WR - DEIS
Public Comment #317

Energy Facility Site Evaluation Council
905 Plum Street SE
P.O. Box 43172
Olympia, WA 98504-3172

RECEIVED
JUL 16 2010
ENERGY FACILITY SITE
EVALUATION COUNCIL

July 15, 2010

Dear Council Members/BPA Representatives:

In our testimony of May 6, 2009 we specifically requested that three issues be directly addressed within the scope of the proposed Whistling Ridge Energy Project EIS. **The current draft EIS does not adequately address the three issues.**

First,
The draft EIS utterly ignores the strongly recommended and extremely useful "The 'How To' Guide To Siting Wind Turbines To Prevent Health Risks From Sound" (authors: George W. Kamperman and Richard R. James, October 28 2008... *we have attached this once again for your convenience)* a version of which was prepared and provided by the authors specifically for EFSEC's consideration. It provides an ecological and scientifically sound approach, which will minimize the likelihood of detrimental impact when industrial wind turbines are to be sited near people's homes.

The draft EIS offers no assurance that Whistling Ridge wind turbine siting will preserve a resident's right to enjoy the current peace and tranquility of his/her homesite. More importantly, the potential negative impacts to a resident's health and well-being are **not** adequately mitigated.

Mr. Richard James, an acoustical engineer, provided **credible testimony** (source provided you in May 2009 material) **that wind turbines generate a type of noise that is not adequately measured by the dBA scale used in the Washington state noise standards.** The dBA scale is designed to detect noises audible to humans. Wind turbines generate low-frequency noise (20Hz or lower) that might cause the body to resonate even if it is not audible. **Such effects are measurable on the C-weighted scale (dBC).**

Your draft EIS dismisses the C-rated scale as insignificant and we quote: "The turbine sound power level manufacturing ratings show C-weighted levels are within 2dB of A-weighted levels. Therefore, low-frequency noise is not anticipated to be an issue for this project"(page 3-130 draft EIS). If this is factual (which cannot be verified given that the data below 31.5 Hz was not provided in the draft EIS) it would only measure 2 decibels difference at the source (wind turbine). **The problem with this rationale has been scientifically proven.** The difference at the affected homesites would be substantial, as the lower-frequency vibrations (dBC) travel greater distances than the higher dBA frequencies, attenuating at approximately half

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the rate of the higher frequencies. **Thus, when you reach the homesites, the dBC values will be roughly 20 dB higher than the dBA values** *(see page 7, Kamperman and James)*. Further, the lower-frequency noise easily penetrates home structure, while the higher frequencies are somewhat attenuated by home structure, thus inside the home the difference between the dBA and dBC scales will be even greater *(see page 11-12, Kamperman and James)*. **This is why it is necessary to use the C-weighted scale in addition to the A-weighted scale.**

Even your cited expert G. Leventhal questions current measurement techniques in *Low Frequency Noise. What we know, what we do not know and what we would like to know, Journal of Low Frequency Noise, Vibration and Active Control, Vol. 28, Number 2, 2009:*

> "Does the way in which we measure low frequency noise hide some of its disturbing characteristics?" *(p. 98)*
>
> "Unfortunately, conventional methods of dealing with environmental noise stressors are A-weighted, which means that the presence of disturbing low frequency noise may not be detected...chronic psychophysiological damage may result from long-term exposure to an audible low-level low frequency noise, which is left uncontrolled, despite complaints." *(p. 95)*

Earlier in the draft EIS, before dismissing the need to use the C-rated scale you state, "C-weighting is often used to assess potential annoyance due to low-frequency noise that may excite vibration in structures" (p. 3-115). This is exactly what happens!

Quoting yet another of your cited experts G.P. van den Berg from *Do wind turbines produce significant low frequency sound levels?, presentation at 11th International Meeting on Low Frequency Noise and Vibration and its Control, Maastricht, The Netherlands, 30 August to 1 September 2004:*

> "Although infrasound levels from large turbines at frequencies below 20 Hz are too low to be audible, they may cause structural elements of buildings to vibrate... Perceptible vibrations of windows may occur at frequencies from 1 to 10 Hz... sound pressure levels above 60 dB at frequencies below 10 Hz occur close to a turbine as well as at 750 m distance and further." *(p. 7)*

This has been validated by the research of S.S. Jung, W. Cheung, C. Cheong and S. Shin, *Experimental Identification of Acoustic Emission Characteristics of Large Wind Turbines with Emphasis on Infrasound and Low-Frequency Noise, Journal of the Korean Physical Society, Vol. 53, No. 4, October 2008.*

> "...we found that the low-frequency noise of the 1.5 MW... wind turbines in the frequency range over 30 Hz would very likely lead to psychological complaints from ordinary adults and that the infrasound in the frequency range from 5 Hz to 8 Hz would very likely lead to complaints about rattling house fittings, such as doors and windows."

We strongly feel the .38-mile set back from the nearest residence is woefully insufficient. This is especially true in this area of canyons, bowls, and mountains, as

the terrain will contain, reflect and transmit the sound from the wind turbines greater distances than in typically used flatter terrain. The simplistic sound modeling and the limited collected data used in this draft EIS result in an **inaccurate** depiction of likely impact. (Decibel levels exceeding predictions has been documented by M.A. Nissenbaum at Mars Hill, 2010 and G.B. van den Berg 2006 in his work at the Rhede Wind Farm).

Again, we request that potential noise (dBA) and low-frequency (dBC) impacts be thoroughly investigated through valid baseline measurements and cutting edge computer simulations that will accurately depict for this mountainous area the sound emissions produced in worst case conditions, such as recommended by Kamperman and James, 2008. This would include ambient sound monitoring on all residential properties within and up to 2 miles of the project property boundary.

Prospathopoulos, J. M. and Voutsinas, S. G.'s work *(Application of a ray theory model to the prediction of noise emissions from isolated wind turbines and wind parks... in Wind Energy, Volume 10 Issue 2, Pages 103 – 119, published online: 6 Dec 2006, John Wiley & Sons, Ltd.)* **proves** that the simple computer model employed in this draft EIS prediction is inadequate. **"In cases of complex terrain... simple projection models are no longer valid."**

The need for using more complex computational models than the ones employed for this draft EIS is well-documented by the U.S. Department of Energy Workshop Report: Research Needs for Wind Resource Characterization, Technical Report NREