be buyers and their agents. Interest that evaporated once potential buyers visited the properties and saw the nearby and surrounding turbines.

The Report also misstated an important fact: The two (2) homes <u>never actually sold</u>, although the text of the Report implies it was just a long marketing time BEFORE they sold. (*See Report page 7, 2nd paragraph*) Clearly, this error distorts the market reaction indicated by the actual facts.

Such a stigma deterrent to the sale of homes, while not perhaps statistically significant or measurable via the methodology employed and data utilized in your study, is entirely significant to an owner unable to reasonably convert their home equity to cash. That real-world experience is virtually mute and is mischaracterized in the Report.

As demonstrated by the two (2) homes, if one was unable to sell their home or even elicit an offer at any price, despite reducing the asking price by 10%, 20% or more from the going in basis and/or current market rates, and if the reason for the loss of reasonable liquidity is isolated as a single factor or influence, then that impact is many things, but "insignificant" is not the phrase that comes to mind.

And while marketing experience for the two (2) homes is only *part* of the basis for opinions I have developed thus far, the Report is inaccurate since I disclosed the 40 recorded, closed sale basis to you (*see McCann review letter*) and that is not mentioned in the Report on *Table 1*, where other such outside input is shown.

I suspect I will need to go on the record at some point to clarify that Report mistake, given the opposite direction of the indication of both the Mendota Hills sale and separate unsold listing data to the Report findings.

On balance, I acknowledge that the Report gave some limited comment to the "*possibility*" that some properties "*may*" have had negative effects from proximity to turbines.

However, based on the size of the < 1 mile data sample, I am surprised that the Report does not unequivocally state that nearby properties **"have shown a discernible and measurably lower"** sale price than the base line data located > 5 miles from the projects studied.

While the qualifying words in the Report may have been intended by the authors to reflect the somewhat lower mathematical certainty of drawing the indicated adverse conclusion, vis a vis the much larger database of sales in the 5+ mile distance, the framing of the comments minimizes the real and significant impacts shown in the Report for the nearest properties sold.

In fact, the Report Executive Summary states: "....neither the view of the wind facilities ***nor the distance*** of the home to those facilities is found to have any consistent, measurable, and statistically significant effect on home sales prices". This claim simply does not comport with the data results.

Report Results – Actual Impact

Contrary to the study conclusions, the Report charts and data are in fact supportive of a distinctly MEASUREABLE reduction in value, on the order of **5.3% to 5.5%,** for homes up to 1 mile away from the nearest turbine(s) (*Report Figure ES-1)*.

The data within the 1 mile distance included 125 sales, compared to 870 baseline sales that were greater than 5 miles in distance. As I understand basic statistical analysis, data in excess of 50 measuring points is generally accepted and deemed statistically "significant".

In the Report, however, this difference is dismissed as "statistically insignificant". The minimization and dismissal of these facts leads the reader to the incorrect belief that wind farms do not reduce nearby property values. Further, the Report Executive Summary (*page ix*) emphasizes the word "<u>possible</u>", rather than draw attention to the factual basis of actual negative impact measured at the nearest properties.

Similarly, your report *(Figure ES-2)* reveals that 310 sales with a vista rated as poor compared to 2,857 sales with an average vista, sold for 21% lower than the average view properties.

The poor vista measurement in the Report, however, is perfectly consistent with the Mendota Hills data I cited to you and the 25% value loss indicated. It follows then, under circumstance whereby the property in question possesses an above average vista and attendant higher than average value *(>10%, per Report)*, and will end up with a below average or poor vista post-turbine development, a value loss of 25% may very well understate the damages in those instances.

While the rating of any vista has some subjective elements to it, it is well established that the subjective rating of turbine views is disproportionately negative by residents of immediate project areas who have no turbine lease agreement or financial interest in the project(s). Again, the Report conclusions are contrary to data contained within.

While the vista or view from a given property is a well recognized value influencing factor, the Report conclusions fail to proportionately reflect the findings contained in Figures ES-1 and ES-2.

Literature Review – Hedonic Analysis

A true peer reviewed article (*supporting data available for peer review*) written by Dr. Sandy Bond, (*acknowledged in the Report*), found an even lower impact on residential property value from cell towers in Florida than the 5% indicated in the Report, and the Appraisal Journal indeed published those findings as being statistically significant. A different determinant standard of significance must be the explanation for these contrary conclusions.

I would also suggest that a single cell tower with a height of 80 to150 feet is far less likely to impact neighboring property use, enjoyment and value than dozens of 400 foot tall turbines with spinning blades, noise, flicker effect, etc.

Thus, the Report conclusions are completely inconsistent with an existing published study, and which was peer reviewed by the leading real estate valuation journal. At a minimum, this important conclusion difference establishes that there was some subjective determination as to what constitutes statistical significance.

Again, with all due respect, the leading real estate valuation journal must be considered as more reliable regarding property value issues than an academic study conducted by researchers untrained in professional real estate evaluation issues. At any level, an appraisal must accurately reflect the market, and any opinion related to value constitutes an appraisal opinion.

Report Findings – Applied

In this review, I have applied the measured proximate Report study area loss of *(rounded)* 5% into a generic (Illinois) project area, encompassing thousands of acres of land. Using simple projections, Report conclusions may not stand a reasonable test of what is or isn't significant, in the context of a zoning standard being met or failing to satisfy the legal requirement of *no substantial impact on "neighboring" property value.*

Please note that neighboring values are the relevant baseline in all zoning standards addressing this issue....not the value of homes 5 or 10 miles distant from a proposed project. Simply put, the homes located in the footprints of these projects are the real "ground zero" on this issue, and what is mathematically measured at distances beyond 1 mile, etc, is inapplicable as a basis for determining ground zero impacts.

Applying a (rounded) 5% reduction of value to a "typical" residential market value of $175,000 to homes within one (1) mile of a project footprint, and 25% impact within the project footprint, and projecting the rural housing density on the basis of 1 house per 40 acres and a 6,000 acre footprint, (10,240 acres within 1 mile) **value loss of $8.8 million** is indicated for a typical Illinois project. (*See attached McCann illustration; PROJECTED TYPICAL IMPACT*)

The actual Report measured loss of 5% includes data up to 1 mile distant but appears to be silent as far as measured value loss for the typical ground zero (footprint) residence. The direction of impact must be logically concluded as greater than 5% in the footprint.

Thus, if the Mendota data indication of 25% value loss is applied to the preceding example *(as also supported by poor vista lower values in Report Figure ES-2)*, the impact is **$8.8 million** of diminished home equity. If this is repeated for 10 new projects in rural residential areas, $88 million in losses can be reasonably forecast.

I suggest that no one could reasonably conclude the collapse of an $88 million office tower or shopping mall and complete destruction of its value would be "insignificant", even with no loss of life. I also suggest that rural residential property is no less deserving of a fair characterization of actual value loss.

As a professional appraiser, it boggles the mind to consider the total property value losses that will result if the renewable energy policy goals are completed via development of utility scale wind energy projects, in rural residential areas.

This magnitude of loss is significant on so many levels that the term "statistically insignificant" is misleading because it ignores the harsh, localized reality, when the projects are developed surrounding and interspersed with homes in rural residential areas.

In these "overlaid" locations, turbine views are not just on the distant horizon, as with the greatest majority of Report data locations and distant proximity to turbines upon which the Report conclusions focus.

Hole in the Doughnut
The most impacted properties are simply not proportionately reflected in the Report, the importance of which is contrary to the Report claim that the number is again, "statistically insignificant". The "hole in the doughnut"(1) of the Report database and stated conclusions is, in my opinion, the most important indication, and it is disproportionately minimized or even misleading via the terminology used.

Any reduction of equity (value) beyond normal negotiation of price and sale commissions must be considered significant, from a land use and zoning standard perspective. Further, since the Report will be utilized for ***exactly that purpose*** rather than as an academic exercise in statistical analysis techniques, I do firmly believe more care should have been given to understanding the members of the public that the Report would be advising, influencing and affecting.

Property Value Guarantee (PVG)
Given the actual value loss to nearby properties shown in the Report, I must question why the Report did not even mention the prudence of Property Value Guarantees.

Such guarantees are used sometimes in high profile and controversial zoning matters such as landfills, quarries and indeed, other wind farms *(See DeKalb, Illinois record, et al)* and are certainly appropriate when value impacts are measurable and predictable with a high degree of certainty, as shown in the Report.

The Report modestly mentions homes bought out by wind farm owners/developers. And while this may be driven by health impact liability reasons, health issues are beyond the scope of the Report, this review and the reviewer's expertise. This area of neighboring owners reported experience, concern and the publicized controversy, however, has a stigma effect that is an appropriate property value issue to be considered even if the stigma effect is not measurably isolated between view and health concerns, or other nuisance-type issues.

With all the other policy and non-mathematical commentary and background cited in the Report, the "statistically insignificant" cost of implementing a property value guarantee, as measured against the huge cost of these projects, would have been a balanced and objective recommendation.

Industry may not embrace that idea nor the funding sponsor of the Report. However, there is no down-side to either of them if the *"no measurable impact on value"* Report conclusion proves out to be applicable at ground zero properties.

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(1) *A graphic depiction of this type of data "doughnut hole" is contained in the 2006 Impacts of Windmill Visibility on Property Values in Madison County, New York and attached to this review. The Lee County, Illinois study Area Map contained in the Report (Figure A-6) is another such example.*

PVG Costs are Insignificant
In the generic Illinois project example, value loss of homes located in the project footprint and within one (1) mile equates to $8.8 million in property value loss compensation, via a legitimate PVG. In proportion to a cost for a 100 turbine development at $3 million per turbine, a cost of 2.9% could easily be absorbed as a cost of doing business, or a simple contingency line item on the development financial pro-forma.

If 5% value loss experienced by nearby homes can be concluded in the Report as "statistically insignificant", then certainly 2.3% additional project costs is far from onerous as to the financial feasibility of wind farm development.

From a policy and planning perspective, which is apparently the intended advisory purpose of the Report, an insignificant PVG cost of that magnitude to protect property values should not have been ignored, since residential values are the fundamental issue and question at hand. The report conclusions within 1 mile and the "doughnut hole" lack of data fully warrant such a recommendation.

Marketing Time
Finally, and with some limited acknowledgement by Report authors of further study being needed, the Report is completely irrelevant to the issue of marketing times. This "variable" is well understood in all real estate professions as a value-related and value-influencing issue, and the opportunity to collect such data was apparently missed during the multi-year research period while LBNL was conducting the study.

The Report also does not state data I provided regarding 800+ day marketing time of a ground zero home, which commenced in the most dynamic residential market of the modern era. Other examples of ongoing marketing times beyond 2 years were omitted as well.

Beyond a property getting "stale" on the market thereby motivating inordinate price reductions, the time-value of money is easily understood, i.e., one dollar ($1) to be received in 3 months has a higher present worth (value) than $1 to be received in 3 years.

The adverse impact on marketability is only mentioned in passing in the Report as a "possibility" rather than a historic fact or trend, notwithstanding that such experience is clear and documented. Future potential research of this issue is suggested as an apparent afterthought.

The report data is not accepted under objective appraisal review as being "rich", since it is incomplete on such an important point.

Focus of Report

In closing, and if you will forgive my analogy, if one wishes to learn the "price of tea in China", then that is where one must look. To apply the analogy, it follows that one is not likely to find the true answer to the question of ground zero impacts if focusing on greater distances.

I suggest that the Report reflects exactly that imbalanced focus, yet leads the reader to apply the findings pretty generically to all properties, whether or not located at "ground zero".

As a statistical analyst and researcher, I hope you find the focused real estate review useful to any updated Report you may ultimately prepare, and which I believe is still warranted.

I trust that you will take my review comments in the intended spirit; that of seeking the truth for this important issue, regardless of the position or agenda of concerned parties on either side of this issue.

Respectfully submitted,

McCANN APPRAISAL, LLC

Michael S. McCann

Michael S. McCann, CRA
State Certified General Real Estate Appraiser
License No. 553.001252 (Expires 9/30/2011)

PROJECTED TYPICAL IMPACT

Combined Nearby Impact Zone

1	2	3	4	5
16	1	2	3	6
15	4	5	6	7
14	7	8	9	8
13	12	11	10	9

9 = square miles in 6000 acre footprint
16 = square miles or 10,240 acres within 1 mile of footprint

Generic Wind Farm Land Area Impacted
Footprint: 6,000-acres / 640 acres per square mile = 9.375 square miles
(***Rounded to 9 square miles***)

Within 1 Mile: 16 square miles X 640 acres per square mile = 10,240 acres

Wind Farm Neighboring Homes
Footprint = 150 homes at 40 acres per home rural density (6,000 / 40 = 150)
Within 1 Mile = 256 homes at 40 acres per home rural density (10,240 / 40 = 256)

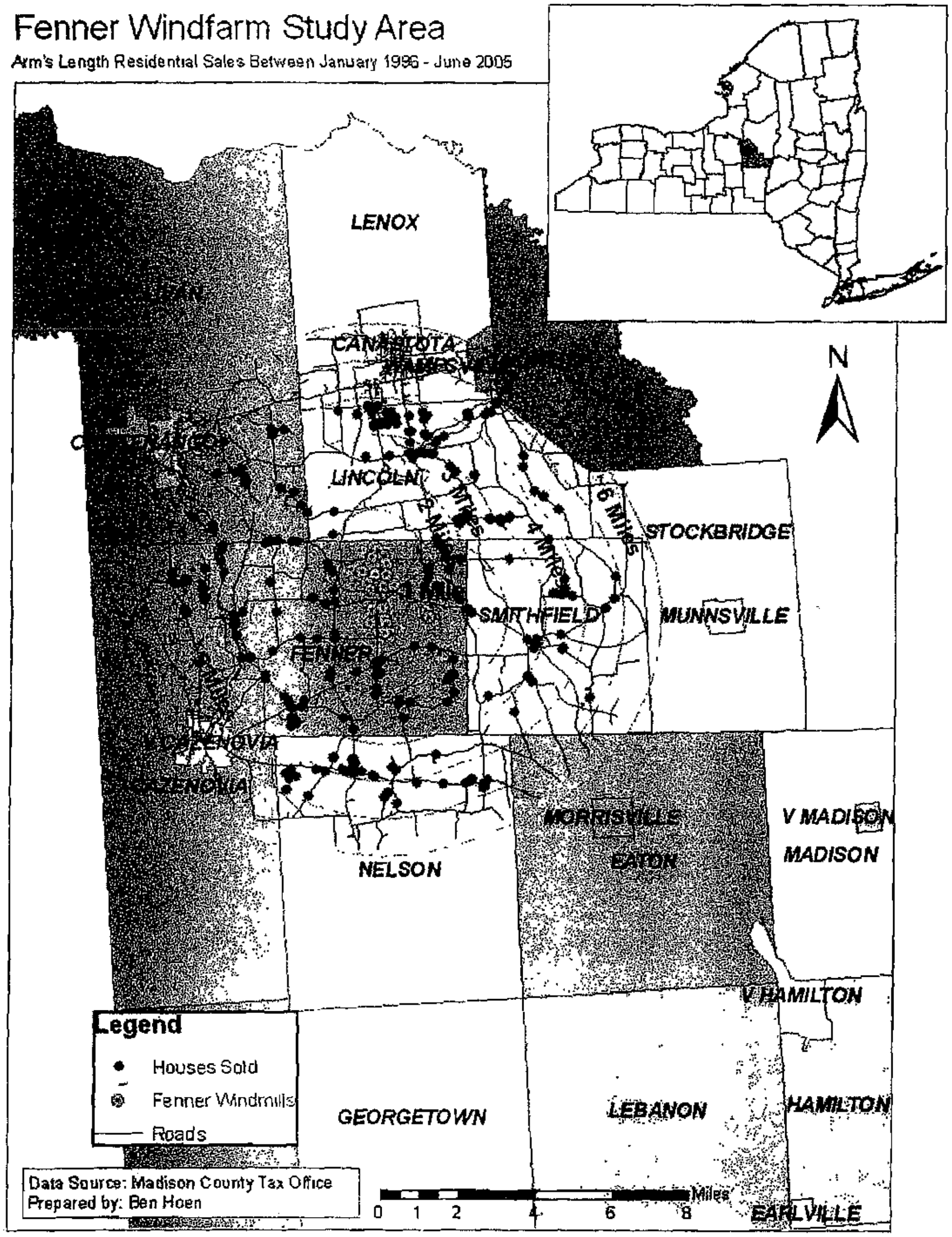
Value Baseline
Footprint = 150 homes X average value of $175,000 = $26,250,000
Within 1 Mile = 256 homes X average value of $175,000 = $44,800,000

Projected Value Impact

Footprint: $26,250,000 X (1) 25% value loss =	$6,562,500
Within 1 Mile: $44,800,000 X (2) 5% value loss =	$2,240,000
Neighboring Properties; Total Impact =	**$8,802,500**

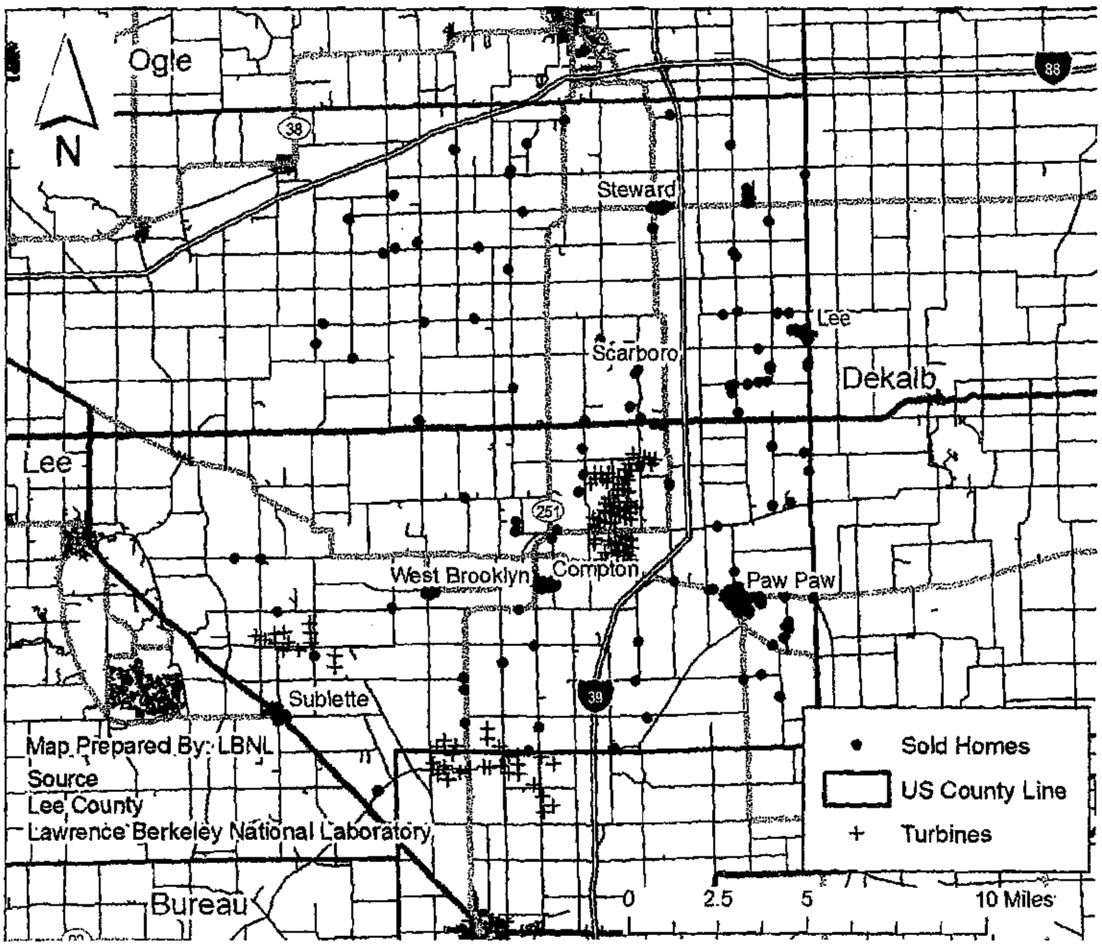
(1) Per Mendota Hills data & as supported by Poor View Vista, Report figure ES-2
(2) Per Report Figure ES-1

Property Value Guarantee - Significance to Wind Farm Project Costs
Thus, if a typical 6,000 acre wind farm project with 100 turbines at cost of $3 million each, and has total project cost of $300 million, the collateral damage impact to property values of $8.8 million is equal to 2.9% of total project costs.


Fenner Windfarm Study Area
Arm's Length Residential Sales Between January 1996 - June 2005
LENOX
CANASTOTA
LINCOLN
STOCKBRIDGE
MUNNSVILLE
SMITHFIELD
FENNER
NELSON
MORRISVILLE
EATON
V MADISON
MADISON
V HAMILTON
HAMILTON
GEORGETOWN
LEBANON
EARLVILLE
N
Legend
Houses Sold
Fenner Windmills
Roads
Data Source: Madison County Tax Office
Prepared by: Ben Hoen
0 1 2 4 6 8 Miles

A.5 ILLC Study Area: Lee County (Illinois)

Figure A - 6: Map of ILLC Study Area



McCann Appraisal, LLC

REVIEW CERTIFICATION

PROJECT DESCRIPTION: Wind Farm Developments in general

EFFECTIVE DATE OF REVIEW: December 14, 2009

The undersigned, representing McCANN APPRAISAL, LLC, do hereby certify to the best of my knowledge and belief that:

FIRST: The statements of fact contained in this review report are true and correct.

SECOND: The reported analyses, opinions and conclusions are limited only by the reported assumptions and limiting conditions and represents the personal, impartial and unbiased professional analyses, opinions, and conclusions of the undersigned.

THIRD: I have no present or prospective interest in the property that is the subject of this report and no personal interest with respect to any of the parties involved.

FOURTH: I have no bias with respect to the property that is the subject of this report or to the parties involved with this assignment.

FIFTH: My engagement in this assignment was not contingent upon developing or reporting predetermined results.

SIXTH: My compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this review report.

SEVENTH: My analysis, opinions, and conclusions were developed, and this report has been prepared in conformity with the Uniform Standards of Professional Appraisal Practice.

EIGHTH: The following person has made an exterior inspection of the public areas of the Mendota Hills project that is part of the basis for the opinions expressed in this report:

**Michael S. McCann has inspected the Mendota Hills wind farm,
Twin Groves, and other wind farm projects
on various dates beginning in 2005**

NINTH: No one other than the undersigned provided significant real property appraisal review assistance to the persons signing this certification.

IN WITNESS WHEREOF, THE UNDERSIGNED has caused these statements to be signed and attested to.

Michael S. McCann

Michael S. McCann, CRA
State Certified General Real Estate Appraiser
License No.553.001252 (Expires 9/30/2011)

The following disclaimer was copied from the LBNL Report, and is considered to be relevant to the author's ratification of the data, methodology and opinions expressed in the Report.

Disclaimer

Submission
No 81

INQUIRY INTO RURAL WIND FARMS

Name: Dr David Burraston and Ms Sarah Last

Date received: 21/08/2009

Inquiry into rural wind farms

Submission to the Legislative Council General Purpose Standing Committee No 5

by

Dr David Burraston and Ms Sarah Last

EXECUTIVE SUMMARY

The current push for fast tracking industrial wind power stations in rural NSW is being put forward as solution to the problems of climate change. However, the public are not being presented with balanced information on the issues surrounding industrial wind energy. Landholders are being persuaded to host industrial wind turbines with little knowledge of the impact this will have on their own and other people's property, the environment or the wider community in general. In this submission we present evidence that demonstrates that industrial wind energy does not live up to the claims of its proponents, and counters the misleading information the wind industry continues to distribute.

The research and information presented in this submission will be of interest to people who care about the environment, the truth and a sustainable future. Our submission comprises of the following broad themes :

- Synopsis of major research requirements for industrial wind energy research
- Brief overview of problems with electricity generation by wind turbines
- Research demonstrating industrial wind energy's **failure** to displace fossil fuels or significantly reduce greenhouse gas emissions
- Discussion of environmental concerns, project lifespan and the urgent need for a realistic decommissioning policy
- Negative health effects and noise pollution
- Negative impacts on property values
- Negative visual impact
- Myths surrounding "green jobs"
- Sustainability considerations for rural landholders without industrialisation of the landscape
- Negative social impacts on rural communities
- Comments on Renewable Energy Strategy
- Conclusions from a rural landholders perspective on the reasons not to sign up to a wind power company lease

Table of Contents

Appendices attached separately : These are a selection of some of the papers referenced throughout this submission.

1. INTRODUCTION

We wholly support the production of energy from sustainable, clean, renewable sources and public education on energy conservation. We are very interested in the development of farming strategies to offset carbon emissions, it is a fast advancing industry, and we regard it as an imperative global/local issue, where farmers will have an increasingly important role and responsibilities.

We have done significant research about renewable energy and the industrial wind power generation industry. We conducted this research when we and our community were approached by industrial wind energy developers, in order to inform ourselves and others. This research includes:

- Dialogue with an Ecological Consultant who has done assessments on Australian industrial wind power stations
- Dialogue with an ARC (Australian Research Council) Professorial Research Fellow and IPCC (Intergovernmental Panel on Climate Change) contributing author with specialist knowledge in global change modelling and carbon cycle interpretation
- Statements by people already affected by industrial wind farm developments
- Peer reviewed journal and conference papers
- Local, national and international media

Based on this information we have concluded that, with its significant social and environmental impacts, industrial wind energy developments are not sustainable, and would be to the detriment of NSW state, its landowners, environment and surrounding communities. We are strongly opposed to all industrial wind turbine power developments of this type, and will be continuing our research to include further IPCC reports, journal and conference papers, and new results and information as it is published.

Sarah grew up on the family farming property in rural NSW and David has spent many years living in rural areas in the UK and NSW. We have now taken over Sarah's family farming property in rural NSW. We are both trained academic researchers, Sarah in the arts and community cultural development, and David in acoustics, electronic engineering, sound, computer science and complex systems science; this training employs methodologies that seek information from a range of considered objective, quantitative and experiential resources. After reviewing this research we conclude that industrial wind farm developments have far too many detrimental impacts in the short and long term. These detrimental impacts include (but are not limited to):

- Decreased community health
- Poor greenhouse gas mitigation potential
- Poor electricity generating potential
- Increased bush fire risks
- Increased noise pollution
- Decreased land values and reduction in future land use rights for stakeholders, other properties and wider communities
- Strobe like 'flickering' across the landscape created by turbines during sunset and sunrise
- Decreased privacy
- Increased interference with communications devices and resources

- Irreparable destruction to farming resources and related ecologies near or adjacent to industrial wind turbines
- Irreparable destruction to native habitats such as the endangered Box Gum Grassy Woodlands and its associated tree, grass, forbs, bat and bird species
- The liability of landholders for third party claims for loss and damages associated with industrial wind turbine power stations.
- Industrial infrastructure on land zoned for farming/food production and the preservation of natural resources and habitat
- Industrial infrastructure and development that is counter productive to any nature regeneration and conservation efforts

We have also experienced at first hand the inappropriate conduct and divisive tactics employed by industrial wind energy companies within our own community, pitting neighbour against neighbour, blatantly lying and telling farmers that *"everyone else is signing or has signed"*. We have repeatedly asked the industrial wind energy developers to get all the landholders together for a meeting rather than be divisive, nut to no avail. The industrial wind developers even admitted that these tactics are divisive to us, and that we should see it from their perspective. This sentiment was stated several times. Such an admission clearly demonstrates a wilful resistance towards transparency and due process, with lack of regard to the concerns landholders and residents may have about the large scale development and impacts associated with industrial wind turbine power stations. The industrial wind developers stated that should the wind farm proposal proceed any direct impact would only be on the landholders with the turbines, not those on surrounding properties. This statement again demonstrates a lack of regard to legitimate community concerns and totally misrepresents the magnitude of industrial wind power developments, their turbines, risk issues and detrimental impacts.

When we asked the industrial wind developers for unbiased information on wind energy we were directed to unreliable industry propaganda. We have watched as our neighbouring landholders have been constantly harassed by industrial wind developers whose only goal is to get a lease contract signed. Such a contractual arrangement for industrial scale development, especially development that is emergent in the Australian context with very few precedents and no Australia specific long-term impact studies, is grossly unfair to landholders, their neighbours and surrounding communities.

We are in no doubt that the wind energy industry and current NSW government's main motivation is money rather than addressing climate change.

2. INDUSTRIAL WIND ENERGY STILL REQUIRES MAJOR RESEARCH

The Proceedings of the 2008 Intergovernmental Panel on Climate Change (IPCC) *"Scoping Meeting on Renewable Energy Sources"* contains some information on problems associated with industrial wind energy (http://www.ipcc.ch/pdf/supporting-material/proc-renewables-lubeck.pdf). This document reports ongoing research and investment into all renewable energy sources, conducted by Working Group III, and will conclude with a Special Report in December 2010. This report discusses renewable energy options and issues, in parallel with the IPCC's other documents leading up to the 5th Assessment Report in 2014. It is worth noting that in the chapter *"Status and Perspectives of Wind Energy"* authored by Prof. A. Zervous, President, European Wind Energy Association and Chairman, Global Wind Energy Council in Section IV Challenges and Perspectives on page 117 he states that *"This agenda for research should be seen as only the first edition of an ongoing identification process, which is currently being updated through the European Technology Platform for Wind Energy. The Priorities listed below are divided into three categories: showstoppers, barriers and bottlenecks"*

i) *Showstoppers : "These are the key priorities, which is to say that they are considered to be issues of such importance that failure to address them could halt progress altogether. Thus they need special and urgent attention."*

ii) *Barriers : "Barriers are defined as being principal physical limitations in current technology, which may be overcome through the opening up of new horizons through generic / basic research over the medium to long term."*

iii) *Bottlenecks : "Bottlenecks are problems which can be relatively quickly overcome through additional short or medium term R&D, i.e. through the application of targeted funding and / other resources."*

These 3 areas are discussed over several pages. Among the 5 showstoppers it should be noted that these include the requirement for research into wind farm energy storage systems, which as yet do not exist, to make up for variability and unpredictability of wind resource. The current storage systems for wind energy are conventional fossil fuel power stations, which have to be kept running as a back up to cover variability in wind resource, which places the conventional plant under greater stress and leads to greater inefficiency. Also important are the need for research results on the effects of wind turbine power plants on ecological systems and public support. Ecological research and public support are also discussed again in regards to barriers and bottlenecks, as are the need for standards and certification, wind resource studies, grid integration and other issues.

A later chapter in this IPCC Scoping Report is titled "Global Investment in the Renewable Energy Sector" by Eric Usher, Head, Renewable Energy Finance Unit, United Nations Environment Program. Fig 5 on page 153 shows that Venture Capital and Private Equity places wind energy in 3rd position, with solar 2nd and biomass 1st. The overwhelming majority of the investment for wind is installing wind turbine capacity only, **leaving a very large shortfall for future research needs.** Fig 8 on page 154 shows Global Asset Financing by Sector for the period 2004 to 2007. In 2004 the $12bn total was mainly taken up by wind, but as overall renewable energy financing increases in the following 3 years wind shows a reduction in proportion and by 2007 is roughly 45% of the $56bn total.

3. WIND TURBINE ELECTRICITY GENERATION

We have given much consideration regarding the viability of hosting industrial wind turbines to enhance our farms income stream. The amount of income per turbine must be carefully calculated and it should be noted the "nameplate" capacity represents the *theoretical maximum* MW output e.g. 1MW, 2MW etc.

3.1 LOAD FACTOR

In order to estimate the actual output of each turbine a Load Factor (LF) figure of 20 to 30% of nameplate capacity is often suggested, due to the high variability of wind speed and the turbines power curve. It should be stressed that 20 to 30% is a *very generous* estimate of efficiency, and the majority of wind installations do not reach this capacity, especially those with relatively poor wind resources such as inland NSW. It is highly unlikely that NSW industrial wind power stations will attain a 30% Load Factor.

This reduction in efficiency is due to a fundamental physical law relating the electrical output to the cube of the wind speed for a wind turbines power curve, usually between about 4m/s (metres per second) and 12 m/s wind speed. This demonstrates how sensitive a turbines output is to wind speed. If the wind speed is below 4m/s (its minimum speed) no power at all is generated from the turbine. If a turbine reaches its maximum capacity at around 12m/s any further increase in wind speed will not result in more power being generated. If the wind speed eventually increases above the turbines maximum rating, often around 25m/s, the turbine is shut down to prevent mechanical damage and no power is generated. Also, if the operating temperature is above 40C wind turbines are shut down to prevent turbine failure.

There is another fundamental physical law, derived by the German physicist Albert Betz in 1919 that further compounds the inefficiency of wind turbines. This law relates to the amount of energy in the wind that a rotor blade can convert. The power extracted from the wind can be no more than 0.59 of the total incoming wind energy. This is due to the fact that the wind is slowed down, but it is not completely stopped. This law puts a fundamental limit on the energy extracted from the wind, resulting in further losses for industrial wind energy.

These two fundamental unchanging physical laws, coupled with variability and unpredictability of the wind has prompted some illuminating studies around the world. We recommend examining documents at the Renewable Energy Foundation (REF) (www.ref.org.uk) who have commissioned independent reports from leading consultants and scientists. In 2006 the REF produced the UK Renewable Energy Data files (www.ref.org.uk/Pages/4/uk_renewable_energy_data.html) which presents publicly available data regarding renewable electricity generation since 2002 (wind, biomass, hydro, landfill gas and sewage gas) in the UK. The raw data for this project is obtained from the Ofgem Renewables Obligation Certificate Register (http://www.rocregister.ofgem.gov.uk/main.asp), which publishes data concerning the issue of Renewables Obligation Certificates to renewable electricity generators. These documents present the Ofgem wind farm data in an easily readable form together with summary, review and comparison to some other European countries. The average national Load Factor for the UK is 27.4% for 2005 to 2007 compared to Germany 22.6%, Spain 20.2% and Denmark 26.2%.

3.2 NSW POOR WIND RESOURCE

We have looked at the Australian Government Department of the Environment, Water, Heritage and the Arts *Renewable Energy Atlas* (http://www.environment.gov.au/settlements/renewable/atlas/index.html). In our area in South West NSW this reports an average wind speed estimate of 6.9m/s at a 3km resolution (higher resolution data will give a more accurate representation). Given that this wind resource estimate is not very high, the other major criteria for sighting industrial wind turbine power stations is their locality to the electricity grid. The fact that such a powerline exists will have a major effect on any wind industry company decisions before and after they have conducted their wind monitoring phase. Proximity to the electricity grid will significantly reduce startup costs and enable a poor quality wind resource to become financially viable for a wind power company, but not for NSW landowners. A poor quality wind resource further reduces the meager greenhouse gas reductions and electricity output of industrial wind power stations in NSW.

It also appears that wind industry lease contracts are based on a percentage of potential income of electricity generated or a flat fee. This is a significant gamble for the landowner hosting an industrial development. These percentage and flat fee figures are agreed in contracts before wind monitoring has taken place, or are based on wind modeling software predictions that are not disclosed by the power company. The primary financial driver for wind power companies in such areas is to place wind turbines near the major powerlines. This has a potentially further detrimental effect on landholders hosting the turbines, because it means that the taxable income from generated electricity will be far less than in an area with a good quality wind resource. It is our understanding that some NSW landholders are making erroneous assumptions of income potential. These assumptions on income are being based on nameplate capacity MW figures, rather than an at best Load Factor of 20% to 30%, and verbal non-legally binding estimates on number of turbines given by wind power company representatives. Any profits from such installations are clearly in favour of the wind power company and not in the interest of the landholder. It is quite possible, and has happened with other wind developments, that landholders signing lease agreements may not end up with any turbines, but are left with an onerous long term lease agreement and extensive access roads to turbines on other properties.

3.3 HOMES POWERED FIGURES ARE MISLEADING

The "homes powered" figures that are constantly portrayed by the wind industry, government and in the media are very misleading for the general public. Professor David JC MacKay in the Department of Physics at the University of Cambridge and member of the World Economic Forum Global Agenda Council on Climate Change in his book (2008) "*Sustainable Energy — without the hot air*", UIT Cambridge Ltd discusses this problem :

"The "home" is commonly used when describing the power of renewable facilities. For example, "The £300 million Whitelee wind farm's 140 turbines will generate 322 MW – enough to power 200 000 homes." The "home" is defined by the British Wind Energy

Association to be a power of 4700 kWh per year."

The "home" annoys me because I worry that people confuse it with the total power consumption of the occupants of a home – but the latter is actually about 24 times bigger. The "home" covers the average domestic electricity consumption of a household, only. Not the household's home heating. Nor their workplace. Nor their transport. Nor all the energy-consuming things that society does for them."

In the UK the Secretary of State for Energy and Climate Change, the Rt Hon Ed Miliband MP recently published a prominent article in *The Times* (27.04.09) regarding number of homes powered by wind energy. Following an enquiry from a member of the public, REF wrote an open letter (07.05.09) to Mr Miliband with regard to this, and published the correspondence on the REF website at : http://www.ref.org.uk/PublicationDetails/52 Mr Milliband stated in his article that :

"To all those who scoff at the idea of wind making a difference, my reply is that last year enough power for all the electricity for two million homes came from wind power."

Some of the REF's comments help to clarify matters (underlining and bold font is their emphasis) :

"...you should not in any case use the homes equivalent figure, which is misleading to the public since domestic houses typically use only 30% of national electricity, and because the comparison suggests that the turbines could take this many houses off-grid, which is not the case."

"... so1.8 million homes equivalent rather than 2 million. (Incidentally, most of this increase appears to be from offshore wind, confirming a long-standing REF argument that given the capacity limit for wind in the UK system, perhaps 10 GW, it makes sense to seek high yielding sites.)"

"However, the real issue is that there are good reasons for not employing the homes equivalent calculation and presentation method:

Explaining Energy Quantities to the Public

In fact, the concluding and main point of my letter goes unaddressed in your response.

I wrote:

8. Further, in my view, you should not in any case use the homes equivalent figure, which is misleading to the public since domestic houses typically use only 30% of national electricity, and because the comparison suggests that the turbines could take this many houses off-grid, which is not the case.

9. It would be much more accurate to express the significance of wind's generation in terms of national consumption (roughly 390 TWh in 2007):

5,777,249 /390,000,000 = 0.015.

My point was that <u>"in any case"</u>, i.e. ***regardless of what exact figure is used, 1.2m, 1.8m, 2m, the "homes equivalent" calculation is potentially very misleading and not helpful in giving clear guidance as to progress towards meeting the 2020 targets.***

Specifically, the "homes equivalent" figure is likely to lead to a misperception of significance, and particularly so should the public wish to understand the value for money offered by the Renewables Obligation. Assuming a ROC price of about £48 in 2007, wind cost the consumer about £278 million in indirect subsidy, a very substantial sum, so it is important to be clear about the scale of the value returned."

"In my view, and I know this view is shared by many observers, a better method of expressing the output of a generator, any generator in fact, is as a fraction of total electrical energy generation, as noted above. (Despatchable generators can also be described as a fraction of peak load, as a means of estimating their national significance, but this option is not open to wind in any straightforward way.)

Some would go further and say that since electrical energy is only roughly a third of total national energy consumption, it would be best to express the wind energy generated as a fraction of Final Energy Consumption (i.e. all energy, heat, electricity, and transport), which is very roughly 1,745 TWh per year at present. Taking the 2007 figure for wind generation we can calculate:

5,777,249 MWh / 1,745,000,000 MWh = 0.0033

In other words ***wind generated 0.3% of UK Final Energy Consumption*** *in 2007, at a cost in subsidy of £278 million."*

"I hope you will agree that this is a great deal less misleading than any homes equivalent figure which I really hope you or your department won't use again, however calculated."

4. ENVIRONMENTAL IMPACTS & LACK OF GREENHOUSE GAS REDUCTION

A significant concern worldwide is the environmental impacts of constructing industrial wind turbine power stations. These range from : calculations of the true carbon costs of industrial wind turbine power stations in the context of all green house gas emissions both nationally and internationally, to risks associated with catastrophic turbine failures, fire risk, fragmentation and destruction of wildlife habitat from industrial wind turbine power station development, irreparable destruction of fauna through industrialization of the landscape, and wind turbine collision fatalities of wildlife such as birds and bats. Research in these areas is ongoing which further demonstrates the need for considered, unrushed and reasoned debate before signing over land and government rubber stamping of such industrial development.

Some areas targeted for industrial wind power station developments are Box-Gum Grassy Woodland, and associated flora and fauna, which are listed as Endangered in NSW and Critically Endangered nationally. Understanding the environmental impact of industrial wind turbine power stations on flora and fauna is of critical importance, particularly in agricultural areas where many animals play a critical role in biological control such as the consumption of insects. For example see : Kunz, T. H., et al (2007) "Methods and metrics for studying impacts of wind energy development on nocturnal birds and bats." *Journal of Wildlife Management* 71: pages 2449-2486. These research studies require extensive monitoring of industrial wind turbine sites, and the use of dog handler teams on properties is likely to become the preferred technique for locating bird and bat carcasses : Arnett, E. B. (2006) "A preliminary evaluation on the use of dogs to recover bat fatalities at wind energy facilities." *Wildlife Society Bulletin*: 34: pages 1440-1445. Ongoing scientific research into bat fatalities are available at http://www.batsandwind.org This and other research clearly demonstrates that industrial wind turbines are environmentally destructive.

Our habitat of Box Gum Grassy Woodland is host to a number of vulnerable and endangered species of bats, birds, plants and trees that are being placed in further danger by industrial wind power station development. Also of note is the fact that NSW has the greatest level of diversity amongst its bird population. This has been identified as a major and growing sustainable tourist industry for NSW.

The wind energy industry and its associated environmental assessment studies claim that flora and fauna are more in danger from climate change than industrial wind power station development. This is completely misleading. Industrial wind power stations fail to live up to their environmentally friendly claim of significantly reducing greenhouse gas emissions as numerous studies have shown.

4.1 RENEWABLE ENERGY FOUNDATION STUDY

In December 2004 REF commissioned and published a report titled : *"Reduction In Carbon Dioxide Emissions: Estimating The Potential Contribution From Wind-Power"*. This report is freely available at : http://www.ref.org.uk/PublicationDetails/27 and includes an executive summary. Some key points from the executive summary are reproduced here (all bold font is their emphasis) :

"Renewable electricity has become synonymous with CO2 reduction. However, ***the***

relationship between renewables and CO2 reduction in the power generation sector does not appear to have been examined in detail, and the likelihood, scale, and cost of emissions abatement from renewables is very poorly understood."

"Wind turbine technology has been developing in Europe for nearly twenty years, and ample experience has been gained to show ***wind generated power to be variable, unpredictable, and uncontrollable.*** *In fact, the European experience shows conclusively that the annual production is* ***routinely disappointing****, and this does not augur well for the UK's chances of achieving significant emissions abatement."*
"Indeed, the accommodation of the variable output from wind turbines into the transmission system is complex and the technical challenges are barely understood outside professional circles. ***Fossil-fuelled capacity operating as reserve and backup is required to accompany wind generation and stabilise supplies to the consumer. That capacity is placed under particular strains when working in this supporting role because it is being used to balance a reasonably predictable but fluctuating demand with a variable and largely unpredictable output from wind turbines.*** *Consequently, operating fossil capacity in this mode generates more CO2 per kWh generated than if operating normally.* ***This compromising effect is very poorly understood****, a fact acknowledged recently by the Council of European Energy Regulators."*

"Thus, the CO2 saving from the use of wind in the UK is probably much less than assumed by Government advisors, who correctly believe that wind could displace some capacity and save some CO2, but have not acknowledged the emissions impact of matching both demand and wind output simultaneously. As a result, current policy appears to have been framed as if CO2 emissions savings are guaranteed by the introduction of wind-power, and that wind power has no concomitant difficulties or costs. ***This is not the case."***

"With this level of disagreement between governmental authorities and trade bodies it is hardly surprising that there is general public confusion over the issue. ***This uncertainty is most undesirable, not least because of the economic implications of an erroneously reasoned choice of carbon abatement technology."***

"Market forces will fix wholesale electricity prices at a level that discourages new investment in modern plant, and the focus on wind power for new generating capacity is likely to lead to the retention of old, low efficiency, coal-fired plant for an extended period."

"In conclusion, it seems reasonable to ask why wind-power is the beneficiary of such extensive support if it not only fails to achieve the CO2 reductions required, but also causes cost increases in back-up, maintenance and transmission, while at the same time discouraging investment in clean, firm generation."

The REF also commissioned a recent study into the effectiveness and reliability of industrial wind turbine power stations to produce 16% to 18.8% of nationwide electricity supply in the UK : Oswald, J., Raine, M. and Hezlin, A., "Will British weather provide reliable electricity?" *Energy Policy* 36(8), August 2008, pages 3212-3225 available at : www.windaction.org/documents/18480 among the negative conclusions of this paper it is important to note that :

i. volatile power swings of up to 70% from wind turbines result in conventional fossil fuel power stations placed under greater stress, reducing reliability and utilisation
ii. this will have cost implications for the network, and hence the consumer
iii. the amount of backup conventional fossil fuel power station CO2 emissions need to be factored into wind industry carbon saving calculations
iv. electricity demand can reach its peak with a simultaneous demise in wind power output

The study for this paper is the British system, **but these are recognised worldwide as industrial wind turbine power station problems that are not yet solved.** Yet the industrial wind industry maintains that the wind will always be blowing somewhere when scientific studies have shown that this is still a major problem.

4.2 ONTARIO STUDY

A recent study in Ontario, Canada by Tom Adams and Francois Cadieux *"Wind Power In Ontario: Quantifying The Benefits Of Geographic Diversity"* presented at the 2nd Climate Change Technology Conference, May 12-15 2009 which specifically looks at the aggregated output of multiple industrial wind power stations states :

"Average wind output is high in winter and low during the summer, whereas demand is highest in summer. This imbalance represents a key limitation with respect to reliance on wind power in Ontario. The seasonal wind output pattern observed in Ontario is very similar to that of wind farms across Canada and throughout central and northern Europe."

"Measurements presented here based on wind outputs from major wind developments in and near Ontario indicate that distances over 250 km between wind farms are required for hourly output correlations to drop to 50%, and distances over 350 km are required for daily correlations to drop to 50%. Moreover, the results presented here suggest that correlation coefficients will be positive over distances greater than 800 km and are not likely to be negative over conceivable distances within the province. The modest benefit of diversifying locations is illustrated when one large wind farm located more than 360 km away from another group of nearly equal capacity was added: the standard deviation in output decreased by only 2.7% of installed capacity. Other studies present similar results for Europe, although distance appears to be less effective in mitigating variability in Ontario than in Europe."

"Thus, to meet the policy objective of maximizing wind's penetration of Ontario's electricity generation mix while minimizing grid impacts, any new wind power capacity should thus be installed far away from other wind farms. Conversely, allowing concentrated wind development, either by co-locating wind farms or building relatively large farms, reduces the total wind capacity the system can accommodate within a given level of load balancing expenditure."

Although adding a distant wind farm to an existing fleet fills the valleys of average output and drops the standard deviation of output by a small fraction, it also increases the magnitude of overall output swings. Large overall wind output swings are inevitable because wind farms within the province are statistically more prone to increase and decrease generation synchronously due to the nature and size of the meteorological *fronts that largely drive wind speeds. In other words, if wind power output swings or peaks challenge the load balancing capacity of the power system, distance between wind farms does not help.*

"Ontario has made a policy commitment to encourage extensive wind power development supported by only a preliminary understanding of the potential power system impacts of a large wind power fleet. Wind power's consumer impacts – incremental transmission, energy storage, ramping generation requirements, and grid reliability service costs such as automatic generation control and operating reserve – may be insignificant at low wind penetration of the overall electricity supply but will rise as wind capacity rises and may become significant. Additional research on the output variability of wind power, grid reliability mitigation measures, and the load carrying capacity of wind power is thus necessary."

Adam's Keynote Address for the Professional Engineers of Ontario Annual General Meeting May 9, 2009 *"Transforming Ontario's Electricity Paradigm: Lessons Arising from Wind Power Integration"* also reports on this Canadian research :

"Advocates and sometimes even government engineers assure us that wind power is decentralized energy, that wind power can help replace coal, that wind volatility is smoothed by distance, and that wind can supply a large fraction of our electricity needs without imposing significant indirect costs on consumers. Although I wish it were otherwise, the data is uncomplimentary to this loose talk."

"Getting wind power to consumers when they want it will be a challenge. Unfortunately wind and load are out of sync across several dimensions."

"Other researchers have identified that Ontario tends to get most of our wind output at the wrong time of day and that the daily wind pattern tends to decline in morning when load is rising and ramp up in evening when load is declining."

"Unfortunately distance provides little smoothing benefit:

Considering hourly correlation coefficients, 250 km cuts the cross correlation by only 50%. No matter how far apart they are, wind farms in Ontario east of Wawa will be positively correlated. This means that the more wind capacity we add, the more output volatility the aggregate fleet will yield. Adding a distant wind farm fills the valleys of average output and drops the standard deviation of output a little but also increases the peaks of output. If output swings or peaks are challenging the system, distance doesn't help."

"Some of these factors are also significant in terms of wind power's ultimate environmental footprint. No one in Ontario can realistically estimate these factors right now, in part because the commercial impact of the GEA [Green Energy Act] *is still very difficult to estimate but also in part because much more technical homework is needed."*

4.3 USA NATIONAL ACADEMY OF SCIENCES STUDY

The National Academies (Science, Engineering and Medicine) in the USA published a recent study relating to the mid-Atlantic region in 2007 *"Environmental Impacts of Wind-*

Energy Projects" available at : http://books.nap.edu/catalog/11935.html which is a 394 page report and a 33 page executive summary. On page 5 of the executive summary regarding the issue of displacement of coal power stations it states :

"However, because current and upcoming regulatory controls on emissions of NOx and SO2 from electricity generation in the eastern United States involve total caps on emissions, the committee concludes that development of wind-powered electricity generation using current technology probably will not result in a significant reduction in total emission of these pollutants from the electricity sector in the mid-Atlantic region."

On page 8 of the executive summary is a section regarding ecological impacts :

"The construction and maintenance of wind-energy facilities also alter ecosystem structure through vegetation clearing, soil disruption and potential for erosion, and noise. Alteration of vegetation, including forest clearing, represents perhaps the most significant potential change through fragmentation and loss of habitat for some species."

A selection of quotes from the Preface of the report on page ix states :

"The generation of electricity from wind energy is surprisingly controversial. At first glance, obtaining electricity from a free source of energy—the wind—seems to be an optimum contribution to the nation's goal of energy independence and to solving the problem of climate warming due to greenhouse gas emissions. As with many first glances, however, a deeper inspection results in a more complicated story."

"Building wind-energy installations with large numbers of turbines can disrupt landscapes and habitats, and the rotating turbine blades sometimes kill birds and bats. Calculating how much wind energy currently displaces other, presumably less-desirable, energy sources is complicated, and predicting future displacements is surrounded by uncertainties."

And from Preface page x :

"The benefits of wind energy depend on the degree to which the adverse effects of other energy sources can be reduced by using wind energy instead of the other sources. Assessing those benefits is complicated. The generation of electricity by wind energy can itself have adverse effects, and projecting the amount of wind-generated electricity available in the future is quite uncertain."

4.4 TYNDALL CENTRE FOR CLIMATE CHANGE RESEARCH STUDY

The Tyndall Centre for Climate Change Research published a report as part of their research project "*Ensuring new and renewable energy can meet electricity demand: security of decarbonised electricity systems*". The final report is, Nedic, D. P., Shakoor, A. A., Strbac, G., Black, M., Watson, J., and Mitchell, C. (2005) "*Security assessment of futures electricity scenarios*", Tyndall Centre Technical Report 30 available at : http://www.tyndall.ac.uk/research/theme2/project_overviews/t2_24.shtml A discussion of the results are also presented on the web page, and of specific note is :

"The performed capacity adequacy studies for the mid-term future UK electricity scenarios clearly show that the capacity value of wind generation plant is limited.

Analysis was carried out for a wide range of wind penetrations to examine the generating capacity of conventional plant that can be displaced by wind, while maintaining a specified security level. We observed that wind generation only displaces a relatively modest amount of conventional plant, which means that in order to maintain the same level of security, a significant capacity of conventional plant will still be required."

"Due to a disproportion between the conventional capacity and the energy substitution by the wind source, a considerable number of thermal plants will be running at low output levels over a significant proportion of their operational time in order to accommodate wind energy. Consequently these plants will have to compromise on their efficiency, resulting in increased levels of fuel consumption as well as emissions per unit of electricity produced."

4.5 CARNEGIE MELLON UNIVERSITY STUDY

The recent research and testimony to US House of Representatives of Professor Jay Apt, the executive director of the Electricity Industry Center at Carnegie Mellon University's Tepper School of Business and Distinguished Service Professor in the Department of Engineering and Public Policy, addresses the issues of lack of emissions reduction by gas power stations used to mitigate the variability of industrial wind power stations. In a research paper co-authored with Warren Katzenstein, "Air Emissions Due To Wind and Solar Power", *Environmental Science & Technology* (2009) Vol 43 No 2 pages 253-258, their research shows :

"Renewable energy emissions studies have not accounted for the change in emissions from power sources that must be paired with variable renewable generators"

"In many locations, natural gas turbines will be used to compensate for variable renewables. When turbines are quickly ramped up and down, their fuel use (and thus CO2 emissions) may be larger than when they are operated at a steady power level. Systems that mitigate other emissions such as NOx may not operate optimally when the turbines' power level is rapidly changed."

"Carbon dioxide emissions reductions from a wind (or solar PV) plus natural gas system are likely to be 75-80% of those presently assumed by policy makers. Nitrous oxide reduction from such a system depends strongly on the type of NOx control and how it is dispatched. For the best system we examined, NOx reductions with 20% wind or solar PV penetration are 30-50% of those expected. For the worst, emissions are increased by 2-4 times the expected reductions with a 20% RPS [Renewables Portfolio Standards] *using wind or solar PV."*

"We have shown that the conventional method used to calculate displaced emissions is inaccurate, particularly for NOx emissions. A region-specific analysis can be performed with knowledge of displaced generators, dispatched compensating generators, and the transient emissions performance of the dispatched compensating generators. The results shown here indicate that at large scale variable renewable generators may require that careful attention be paid to the emissions of compensating generators to minimize additional pollution."

In Apt's testimony to U.S. House of Representatives Committee on Energy and

Commerce Subcommittee on Energy and Environment's Hearing on The American Clean Energy Security Act of 2009 "Panel on Low Carbon Electricity, Carbon Capture and Storage, Renewables and Grid Modernization" of April 23, 2009 he states :

"Even in good areas, the wind doesn't blow all the time. Looking at all the wind power plants in Texas in 2008, we find that in a quarter of the hours during the year Texas wind production was less than 10% of its rated capacity. That means that when a wind farm is built, some other power source of the same size must be built to provide power during those calm hours. Our research shows that natural gas turbines, that are often used to provide this fill-in power, produce more CO2 and much more nitrous oxide (as they quickly spin up and then slow down to counter the variability of wind than) than they do when they are run steadily."

"The point is that wind and solar can lower the amount of fossil fuels used for generation, but they don't lessen the need for spending money on always-available generation capacity, nor do we get all the air emissions benefits we once expected."

"Wind farms can affect climate downwind, reducing precipitation. Massive reliance on wind energy would take energy out of the wind, changing the Earth's climate. All power generation options have feet of clay. There is no generation utopia. But just because there is no free lunch doesn't mean we can't eat: we just have to acknowledge the issues honestly so that we are not faced with a public backlash later on."

Apt and colleagues have recently published in the American National Academies of Science Fall 2008 on-line journal "Issues in Science and Technology" a paper titled *"A National Renewable Portfolio Standard? Not Practical"* covering issues regarding problems with wind energy :

"Producing sufficient wind turbines would require a major increase in manufacturing capacity. Demand (driven by state RPSs and the federal renewable production tax credit) has already stretched supplies thin, creating an 18-month delivery delay for wind machines. It has also emboldened manufactures to reduce wind turbine warranties from five years to two."

"Among the disadvantages of wind systems are that they produce power only when the wind is strong and that they are most productive at night and during spring and fall, when electricity demand is low. The capacity factor (the percent of maximum generation potential actually generated) of the best sites for wind turbines is about 40%, and the average capacity of all the wind turbines used to generate utility power in the United States was 25% in 2007."

"...if wind supplied 15% of the electricity, it would save less than 15% of fuel because other generators backing up the wind must often run at idle even when the wind is blowing and because their fuel economy suffers when they have to ramp up and slow down to compensate for variability in wind."

"Variability also requires constant attention, lest it threaten the reliability of the electric system. On February 26, 2008, the power system in Texas narrowly avoided a breakdown. At 3 p.m., wind power was supplying a bit more than 5% of demand. But over the course of the next 3.5 hours, an unforecast lull caused wind power to fall from

2,000 MW to 350 MW, just as evening demand was peaking. Grid operators declared an emergency and blacked out 1,100 MW of load in a successful attempt to avoid a system collapse. According to the Electric Reliability Council of Texas, "This was not the first or even the worst such incident in ERCOT's area. Of 82 alerts in 2007, 27 were 'strongly correlated to the drop in wind'."

"Finally, wind energy is a finite resource. At large scale, slowing down the wind by using its energy to turn turbines has environmental consequences. A group of researchers at Princeton University found that wind farms may change the mixing of air near the surface, drying the soil near the site. At planetary scales, David Keith (then at Carnegie Mellon) and coworkers found that if wind supplied 10% of expected global electricity demand in 2100, the resulting change in the atmosphere's energy might cause some regions of the world to experience temperature changes of approximately 1°C."

In the July 2009 edition of Power Engineering Thomas Hewson Jr. and David Pressman's paper "Calculating wind power's environmental benefits" also presents negative conclusions regarding emissions reduction of industrial wind energy :

"Finally, proponents who suggest that wind is able to entirely displace CO2 overlook a fact fundamental to energy generation: wind's unpredictability means it truly has no generating capacity value and its construction will not displace building any new coal or natural gas generating capacity. Grid reserve margins require wind back up and the inefficiency of quickly firing up a natural gas unit to meet erratic wind generation output means any emissions displacement is minimal. Wind is simply an additional capital cost which proves to be more than twice as expensive for the ratepayer."

"Creating a federal renewable portfolio standard would create a nationwide closed market for renewables, meaning wind projects would again offer no incremental emissions benefits given their direct competition with other renewables and not coal or natural gas. Unfortunately, many of the claims made regarding wind's supposed avoided air benefits are overstated."

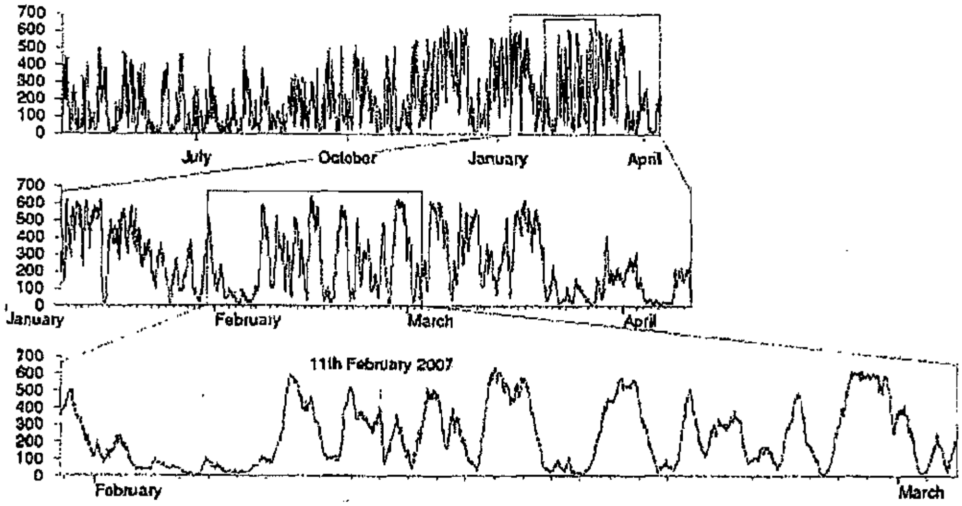
4.6 OTHER STUDIES

Professor David JC MacKay in the Department of Physics at the University of Cambridge and member of the World Economic Forum Global Agenda Council on Climate Change in his book (2008) "*Sustainable Energy — without the hot air*", UIT Cambridge Ltd discusses the problems of fluctuation and storage of wind energy. On page 187-188 he states :

"However much we love renewables, we must not kid ourselves about the fact that wind does fluctuate.

Critics of wind power say: "Wind power is intermittent and unpredictable, so it can make no contribution to security of supply; if we create lots of wind power, we'll have to maintain lots of fossil-fuel power plant to replace the wind when it drops." Headlines such as "Loss of wind causes Texas power grid emergency" reinforce this view. Supporters of wind energy play down this problem: "Don't worry – individual wind farms may be intermittent, but taken together, the sum of all wind farms in different locations is much less intermittent."

Let's look at real data and try to figure out a balanced viewpoint. Figure 26.2 shows the summed output of the wind fleet of the Republic of Ireland from April 2006 to April 2007. Clearly wind is intermittent, even if we add up lots of turbines covering a whole country. The UK is a bit larger than Ireland, but the same problem holds there too. Between October 2006 and February 2007 there were 17 days when the output from Britain's 1632 windmills was less than 10% of their capacity. During that period there were five days when output was less than 5% and one day when it was only 2%."

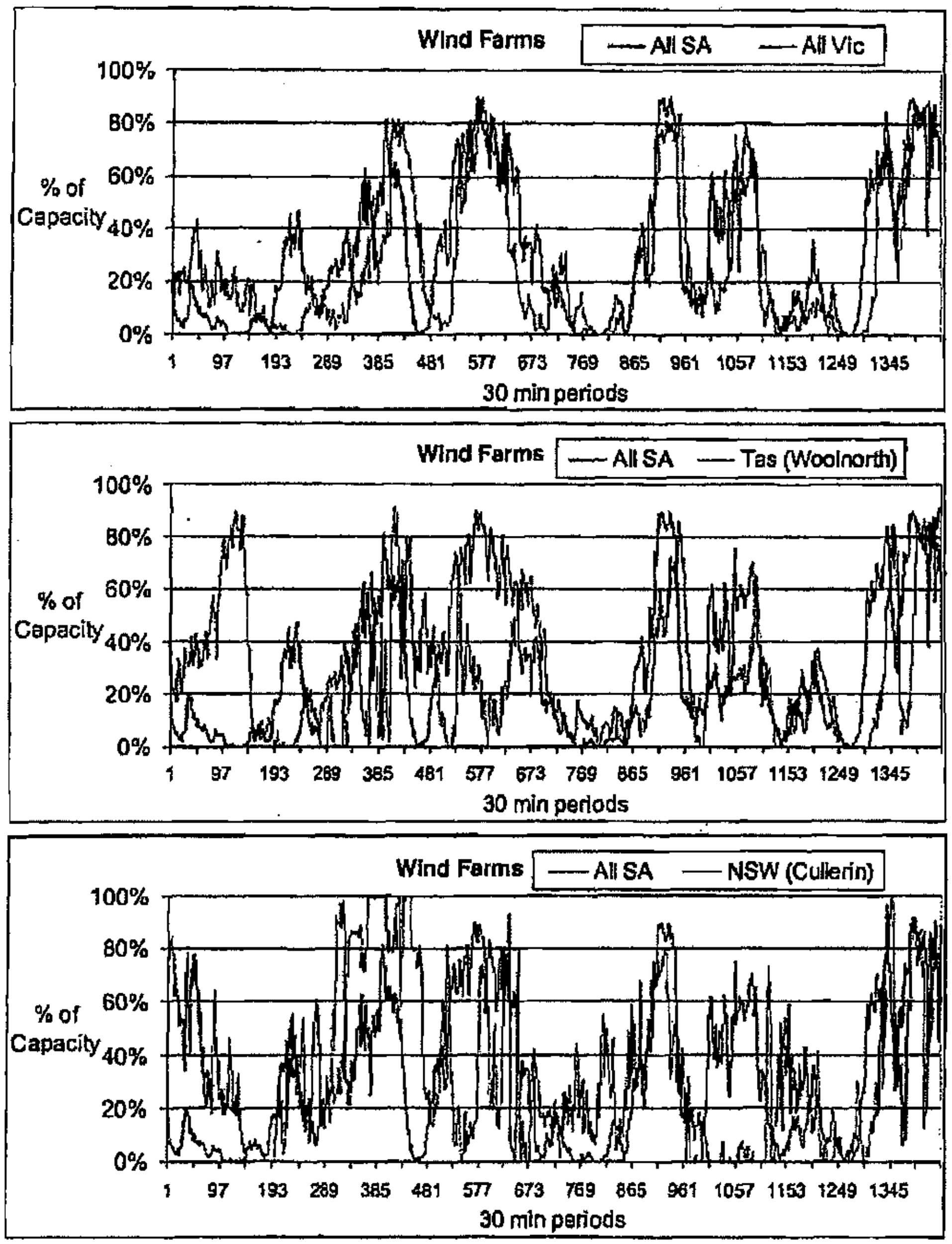


Total output, in MW, of all wind farms of the Republic of Ireland, from April 2006 to April 2007 (top), and detail from January 2007 to April 2007 (middle), and February 2007 (bottom). Peak electricity demand in Ireland is about 5000 MW. Its wind "capacity" in 2007 is 745 MW, dispersed in about 60 wind farms. Data are provided every 15 minutes by www.eirgrid.com. (Figure 26.2 from MacKay, D. (2008) "*Sustainable Energy — without the hot air*" UIT Cambridge Ltd : http://withouthotair.com)

A preliminary study in Australia on existing industrial wind power stations by Andrew Miskelly and Tom Quirk shows that this intermittency is happening in Australia. Their analysis is based on 11 industrial wind power stations spread across 900km in South Australia, New South Wales, Victoria and Tasmania for the month June 2009. The data is obtained from the publically available *Non-Scheduled Generation Data* at the AEMO website (http://www.aemo.com.au/data/csv.html). They state :

"South Australian wind power generation has been used as the standard as it is the largest sample and despite having 6 wind farms added together performs as if it were one farm despite a spread of some 500 km.

It is clear that the responses in each area are correlated. The correlation of South Australia with Victoria is the clearest example."

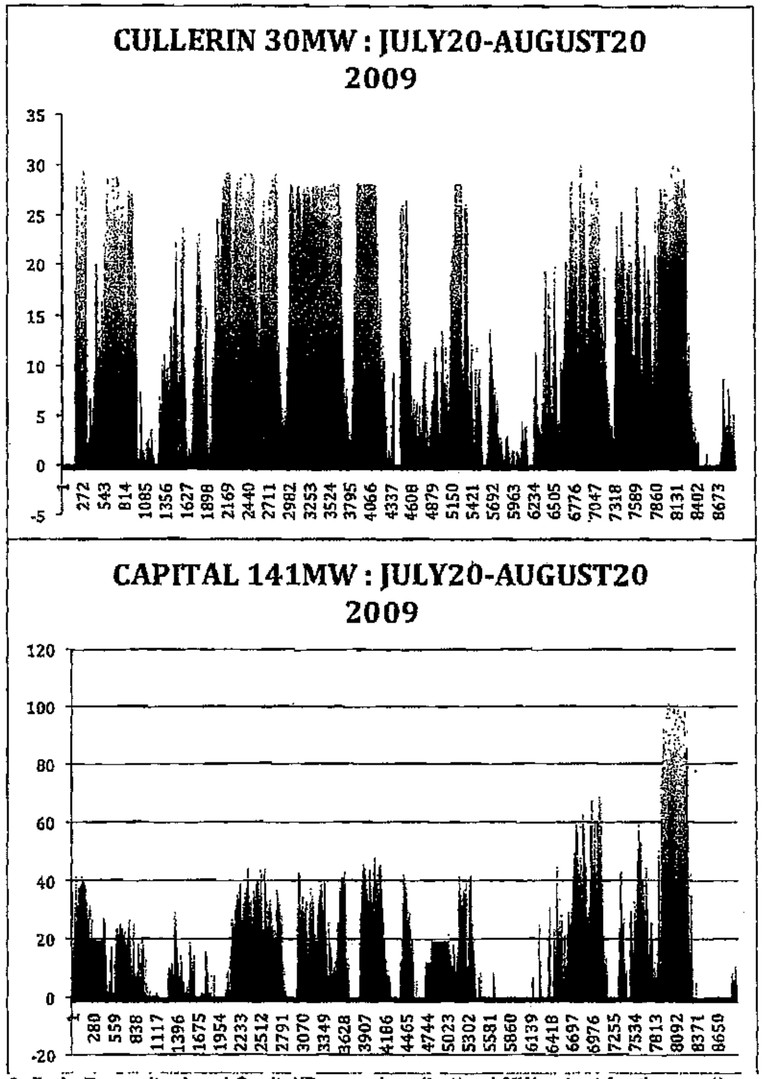


June 2009 performance of the wind farms in NSW, Victoria and Tasmania compared to that of South Australia. (From Miskelly, A and Quirk, T. (2009) Wind Farming in South East Australia)

All of these studies show that significant smoothing does not occur from such correlation, and that more industrial wind power stations result even greater fluctuations in electrical output. The fact that the electricity outputs from large geographical distributions of industrial wind power station are *correlated* means that they tend to act as one power station, because weather fronts cover vast distances. This can result in simultaneous lulls affecting multiple wind power stations.

The AEMO data for a number of wind power stations can be obtained selectively through the Australian Landscape Guardians website :
http://www.landscapeguardians.org.au/data/aemo/ We have computed the graph for the output of the 30MW Cullerin Range Wind Farm and the 141MW Capital Wind Farm at Bungendore for the month from 20th July to 20th August, data sampled at 5 minute intervals. The output is seen to be highly variable, with very extreme shifts in output noticeable.The output is again seen to be highly variable, with very extreme shifts in output noticeable.

It is also easily seen that in the July 20 to August 20 data sets for both Cullerin Range and Capital/Bungendore there are simultaneous dips in power output.



Cullerin Range (top) and Capital/Bungendore (bottom) MW output for the month July 20 to August 20 2009 from AEMO 5 minute data

Peter Lang is a retired engineer with 40 years experience on a wide range of energy projects throughout the world, including managing energy R&D and providing policy advice for government and opposition. His experience includes: coal, oil, gas, hydro, geothermal, nuclear power plants and nuclear waste disposal (6.5 years managing a component of the Canadian Nuclear Fuel Waste Management Program). In 2009 he self published the paper "*Cost and Quantity of Greenhouse Gas Emissions Avoided by Wind Generation*" and provided a simple analysis of the amount of greenhouse gas emissions avoided by wind power and its associated cost. In agreement with the other studies cited above he concludes :

"These calculations suggest that wind generation saves little greenhouse gas emissions when the emissions from the back-up are taken into account.

1. Wind power does not avoid significant amounts of greenhouse gas emissions.

2. Wind power is a very high cost way to avoid greenhouse gas emissions.

3. Wind power, even with high capacity penetration, can not make a significant contribution to reducing greenhouse gas emissions."

It is clear from all these studies just cited in this section that **industrial wind power fails to deliver any significant savings in greenhouse gas reduction. No independent scientific study has ever shown that industrial wind energy saves a significant amount of greenhouse gases.**

This fact has been well known for many years, the REF study was published in Dec 2004, over four and a half years ago. Despite the repeated claims the wind industry may make about any recent improvements the most recent 2009 study by Carnegie Mellon University states that **emissions can actually be increased by industrial wind power.** Industrial wind power stations are therefore of no environmental benefit and should not be built.

5. PROJECT LIFESPANS

Wind industry developers suggest a 20 to 25 year lifespan for an industrial wind turbine, which involves continuous monitoring and maintenance requiring unlimited 24 hour / 7 days per week / 365 days per year access to the leased land. However, due to the majority of these installations being new developments, few turbines have been around to test these lifespan assumptions under real world conditions. Regarding wind turbine warranties Apt and colleagues state in the American National Academies of Science Fall 2008 on-line journal "Issues in Science and Technology" in a paper titled *"A National Renewable Portfolio Standard? Not Practical"* that :

"Demand (driven by state RPSs and the federal renewable production tax credit) has already stretched supplies thin, creating an 18-month delivery delay for wind machines. It has also emboldened manufactures to reduce wind turbine warranties from five years to two."

Turbine failures and engineering problems are an occurrence that has also affected our decision not to host wind turbines. For example, TrustPower's Snowtown installation was built and is maintained by India's industrial wind turbine manufacturer Suzlon Energy Ltd. Suzlon have experienced problems with blade failure which has impacted on their share price recently. The 25th October 2008 Wall Street Journal article "Windmill Mishap Weighs on Suzlon" at (http://online.wsj.com/article/SB122485006026866321.html) reported on a blade failure incident which drove down the Suzlon shares by 39%. This report tells of a 140ft (42.67m) long turbine blade snapping off and being thrown 150ft (45.72m) from the tower. This is a known problem with Suzlon's turbine blades : *"Earlier this year, Suzlon, of Pune, India, said it would strengthen or replace 1,251 blades – almost the entire number it has sold to date in the U.S. – after cracks were found on more than 60 blades on turbines run by Deere and Edison International's Edison Mission Energy."* Suzlon has been in further trouble as seen in a recent Bloomberg news report on 16th April 2009 "Suzlon Falls Most in 3 Months on Faulty Blade Report" (http://www.bloomberg.com/apps/news?pid=20601091&sid=aEEY_nocEVzo). Suzlon shares fell 84% last year, with further losses already in 2009. These technical problems are experienced across the whole wind industry and are not just limited to Suzlon. An article in Business Week, 24th August 2007, " The Dangers of Wind Power" discusses the global rise in the number of accidents and failures (http://www.businessweek.com/globalbiz/content/aug2007/gb20070824_562452.htm?chan=globalbiz_europe+index+page_top+stories). Gearboxes in wind turbines are often replaced within the first 5 years. Wind turbines can stand idle for up to 18 months waiting for replacement parts. Also in this report Jan Pohl of insurance firm Allianz in Munich, who faced about 1000 claims in 2006 stated : "an operator has to expect damage to his facility every four years, not including malfunctions and uninsured breakdowns."

Land leases also commonly have options to renew for a further term, meaning that leases can be tied up for up to 50 or more years. This is similar to the contracts that the wind industry are currently urging landholders to sign. Leases are often on-sold to other companies, bearing in mind that a wind energy company will expect to have profited from their investment well before the lease expires.

For the landholder attempting to judge the lifetime of an industrial wind plant it is also vital to consider research on the effects of climate change on energy infrastructure. In

Chapter 11 (Australia and New Zealand) of the IPCC Working Group II Contribution to the 4th Assessment Report *"Climate Change 2007 – Impacts, Adaptation and Vulnerability"* it is worth noting the following in Section 11.4.10 Energy on page 523 : *"Climate change is likely to affect energy infrastructure in Australia and New Zealand through impacts of severe weather events on wind power stations, electricity transmission and distribution networks"*. Later in the same section an assessment of potential risks for Australia found, among other risks, that : *"increased peak and average temperatures are likely to reduce electricity generation efficiency, transmission line capacity, transformer capacity and the life of switchgear and other components"*. This potential for future failures coupled with the known unreliability of wind energy further diminishes the financial returns of industrial wind turbines for the landholder.

Other studies have shown that there is also the potential for climate change to impact directly on wind resource : Sailor, D.J., M. Smith, and M. Hart, 2008. "Climate change implications for wind power resources in the Northwest United States," *Renewable Energy*, 33 (11), pages 2393-2406. This paper concludes that wind generated electricity in the area studied could be reduced by up to 40% through climate change. This research builds on their earlier study Breslow, P., and D.J. Sailor, (2002) "Vulnerability of Wind Power Resources to Climate Change in the Continental United States", *Renewable Energy*, 27 (4), pages 585-598. In this work they estimate a 1% to 3.2% reduction in wind speeds in the area studied over the next 50 years, and a 1.4% to 4.5% reduction over the next 100 years. As mentioned in Section 3 of this submission, turbine power output is greatly affected by any small change in wind speed on the power curve, so even small reductions in future wind speeds can have a significant effect on maintaining industrial wind turbine power station viability.

6. DECOMMISSIONING WIND TURBINES AND INFRASTRUCTURE

From our meetings with other NSW landholders who are or have been coerced by industrial wind energy companies it is evident that they are under the impression that they will benefit from the "scrap value" for turbines when they are no longer in service. Governments, on the other hand, are being given the false impression by the wind industries project application documents that decommissioning costs will be covered by scrap value. **This is not true and represents a significant problem for the future and further demonstrates that industrial wind energy developments are NOT environmentally responsible.**

For example, the false assumption of scrap value covering decommissioning costs is stated by the developer Epuron (http://www.epuron.com.au) in the current Harden / Yass Preliminary Assessment document Chapter 4, Page 13, Section 4.5.3 available at (http://majorprojects.planning.nsw.gov.au/page/project-sectors/transport--communications--energy---water/generation-of-electricity-or-heat-or-co-generation/?action=view_job&job_id=2765) :

"It should be noted that the scrap value of turbines and other equipment is expected to be sufficient to cover the majority of the costs of their dismantling and site rehabilitation."

The final Environmental Assessment document for the now approved Conroy's Gap site, Chapter 1, Page 42, Section 3.4.3 available at (http://www.epuron.com.au/desktopdefault.aspx/tabid-786/) :

"The scrap value of turbines and other equipment is expected to be sufficient to cover the majority of the costs of their dismantling and site restoration."

These are incorrect assumptions and highlight that decommissioning plans are a more recent problem the wind industry and the NSW Government should now be addressing. **All industrial wind energy developers are making exactly these same claims in their planning applications which are being systematically approved in NSW without question.**

Decommissioning is a very expensive, industrially intensive process. The decommissioning process outweighs potential scrap value and currently requires adherence to State Government legislation in the form of a Decommissioning Management Plan, which currently includes, but is not limited to: disposal of non-recyclable components, removal within 18 months of any wind turbine that is continuously inoperable for 12 months (which may occur through a fault or economics), restoration of land and vegetation, removal of infrastructure and access roads within 12 months, procedures for notification of surrounding landholders of decommissioning activities as this will again be intrusive to the surrounding community. For an example of this requirement see Page 6 of the Project Approval document for Conroy's Gap at (http://majorprojects.planning.nsw.gov.au/page/project-sectors/transport--communications--energy---water/generation-of-electricity-or-heat-or-co-generation/?action=view_job&job_id=140).

A recent USA study on public record was independently commissioned regarding realistic decommissioning costs for a currently proposed 124 turbine project in West

Virginia. This study, by Energy Ventures Analysis Inc (EVA), found that the wind energy companies engineering decommissioning report stating that costs would be covered by scrap were incorrect. **EVA found that the decommissioning costs for that particular 124 wind turbine development were underestimated by US$10million.** The final decommissioning estimate was US$100,000 per turbine, resulting in an up front bond estimate of US$12+million at the start of the project. It is becoming more likely that future industrial wind energy projects will now require an up front bond, without inclusion of any scrap value due to the fluctuating nature of the scrap metal market. Should such large bonds be required by any future government legislation, these would be an additional financial burden that may halt a project after a lease has been signed, potentially leaving the landholder tied to an onerous long term lease agreement without income. The potential problem should decommissioning not be underwritten is that this financial burden reverts to the landholder and/or the community. **However, nowhere in the project approval documents for Conroy's Gap is there any requirement for a bond to cover decommissioning costs.**

7. HEALTH PROBLEMS AND WIND TURBINE NOISE POLLUTION

A further example of the environmentally negative impacts is the many health problems caused by industrial wind turbine power stations. Among the increasing worldwide reports of negative health effects of industrial wind turbines we draw particular attention to the work of many health professionals who have produced papers and studies on this issue. The National Academy of Medicine of France in their March 2006 report "Repercussions of the Operation of Wind Turbines on the Health of Man" requested the necessity of epidemiological studies, these issues have been systematically ignored and denied by the industrial wind industry and governments :

http://www.academie-medecine.fr/detailPublication.cfm?idRub=26&idLigne=294

The following is brief summary of just some of the reports currently published, further references are given in these reports.

7.1 WIND TURBINE SYNDROME

Dr Nina Pierpont MD, PhD (www.windturbinesyndrome.com), who has recently published a book and several articles on the detrimental health effects. Dr Pierponts research and observations are reiterated in the press release by the Medical Staff of Northern Maine Medical Center (http://www.windaction.org/documents/20306). These issues of are of considerable concern for landholders, neighbours, residents, the general public and particularly for young children and the elderly. According to Dr Pierpont the symptoms of Wind Turbine Syndrome include :

1) Sleep problems: noise or physical sensations of pulsation or pressure make it hard to go to sleep and cause frequent awakening.
2) Headaches which are increased in frequency or severity.
3) Dizziness, unsteadiness, and nausea.
4) Exhaustion, anxiety, anger, irritability, and depression.
5) Problems with concentration and learning.
6) Tinnitus (ringing in the ears).

A very recent paper has demonstrated new results on human sensitivity to low frequency vibration, offering substantial support for Dr Pierpont's work : Neil P. McAngus Todd, Sally M. Rosengren, James G. Colebatch, "*Tuning and sensitivity of the human vestibular system to low-frequency vibration*", Neuroscience Letters 444 (2008) pages 36-41.

7.2 DR HANNING'S REPORT

One of the most recent reports (June 2009) is by Dr Christopher Hanning MD on "Sleep Disturbance and Wind Turbine Noise". Hanning founded, and until retirement, ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the United Kingdom, and he has 30 years of experience in the field. Hanning's report is very comprehensive and some points are mentioned here :

"There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby." **Section 2.1.1**

"The swishing or thumping noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause [of the wind turbine noise] *has not yet been fully elucidated."* **Section 2.2.4**

"Unfortunately ***all*** *government and industry sponsored research in this area has used* ***reported awakenings*** *from sleep as an index of the effects of turbine noise and dismisses the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously* ***underestimates*** *the effects of wind turbine noise on sleep."* **Section 3.1.2** (Bold emphasis by Hanning)

Hanning later refers to this issue in Section 3.5 in relation to a 2006 UK DTI report :

"The lack of physiological expertise in the investigators in not recognising that noise can disturb sleep without actual recalled awakening is a major methodological flaw rendering the conclusions unreliable, as is the short recording period. It is well recognised also that not every resident affected by a nuisance such as noise will actually register a complaint. Many will not be sufficiently literate or confident so to do and others may wish to avoid drawing attention to the problem to protect property prices. They may assume also that protest is futile, which seems to be the experience of many with wind turbine noise. Recorded complaints are thus the tip of the iceberg."

"In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions cause sleep disturbance and ill health. " **Section 3.8.3** (Bold emphasis by Hanning)

7.3 ONTARIO HEALTH SURVEY

A recent study, the Ontario Health Survey, was made public on 22nd April 2009 by Wind Concerns Ontario. Of the 76 respondents, 53 people living near industrial wind turbine generators have reported significant negative impact and adverse health effects. The Ontario Health Survey reports problems associated with both humans and animals such as birds, cats, dogs, farming livestock, horses, ponies and wildlife, as well as stress related problems due to decline in property values. In conjunction with this study is a Deputation to the Standing Committee on General Government by Dr. Robert McMurtry M.D., F.R.C.S (C), F.A.C.S. Both documents are available at :

http://www.windaction.org/documents/22261

7.4 PHOTOSENSITIVE EPILEPSY AND FLICKER

The flicker effect of wind turbines blades are also known to precipitate seizures in people with photosensitive epilepsy. This research was published in Graham Harding, Pamela Harding, and Arnold Wilkins, (2008) "Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them" *Epilepsia* 49(6) pages 1095-1098. Some key points made by this paper are :

"Rotating blades interrupt the sunlight producing unavoidable flicker bright enough to

pass through closed eyelids, and moving shadows cast by the blades on windows can affect illumination inside buildings."

"Planning permission for wind farms often consider flicker, but guidelines relate to annoyance and are based on physical or engineering considerations rather than the danger to people who may be photosensitive."

"Two examples of seizures induced by wind turbines on small wind turbine farms in the UK have been reported to the authors in 2007."

"Note that the risk of seizures does not decrease appreciably until the viewing distance exceeds 100 times the height of the hub, a distance typically more than 4 km."

7.5 VIBROACOUSTIC DISEASE

Pathologist Nuno Castelo Branco MD has been conducting extensive research on Vibroacoustic Disease (VAD) since 1980, including in relation to wind turbine generators. VAD is detailed in Castelo Branco NAA, Alves-Pereira M. (2004) "Vibroacoustic disease", *Noise & Health* 2004; 6(23): pages 3-20. VAD specifically related to industrial wind turbines is reported in Castelo Branco NAA, Alves-Pereira M. (2007) "In-Home Wind Turbine Noise Is Conducive to Vibroacoustic Disease", *Second International Conference on Wind Turbine Noise, Lyon, France.* The VAD study in relation to wind turbines discusses a rural property in an agricultural area occupied by 2 adults and a 10 year old child, with four 2MW wind turbines which began operation in Nov 2006. A section from the paper follows, note that ILFN stands for Infrasound and Low Frequency Noise, and WT stands for Wind Turbines :

"ILFN levels contaminating the home of Case 2 are amply sufficient to cause VAD. This family has already received standard diagnostic tests to monitor clinical evolution of VAD. Safe distances from residences have not yet been scientifically established, despite statements by other authors claiming to possess this knowledge. Acceptance, as fact, of statements or assertions not supported by any type of valid scientific data, defeats all principles on which true scientific endeavor is founded. Thus, widespread statements claiming no harm is caused by in-home ILFN produced by WT are fallacies that cannot, in good conscience, continue to be perpetuated. In-home ILFN generated by WT can lead to severe health problems, specifically, VAD. Therefore, real and efficient zoning for WT must be scientifically determined, and quickly adopted, in order to competently and responsibly protect Public Health."

7.6 WIND TURBINE NOISE

Contrary to statements by wind industry proponents, industrial wind turbines are noisy. A major issue with industrial wind turbines is noise pollution and the ongoing setting of standards to mitigate these effects. There has been much independent research indicating the failure of current legislation and the potential for this to be changed in the future. This will have a direct effect on the number and location of any wind turbines near residential homes and property boundaries, or their operation and potential for being shut down once built. **It will also impact upon and limit any future land use within the vicinity of wind turbines once they are erected.** Noise pollution is also directly linked to the adverse health effects described by Dr Pierpont and others in the previous section of this submission.

Noise measurements are an important part of an industrial wind turbine power station development. These are conducted before, during and after construction at residential properties in the local area, as well as at properties hosting turbines. A recent paper by community noise experts George Kamperman and Richard R. James, was presented at the 2008 International Noise Conference held in Dearborn, Michigan "Simple guidelines for siting wind turbines to prevent health risks" available at (http://www.windaction.org/documents/17095). This paper reviews wind turbine noise studies to determine a set of safe guidelines. Also noted are the unique aspects of wind turbine noise, which are different from other common forms of noise such as traffic and industrial factories. Their review shows that residents as far away as 3km can experience sleep disturbance. The study specifically makes note of wind industry claims that turbine noise is masked by background noise. However this is not the case and due to atmospheric effects, particularly at night, the wind speed at the turbine hub height can be high but almost no wind can be experienced at nearby dwellings : *"This is the heart of the wind turbine noise problem for residents within 3 km (approx. two miles) of a wind farm."* This was first noted by G. P van den Berg in his PhD thesis "*The Sounds of High Winds: the effect of atmospheric stability on wind turbine sound and microphone noise*" and associated papers. G. P van den Berg's thesis is freely available online (http://dissertations.ub.rug.nl/faculties/science/2006/g.p.van.den.berg/). The research of van den Berg shows that there are significantly higher levels of noise pollution at night than are experienced in the daytime, and the effects of complex terrain such as hills are different to flat terrain. This research was first published in : Van den Berg G.P. (2004) "Effects of the wind profile at night on wind turbine sound", *Journal of Sound and Vibration* 277 (4-5), pages 955-970. More recent research relating to complex terrains as opposed to flat terrains is discussed in : Van den Berg G.P. (2007) "Wind profiles over complex terrain." *Second International Conference on Wind Turbine Noise, Lyon, France.*

On the 29th Feb 2009, the REF obtained data under the Freedom of Information Act relating to work conducted in 2007 by the University of Salford who were under contract to the Department of Business, Enterprise and Regulatory Reform: *Research into aerodynamic modulation of wind turbine noise* (www.ref.org.uk/PublicationDetails/49). This work indicates that current UK regulations on noise pollution relating to wind turbines *"(ETSU-R-97) is not fit for purpose, is failing to protect the amenity of neighbours and is urgently in need of revision."* A summary of wind turbine noise studies with links to articles is also available at (www.windaction.org/faqs/12759).

The Acoustic Ecology Institute produced a special report in January 2009 on Wind Energy Noise Impacts (www.acousticecology.org/srwind.html). More recent research was presented at the 3rd International Conference on Wind Turbine Noise held in Denmark in June 2009 (www.windturbinenoise2009.org), and the previous two conferences also contain research documents relating to negative impacts of wind turbine noise (www.confweb.org/wtn2005/) and (www.confweb.org/wtn2007/). The 4th International Conference on Wind Turbine Noise is scheduled for 2011.

8. PROPERTY DEVALUATION

It is worth noting that the negative environmental effects of industrial wind turbine power stations on property values are not just purely based on visual amenity. As mentioned above in the excerpt from Section 3.5 of Dr Hannings report "Sleep Disturbance and Wind Turbine Noise" he states in relation to complaints about noise pollution that "*others may wish to avoid drawing attention to the problem to protect property prices.*" The Ontario Health Survey, and other health reports have mentioned the issue of stress related problems due to decline in property values.

A recent presentation by Gardner Appraisal Group Inc. given at the South Plains Agriculture Wind & Wildlife Conference in Lubbock, Texas, USA on February 13, 2009 titled "*Impact of wind turbines on market value of Texas rural land*" which discusses the **reduction of property values for landholders hosting turbines, as well as properties in the surrounding areas of such developments :** (www.windaction.org/documents/20145). Their appraisal research showed :

- A view adds value to rural property
- Take away view – added value goes away
- Brokers in rural areas confirm that property values in areas of wind facilities are 10% - 30% less than property not in areas of wind facilities
- Wind energy development creates an income stream for a property but this does not necessarily result in increased market value
- Previous studies funded by wind power proponents declaring no loss of property value are flawed due to built in bias and poor methodology

Two case studies are presented in this presentation. Case Study 1 is a 350 acre property with 27 turbines within 1.5 miles on the market in 2007. A prospective buyer agreed a purchase price but on disclosure of the wind turbine project the buyer backed out. The seller discounted the property by 25% but the buyer declined and little interest remains in the property. Case Study 2 is an analysis of seven properties with varying proximity to wind turbines, with two properties hosting turbines. **Loss in property value was reported as :**

- turbines on property = 37% loss on average
- turbines within .2 to .4 miles (0.32km to 0.64km) = 26% loss on average
- turbines within 1.8 miles (2.89km) = 25% loss on average

Further potential for loss in property value can occur due to

- wind turbine infrastructure
- high power transmission lines
- substations
- additional traffic for service of wind turbines and power lines
- additional roads

Gardner states that "*Market data and common sense tell us property values are negatively impacted by the presence of wind turbines.*"

Land value issues are also addressed in many of the invited submissions to the Australian Federal Government's 2007 *"Inquiry into developing Australia's non-fossil fuel energy industry in Australia: Case study into selected renewable energy sectors"*. is available online and this report mentions some of the problems and issues with wind energy. The report also outlines other fast advancing renewable energy sources such as solar thermal and geothermal :

http://www.aph.gov.au/house/committee/isr/renewables/report.htm

This inquiry invited numerous Parliamentary Submissions from individuals and organizations, many of which address the negative impacts of industrial wind turbine developments :

http://www.aph.gov.au/house/committee/isr/renewables/subs.htm

Many of the invited submissions address the decline of property values. Submission 90 by the Molonglo Landscape Guardians is also recommended reading for an overview of issues of concern such as wind industry motivations, property value decline, questionable sustainability, and dubious economic benefits. The Tarwin Valley Coastal Guardians submission 7 and 7_1 presents, among others, some of the issues surrounding jobs that never appeared, variability of wind energy supply, noise levels and land value decline.

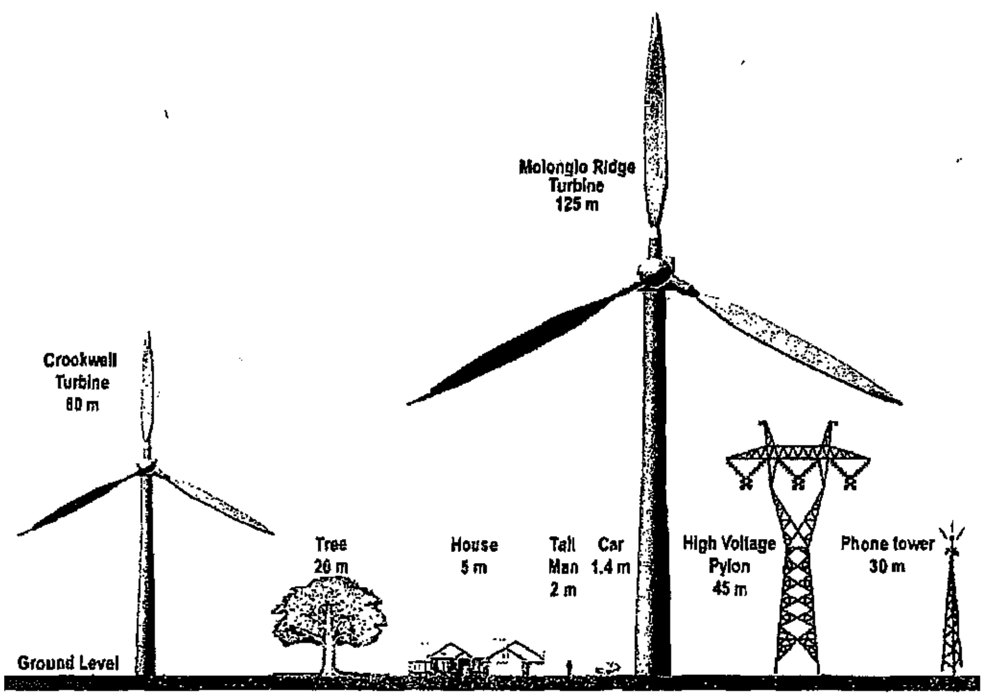
We are also aware of farmers experiencing negative effects on the value of their properties in NSW and Victoria where industrial wind energy developments have been proposed or established in their communities. It should also be noted that property value decline has occurred both during the proposal and contract phase, as well as once turbines are constructed. Decline of property values are noted throughout the 2007 Parliamentary submissions. In pages 14 to 16 of Submission 90 e.g. *"Bruce Richards, managing director of PBE Real Estate in South Gippsland, said that it was nearly impossible to sell a property within one kilometer of a wind turbine or a proposed wind turbine."*

9. VISUAL IMPACT

In terms of the visual impact of industrial wind turbines their size is increasing rapidly, and this has also been part of our decision not to host turbines on our property. As confirmed by our meeting with wind industry developers attempting to sign up land holders, and our knowledge of other industrial wind turbine developments, the areas of leased land hosting turbines and associated infrastructure, access roads, powerlines and substations, cannot be specified with certainty until after the lease agreement has been signed, monitoring has taken place and planning permission granted.

Many NSW landholders are under the impression they know the amount and location of turbines on their properties before monitoring takes place or planning permission sought, **which is clearly incorrect**. Any communication by wind power companies that is not in writing regarding specific siting (or any aspect) is unlikely to be legally binding. Wind industry representatives clearly stated during our meetings that even after the monitoring phase they would not be able to confirm exactly where the developments would be located.

Industrial wind turbine heights have risen from 60m, such as those seen at the original Crookwell site, to the now common height of 125m for 2MW turbines, almost the same height as Sydney Harbour Bridge, with a rotor diameter roughly the size of a 747 jumbo jet. A picture showing the scale of a 2MW 125m turbine is shown below obtained from the Molonglo Ridge Landscape Guardians site (http://www.mlg.org.au).



The current REPower 5MW turbines available for onshore sighting are much larger at 180m tall, almost the height of Canberra's Black Mountain Tower which is 195m, with rotor diameters of 126m. The 5MW turbines have been in use since 2005. Wind industry representatives stated in meetings that they would not be able, nor are they obliged, to stipulate to the landholder the type / size of turbines they may use in the developments.

According to the Zervous paper (mentioned in Section 2 of this submission) on "*Status and Perspectives of Wind Energy*" on page 105 of the IPCC 2008 report *Scoping Meeting on Renewable Energy Sources* and other wind industry documents, turbine heights and diameters continue to grow in size. For 8MW to 10MW turbines rotor diameters alone are estimated to reach 160m, twice the wingspan of an Airbus A380. As every increase in rotor diameter requires an increase in tower (hub) height, these newer turbines will be taller than Canberra's Black Mountain Tower. **How are NSW Government planning regulations addressing these new turbines to protect public health and amenity?**

The rapidly expanding size of wind turbines to obtain higher power outputs clearly demonstrates that as a minimum landholders should expect 125m high 2MW turbines in any development proposal that is currently in progress. For landholders still with contracts in the wind monitoring phase they could be in for a very tall shock. Again this is indicative of the enormous scale and visual impact industrial wind turbines will have in the rural NSW and surrounds. The approved Conroy's Gap development is to contain 15 x 2MW turbines, and the currently under submission Harden / Yass Valley (Coppabella Hills, Marilba Hills, Carrolls Ridge) proposal is for up to 200 turbines of 1.75MW to 3.3MW each.

10. THE GREEN JOBS MYTH & THE RENEWABLES BUBBLE

It is often stated that "green jobs" will be created by industrial wind energy developments. Two important recent studies from the USA and Spain have reported on problems with the strategy to support so-called "green jobs". The recent report "*Study of the effects on employment of public aid to renewable energy sources*" by Dr. Gabriel Calzada, an economics professor at Juan Carlos University in Madrid, demonstrates that for Spain the "green job" has proven elusive and unsustainable. This study is available from : http://www.juandemariana.org/pdf/090327-employment-public-aid-renewable.pdf Some important points from the executive summary are :

"This study is important for several reasons. First is that the Spanish experience is considered a leading example to be followed by many policy advocates and politicians. This study marks the very first time a critical analysis of the actual performance and impact has been made. Most important, it demonstrates that the Spanish/EU-style "green jobs" agenda now being promoted in the U.S. in fact destroys jobs, detailing this in terms of jobs destroyed per job created and the net destruction per installed MW."

"Optimistically treating European Commission partially funded data, we find that for every renewable energy job that the State manages to finance, Spain's experience cited by President Obama as a model reveals with high confidence, by two different methods, that the U.S. should expect a loss of at least 2.2 jobs on average, or about 9 jobs lost for every 4 created, to which we have to add those jobs that non-subsidized investments with the same resources would have created."

"Despite its hyper-aggressive (expensive and extensive) "green jobs" policies it appears that Spain likely has created a surprisingly low number of jobs, two thirds of which came in construction, fabrication and installation, one quarter in administrative positions, marketing and projects engineering, and just one out of ten jobs has been created at the more permanent level of actual operation and maintenance of the renewable sources of electricity."

"This came at great financial cost as well as cost in terms of jobs destroyed elsewhere in the economy."

"The study calculates that since 2000 Spain spent €571,138 to create each "green job", including subsidies of more than €1 million per wind industry job."

"The study calculates that the programs creating those jobs also resulted in the destruction of nearly 110,000 jobs elsewhere in the economy, or 2.2 jobs destroyed for every "green job" created."

"Each "green" megawatt installed destroys 5.28 jobs on average elsewhere in the economy: 8.99 by photovoltaics, 4.27 by wind energy, 5.05 by mini-hydro."

"These costs do not appear to be unique to Spain's approach but instead are largely inherent in schemes to promote renewable energy sources."

"The high cost of electricity due to the green job policy tends to drive the relatively most

energy-intensive companies and industries away, seeking areas where costs are lower."

"The study offers a caution against a certain form of green energy mandate. Minimum guaranteed prices generate surpluses that are difficult to manage. In Spain's case, the minimum electricity prices for renewable-generated electricity, far above market prices, wasted a vast amount of capital that could have been otherwise economically allocated in other sectors. Arbitrary, state-established price systems inherent in "green energy" schemes leave the subsidized renewable industry hanging by a very weak thread and, it appears, doomed to dramatic adjustments that will include massive unemployment, loss of capital, dismantlement of productive facilities and perpetuation of inefficient ones."

"The energy future has been jeopardized by the current state of wind or photovoltaic technology (more expensive and less efficient than conventional energy sources). These policies will leave Spain saddled with and further artificially perpetuating obsolete fixed assets, far less productive than cutting-edge technologies, the soaring rates for which soon-to-be obsolete assets the government has committed to maintain at high levels during their lifetime."

The 97 page University of Illinois Law & Economics Research Paper published in March 2009 authored by Professor Andrew P. Morriss, Professor William T. Bogart, Andrew Dorchak and Distinguished Professor Roger E. Meiners titled *Green Jobs Myths* contains an extensive survey and analysis. They show how the special interest groups promoting the idea of green jobs have embedded dubious assumptions and techniques within their analyses. The paper can be downloaded at : http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1358423

Their abstract states the main points of the study :

"A rapidly growing literature promises that a massive program of government mandates, subsidies, and forced technological interventions will reward the nation with an economy brimming with green jobs. Not only will these jobs improve the environment, but they will be high paying, interesting, and provide collective rights. This literature is built on mythologies about economics, forecasting, and technology.

***Myth:** Everyone understands what a green job is.*

***Reality:** No standard definition of a green job exists.*

***Myth:** Creating green jobs will boost productive employment.*

***Reality:** Green jobs estimates include huge numbers of clerical, bureaucratic, and administrative positions that do not produce goods and services for consumption.*

***Myth:** Green jobs forecasts are reliable.*

***Reality:** The green jobs studies made estimates using poor economic models based on dubious assumptions.*

***Myth:** Green jobs promote employment growth.*

***Reality:** By promoting more jobs instead of more productivity, the green jobs described* *in the literature encourage low-paying jobs in less desirable conditions. Economic growth cannot be ordered by Congress or by the United Nations. Government interference - such as restricting successful technologies in favor of speculative technologies favored by special interests - will generate stagnation.*

Myth: *The world economy can be remade by reducing trade and relying on local production and reduced consumption without dramatically decreasing our standard of living.*

Reality: *History shows that nations cannot produce everything their citizens need or desire. People and firms have talents that allow specialization that make goods and services ever more efficient and lower-cost, thereby enriching society.*

Myth: *Government mandates are a substitute for free markets.*

Reality: *Companies react more swiftly and efficiently to the demands of their customers and markets, than to cumbersome government mandates.*

Myth: *Imposing technological progress by regulation is desirable.*

Reality: *Some technologies preferred by the green jobs studies are not capable of efficiently reaching the scale necessary to meet today's demands and could be counterproductive to environmental quality.*

11. MORE SUSTAINABLE & RELIABLE CONSIDERATIONS

The first chapter of the Proceedings of the 2008 Intergovernmental Panel on Climate Change (IPCC) *"Scoping Meeting on Renewable Energy Sources"* mentioned in Section 2 of this submission, *"Renewable Energy and Climate Change An Overview"* by William Moomaw, discusses and identifies the 3 primary categories of renewable energy sources. The 3 categories are solar, geothermal, and gravitational energy. Solar energy directly provides heat for ocean and land surfaces, drives wind and wave resources, produces biomass and fuels via photosynthesis, and provides energy for the hydrological cycle. Table 1 on page 6 of that paper gives a good overview of the potential of renewable energy sources. The annual flux of global energy use is roughly between 450 and 500 EJ per year. 1EJ = 10^{18} joules. To put this in perspective, the amount of renewable energy available from solar is 3,900,000 EJ per year, for wind it is 6,000 EJ per year and for geothermal it is 140,000,000 EJ per year.

Some important points to consider with electric power, particularly in light of potential climate change effects on infrastructure (as discussed in Section 5 of this submission), are noted on pages 7 and 8 of the IPCC chapter :

"Another important aspect of the cost of electric power production is the transmission and distribution systems. According to IEA, approximately 55% of the capital cost of electric power systems is in the "wires" and only 45% is invested in the generation technology. Hence if on-site, distributed generation is utilized (whether fossil fueled or building integrated solar or renewable technology), the transmission costs are generally zero, and the marginal cost of distribution if grid connected is much lower since most of the electricity is utilized where it is generated. This fact needs to be taken into account when comparing costs of alternatives. There are few studies to date that account for this sizable cost component."

The Fenner School of Environment and Society at ANU has, among many other research areas, an excellent online resource *Sustainable Farms: Pathways for Rural Landscapes* at (http://fennerschool-research.anu.edu.au/sustfarms/).

The Australian Government Department of Resources, Energy and Tourism (www.ret.gov.au/energy/Pages/index.aspx) has recently announced its $500 million Renewable Energy Fund and the $150 million Energy Innovation Fund, $100 million of which is allocated to the establishment of the Australian Solar Institute. There is also an Energy White Paper scheduled for release at the end of 2009 to announce Australian energy policy (www.ret.gov.au/energy/facts/white_paper/Pages/default.aspx).

Australian funding in renewable energy is undergoing rapid change, with the majority of renewable energy funds being directed to solar (photovoltaic panels, solar hot water and concentrating solar thermal power stations). For the latest research in solar see the ARC Centre for Solar Energy Systems at ANU (http://solararc.anu.edu.au/), Solar Energy at ANU (http://solar.anu.edu.au/) and the Centre for Sustainable Energy Systems (http://solar.anu.edu.au/cses.php). The most recent research supported by the Australian Government Department of Resources, Energy and Tourism for storage technologies for solar power stations are $7.4million (www.wizardpower.com.au/) and $5million (www.lloydenergy.com). For the Australian solar industry it is anticipated that this funding will continue to increase in the future.

Recent advances in photovoltaic solar panels in Australia are Sliver Cells (http://solar.anu.edu.au/research/sliver.php), which have been licensed by Origin Energy (www.originenergy.com.au/1233/SLIVER-technology). Other research in solar technology are the flexible printable organic cells being developed at Monash University (http://www.chem.monash.edu.au/solar/index.html) and the Victorian Organic Solar Cell Consortium (http://www.vicosc.unimelb.edu.au/index.html) also reported by ABC TV Catalyst program 23rd April 2009 (http://www.abc.net.au/catalyst/stories/2550612.htm).

Overseas MIT is developing solar concentrators (http://web.mit.edu/newsoffice/2008/solarcells-faq-0710.html). One of the most recent developments in the commercial sector for photovoltaics is from Morgan Solar Inc (http://www.morgansolar.com).

As mentioned earlier in this section the global wind resource of 600 EJ/year demonstrates the paucity of resource globally for wind. Solar thermal and geothermal resources are greater, more cost effective, have less negative impacts and better reliability and predictability. Solar energy advances clearly demonstrate the practicalities of managing Australian electricity resources locally and reliably. Landholders have the opportunity to empower themselves to create their own projects and sell electricity directly into the standard 240v ac mains supply. This enables them to manage their own projects, at their own pace, with minimum stress and negative impacts, without giving up control of their land, without dividing rural communities, whilst making a positive contribution to the environment, creating a new and sustainable industry.

12. CONCLUSIONS

The short and long term problems of industrial wind turbines for the landholder, and surrounding communities is a subject of great concern. We have investigated these issues in order to come to a decision regarding leasing our land for industrial wind turbine developments. We ask that this Inquiry make particular note of the destruction of the local environment and communities, and the loss of ours and others future livelihood and land use, when considering industrial wind turbine development in NSW.

12.1 SUMMARY OF KEY PROBLEMS

A summary of some of the key problems for NSW include :

- wind is a poor, highly variable, intermittent and unreliable resource for electricity generation
- potential landholder liability to 3rd party claims e.g. from neighbouring properties, local community and wind industry contractors / investors
- ongoing legislative changes e.g. planning, tax, emissions trading schemes, carbon credits etc.
- uncertainty regarding number, type and location of turbines
- uncertainty of associated access and infrastructure
- uncertainty of essential future infrastructure requirements, such as wind turbine energy storage devices, maintenance and access issues
- uncertainty of landholder income and the tax liabilities for the landholder
- considerable decommissioning expenses for abandoned projects and turbines, coupled with state regulations regarding decommissioning
- on-selling of leases by power companies
- electricity generated will be fed into the grid and is unlikely to be used by the surrounding community
- uncertainty of construction duration, which may be at least 18 months, 2 years or even longer
- uncertainty of length of time before wind turbine income stream begins, project could easily take 5 years before installation is complete
- meager income from onerous lease before and after wind turbines installed
- construction phase is a period of intense industrial development involving significant disruption to all landholders, neighbouring properties, the environment, local communities and surrounding towns
- ongoing access requirements for wind turbine security, monitoring, maintenance and upgrading
- destruction of environment and environmental monitoring required pre, during and post construction
- ongoing environmental and ecological monitoring of bird and bat fatalities necessitating further access to land, potentially with dog handler teams for carcass recovery without requiring owners permission
- ongoing environmental and ecological monitoring of flora and fauna necessitating further access to land without requiring owners permission
- noise pollution and the need for ongoing monitoring of noise pollution without requiring owners permission
- increased potential for trespassers and vandalism
- increased risk of theft for owners and neighbouring properties

- loss of privacy
- landholders loss of rights of complaint after signing lease agreement
- landholders loss of rights of disclosing any negative impacts after signing lease agreement
- loss of rural night sky views and sleep due to high visibility aviation warning lights for entire local community
- additional structures specifically to warn aviation of true height of turbines blade tip because height has to be indicated by stationary structures
- loss of ability for light aircraft to fly in vicinity of turbines for safety reasons, resulting in a diminished service for rural communities
- reduction in rights for landholder regarding wind turbine sighting after signing lease agreements e.g. participating properties have to tolerate higher noise levels from wind turbines than non-participating properties, which equates to closer sighting of turbines to dwellings
- restrictions on landholder and neighbours future land use with or without turbines being erected
- decline in property values for wind turbine hosts, neighbouring properties and wider community in vicinity of development
- irreparable destruction of environment and ecology through destruction and fragmentation of wildlife habitat
- unnecessary community divisions and loss of amenity for stakeholders and non-stakeholders
- loss and destruction of environmental, familial and cultural heritage

These are just some of the many concerns we have considered from a landholders point of view when considering industrial turbine wind energy lease agreements, irrespective of our more detailed environmental and other areas of concern.

Our conclusion is that there are far too many financial, legal, health and environmental risks for the landholder, for surrounding communities and for NSW to make industrial wind turbine development worthwhile. The only certainty from such a development within rural communities is the bitter and counter productive divisions of those rural communities. To commit unknown parts of our property to an onerous lease, drawn up by an uninvited tenant in a tenant oriented manner seems unwise. Such a lease with its intended development would restrict both our and our neighbours future rural land use. In addition, the rapidly advancing technology of other renewables, climate change predictions, volatile economic climate, ongoing debate of "true" carbon costs for wind energy and other variable / intermittent renewables requiring fossil fuel backup, and shifting government policies surrounding these issues, produces more uncertainty. Committing to a long term agreement with the wind industry would therefore be a bad business decision for us, our neighbours and our community.

Further large scale industrial wind turbine power plant developments in our rural NSW communities would have a major detrimental impact to our current and future business, research, lifestyle and investment activities.

The issues surrounding industrial wind energy development are broad and wide ranging. We have only briefly covered some of the issues of concern in this submission, in **particular the failure of industrial wind to have any significant impact on greenhouse gas reduction as evidenced by numerous studies, and their inability**

to replace any fossil fuel power stations. Other issues such as flora and fauna biodiversity, community consultation, land use, archeological, traffic / transportation, cultural heritage and fire risk due to industrial wind power station development are therefore issues of significant concern. **Is this really the legacy we want to leave for our children?**

12.2 SOME UNANSWERED QUESTIONS

There are many unanswered questions that industrial wind energy poses for Australia. For example :

- **What watchdog or committee is continually assessing whether wind power stations are living up to their promises?**
- **Who is assessing the ongoing environmental impacts on flora and fauna once these installations are built?**
- **Why are industrial wind turbine power station developments being allowed in vulnerable and endangered ecosystems in NSW, such as Box Gum Grassy Woodlands? (As noted in recent Federal Government "Caring for Country" publications conventional farming is already putting significant stress on such ecosystems.**
- **Who is assessing whether the electricity output of these wind power stations is living up to the original claims of the developers?**
- **How many fossil fuel power stations have been decommissioned in Australia as a direct result of displacement by existing wind power stations?**
- **How many fossil fuel power stations are expected to be decommissioned in Australia as a direct result of the currently proposed wind power station developments?**
- **Who is assessing what, if any, greenhouse gas reduction benefit wind power stations are producing and how close are they to the developers claims?**
- **What studies are to be conducted in Australia to assess whether peoples health have been affected by wind power stations?**

These unanswered questions must be addressed prior to any further rubber stamping and fast tracking of industrial wind turbine power station developments in NSW.

12.2 INDEPENDENT WEB RESOURCE ON INDUSTRIAL WIND ENERGY

We recommend visiting the Industrial Wind Action (IWA) Group website (www.windaction.org) which is a quality worldwide resource on industrial wind energy issues. As well as providing a continually updated web based resource the IWA are considered professionals who advise officials at federal, state and local levels to counteract misleading information from the wind energy industry.

The recent invited presentation by IWA Executive Director Ms Lisa Linowes at the 2009 Midwest Energy Conference in Chicago, USA (March 4-5) is an informative overview of the technical problems of large-scale wind turbine integration into the electricity grid : (http://www.windaction.org/documents/20337)

A subscription to the IWA news feed (www.windaction.org/subscribe) is a particularly constructive resource, as it compiles news stories and opinion from around the world. These news stories and academic research papers demonstrate that there are many negative impacts from industrial wind turbine developments, and around the world these detrimental impacts consistently outweigh the very few (if any) positive impacts.

IWA's *Important Docs* section (http://www.windaction.org/?tab=topdocs) contains a number of peer reviewed documents from internationally recognised journals and conferences, as well as working papers by academics, medical doctors and industry professionals. These documents address many concerns regarding industrial wind energy and also provide cautionary information on lease agreements / easements between landholders, neighbouring / nearby properties and industrial wind energy companies.

12.3 RENEWABLE ENERGY STRATEGIES

The governments renewable strategy is based on targets for quantities of energy that are unknown. Again the REF in the UK makes this quite clear and in a briefing note in response to the UK governments 2009 strategy the issues are made quite plain. This briefing note, published on 27-07-09 is available from
http://www.ref.org.uk/PublicationDetails/54

This briefing note is highly relevant to this inquiry and some selected comments are included below (bold emphasis is theirs) :

"It should be noted this target is focused specifically on obtaining quantities of energy and does not bear directly on green house gas emissions reductions targets, though it is related at one remove with climate change policy.

"In the following discussion we show that, regrettably, the UK Government is probably mistaken with regard to the size of the target. This error arises since the target is 15% of an unknown quantity, namely Final Energy Consumption in 2020. In our view Government estimates of FEC in 2020 are overly optimistic. The potential error is large, and ***the target will probably be around 20% greater than that for which the government is planning****. This has significant implications for feasibility and cost."*

"REF noted that since energy consumption would probably increase Government was almost certainly underestimating the target magnitude. REF pointed out that in some EU data sets Final Energy Consumption was predicted to rise to around 185 mtoe, an increase of over 23% on current levels. This scenario is not addressed in the Renewable Energy Strategy."

At the lower levels Government admits that these targets will be very difficult to achieve. At the higher levels they are almost certainly infeasible. Indeed, there are reasonable doubts about the attainability of the lower quantities. For example, the levels of wind currently suggested (upwards of 25 GW) as necessary for the lower target would confront the UK with unprecedented balancing and grid management problems..."

"REF concludes that ***the Government's Renewable Energy Strategy is extremely and heroically optimistic about the scale of the targets, and so almost certainly underestimates the risks, the difficulties and the costs facing the UK."***

"So the Renewable Energy Strategy would deliver annual savings of 7% of UK

emissions and just 0.1% of current world emissions at extreme costs, and additional fiscal strain on already fragile economy. Clearly, this is not a good bargain, and reinforces the point we have often made that renewables are poor emissions reducers, whatever other virtues they might have."

"This is particularly disappointing since the UK's role in global climate change policy is to provide an economically compelling example, rather than any quantitatively significant contribution. At present our policy is unlikely to provide a constructive lead to any state in either the developing or developed world."

"For example, subsidised and mandated wind power on the scales currently contemplated by government will impair the economics of other plant but fail to provide compensating value. Investors in the still indispensable firm capacity needed to meet peak load (60 GW at 5.30 on a winter's day) will have no option but to minimise their risk by seeking the least capital intensive generation, which is gas-fired."

*"...in the electricity sector **the very aggressive wind policy (26GW of installed capacity) will ensure that for economic and technical reasons no other generation capacity except gas can be built, thus deepening and compounding UK gas dependency rather than alleviating it."***

"In other words, the Renewable Energy Strategy effectively makes capital intensive but high efficiency coal and nuclear infinitely too risky for investors, who will reduce their exposure by selecting the least capital intensive plant available, namely gas-fired generators, or, as is already apparent, scaling back investment in the UK altogether."

*"It must be emphasised that **contrary to Government assertions the renewables policy is a gas policy in disguise."***

*"... **renewables on the irrational and politically driven scale outlined in the Renewable Energy Strategy will become a dangerous liability**. Distressed and painful policy corrections are inevitable."*

We thank you for taking the time to consider our submission.

Sarah Last and David Burraston

Impact of wind farms on the value of residential property and agricultural land

An RICS survey

Background

In the past century, the global average temperature has increased by approximately 0.6 °C while sea levels have risen by 10 – 20 cm. Climate change, as described by the UK's Prime Minister, is "the most important environmental issue facing the world today". There is a broad scientific consensus that the acceleration in the rate of climate change is due largely to the emission of greenhouse gases such as carbon dioxide (CO_2) and methane.

The UK government has ratified the Kyoto Protocol and is committed to reducing carbon dioxide emissions by 20% by 2020. To achieve this target, the UK government published the Energy White Paper[i] in February 2003 and recommended that 20% of the UK's electricity should be generated by renewable energy by 2020. To pave the way for this the Government updated planning advice (Planning Policy Statement 22) on renewable energy earlier this year. One of the major components of its strategy is an increase in wind-generated energy.

As the windiest country in Europe the UK is uniquely well placed to exploit this form of renewable energy. According to the British Wind Energy Association (BWEA), there are currently 90 wind farm projects in operation in the UK, adding up to a total of 1125 turbines and supplying enough energy for 440,000 homes. 15 projects are due to come online in 2004, adding a further 222 turbines. By 2005, it is predicted that the total installed wind energy generators will be enough to meet 1.3% of total supply (i.e. just under 1 million homes).

Whilst wind farm technologies offer many advantages, questions are being asked about the potential impact of this expansion on property values, particularly in the residential sphere. In order to examine whether there is any substance in these concerns, and to monitor the effects on land and residential property affected by wind farm developments, RICS (The

Royal Institution of Chartered Surveyors) has carried out an initial study to examine the impact of wind farm development. The purpose of the study is not to endorse or criticise wind technology, but rather to gauge professional property opinion about its impact on both residential property and agricultural land values.

Executive Summary

- 60% of the sample suggested that wind farms decrease the value of residential properties where the development is within view

- 67% of the sample indicated that the negative impact on property prices starts when a planning application to erect a wind farm is made

- The main factors cited for the negative impact on property values are:
    - visual impact of wind farm after completion
    - fear of blight
    - the proximity of a property to a wind farm

- Once a wind farm is completed, the negative impact on property values continues but becomes less severe after two years or so after completion

- A significant minority of surveyors with experience of residential sales affected by wind farm developments (40%) indicated that there is no negative price impact

- Only 28% suggested wind farm development negatively influences the value of agricultural land, while 63% suggested there is no impact at all (either positive or negative). The remaining 9% suggest a positive impact

- The survey suggests that wind farms do not impact on residential property values in a uniform way. The circumstances of each development can be different

- This report points to a need for further research to track the impact of wind farms and to examine in particular whether the nature of any adverse impact diminishes as wind farms become an increasingly familiar part of the rural scene.

Research methods

RICS conducted an initial questionnaire-based survey among its members at the beginning of September 2004. At the time of sampling for the survey, there were no onshore wind farm developments in the South East region connected to the national grid. This region was therefore excluded from the study. A total of 1,942 questionnaires were sent out and 405 responses received. Approximately a fifth of those persons responding say they have dealt with residential transactions affected by wind farm developments.

The study focused on those responses from surveyors with experiences of transactions affected by wind farms, analysing the data at both national and regional levels (i.e. five regions: Scotland, Wales, Midlands & Eastern Regions, Northern England and South West)[ii]. RICS conducted a follow-up survey with this specific group of respondents in October 2004 on the reasons behind any price impact. The response rate for the follow-up survey was 34% and therefore only national results are provided for this part of the survey.

Survey results

Experience of Chartered Surveyors in transactions affected by wind farms

Only 20% of the surveyors who responded to this survey have dealt with transactions affected by wind farms and their experiences vary.

In interpreting the results of the survey no attempt has been made to make a quantitative assessment of the impact of wind farm developments on the residential property market. The sample size of responses at a regional level is low and the distribution of responses by region in the main reflects the concentration of wind farms in particular locations around the country.

The largest responses were received from Scotland and Wales (representing 25% and 20% of the sample that have dealt with wind farm affected transactions respectively). Information obtained from the BWEA website (www.bwea.org) indicates that Scotland and Wales account for 43% of all wind farm projects in the UK. We have used information from the BWEA regarding the regional distribution of wind farms to derive weightings for the national results.

Impact of wind farms on the value of residential property and agricultural land

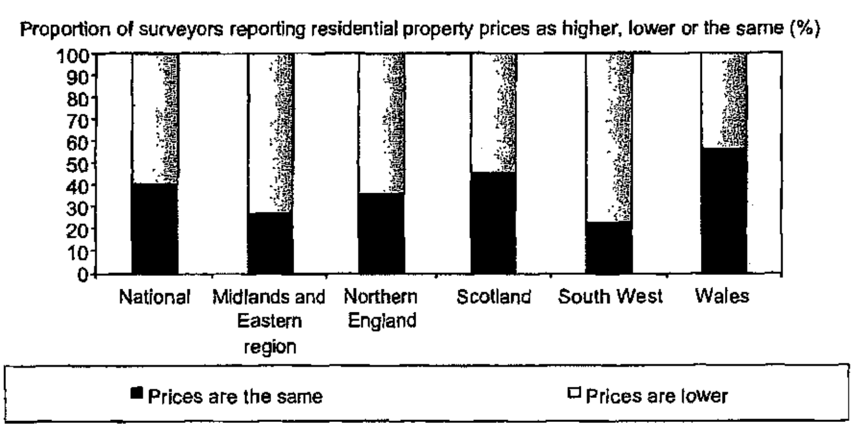
Actual effect

The findings suggest three effects of wind farms on the value of residential property and agricultural land:

- there are negative influences on the value of residential properties, though a sizeable minority report no impact on prices
- the influence is much less on agricultural land values, to the point that the majority of responses suggested the impact was nil
- nowhere is it considered that wind farms positively affect residential property values, although there was evidence of some positive impact on agricultural land

More than half (60%) of those surveyors involved in residential property transactions affected by a wind farm development (i.e where a wind farm is visible from the property), reported that values were lower than for comparable properties which were unaffected (Figure 1). However, this still leaves a sizeable minority of 40% of surveyors reporting no impact from wind farm developments on values.

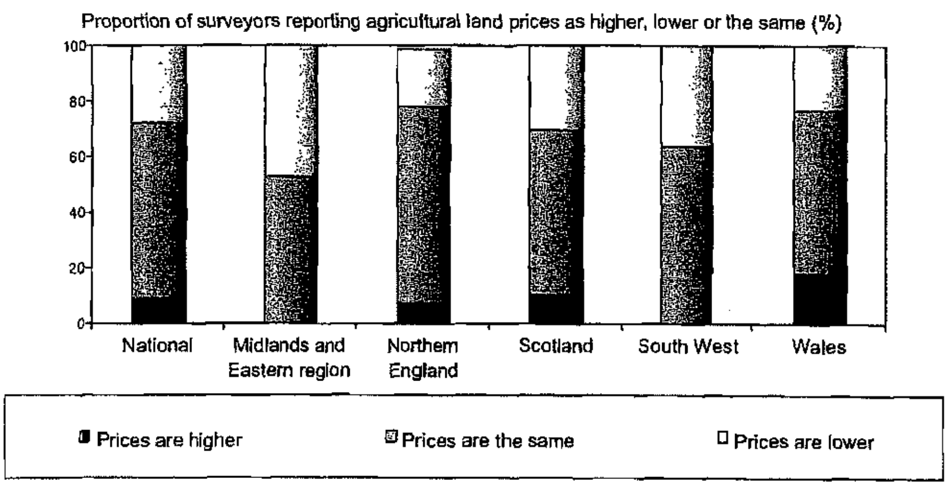
Figure 1 : Impact of wind farms on residential property values relative to comparable properties which are not affected



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.

Separately, we asked surveyors what impact wind farm developments had on agricultural land values. Of the sample, 28% indicated that wind farms have a negative impact on the value of agricultural land, whilst a majority (63%) suggest there is no impact. A small proportion, (9%) indicated that wind farms enhanced agricultural land values (Figure 2).

Figure 2 : Impact of wind farms on agricultural land values relative to comparable land which is not affected

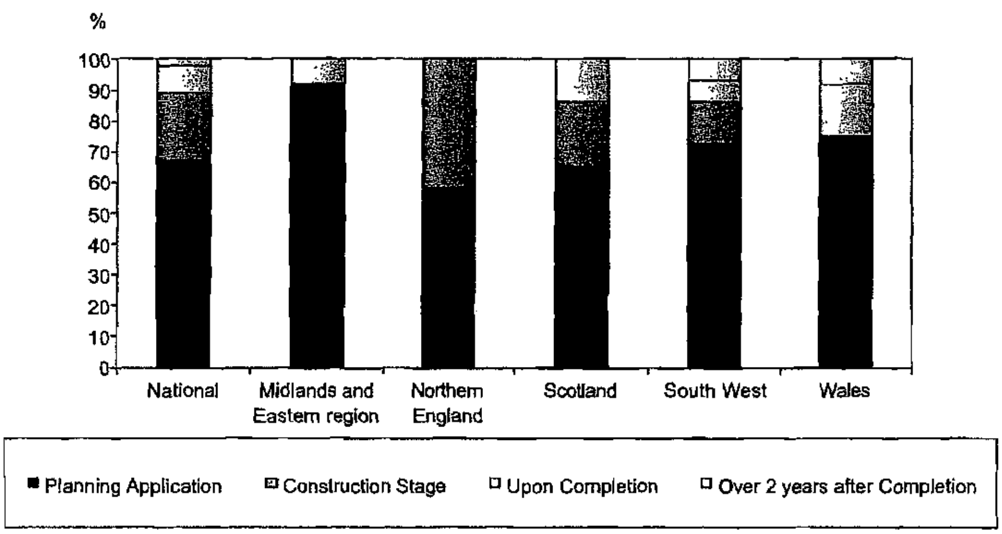


At what stage do wind farm developments start to impact on property values

For those surveyors who believe that residential property values are lower as a result of wind farm developments, a majority (67%) believe that there is an impact on values as early as the planning application stage. A further 22% report that the impact is first evident at the construction phase of development (Figure 3).

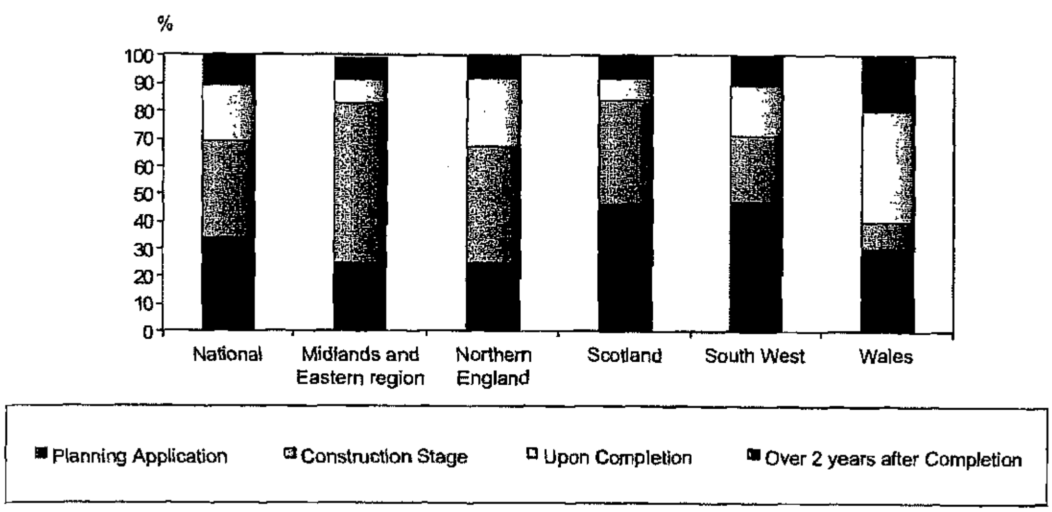
The results suggest that buyers are wary of potential developments at a very early stage in anticipation of a negative impact because of uncertainty over the size and location of a proposed wind farm.

Figure 3 : At what stage do wind farm developments start to negatively influence the value of residential property relative to unaffected comparable properties



The survey also asked at what point in time the negative impact of wind farm developments on residential property values is the greatest. Whilst the results highlight significant variations between the regions, from a national perspective the greatest impact comes at the planning application and construction stages (Figure 4). The results imply that the discount in property values (relative to comparable properties which are unaffected) reduces over time as buyers become aware of the specific characteristics of a development.

Figure 4 : At what stage do wind farm developments have their greatest influence on the value of residential property compared to property which is not affected



Reasons for the impact of wind farms on the value of residential property values

A follow-up survey asked surveyors who reported that wind farm developments had a negative impact on property values, to assign a degree of importance to various factors which may explain the existence of a price discount (Figure 5). Some of these factors may not be mutually exclusive but provide a guide to issues which may be impacting upon the market.

The most important reason for a negative impact of wind farms on the value of residential property is the visual impact after completion, closely followed by the fear of blight. The proximity of a property to a wind farm is also deemed fairly significant. The size of a wind farm is viewed as less important than the above issues, though its impact is likely to depend upon the distance from the development.

Figure 5: Reasons for negative impact on residential property values from a wind farm development

	Scale of 1-5 of importance; 1 = least important, 5 = most important					
% response for each issue	**1**	**2**	**3**	**4**	**5**	**Don't know**
Fear of blight	11	0	17	11	56	6
Construction disturbance	22	17	22	28	6	6
Visual impact after completion	11	0	11	21	58	0
Size of wind farm	6	18	35	6	35	0
Proximity to wind farm	11	22	6	11	50	0
Other environmental damage	25	31	19	6	6	13
Health risk	36	21	7	21	0	14

NB: figures may not sum up to 100% due to rounding errors for each issue

Conclusion

- The wind farm industry is still relatively new compared to other renewable energy industries. The number of surveyors who deal with property affected by wind farms will always be relatively low

- Among those respondents with experience in dealing with residential property transactions affected by wind farms, the survey results suggest that wind farm development reduces property values to some extent and that this impact starts at the planning application stage

- 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

- A significant minority of surveyors (40%) reported no impact from wind farm developments on residential property values

- 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 a more established part of the rural landscape

- There is a need for more work to provide a better understanding of the way in which wind farms impact on property, thereby enabling strategies to be developed to minimise any deleterious effects

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[i] DTI (2003) Our Energy Future – Creating A Low Carbon Economy. Energy White Paper, www.dti.gov.uk/energy/whitepaper

[ii] Surveyors in Northern Ireland were included in the questionnaire survey, but due to the low response rate, the analysis did not cover Northern Ireland.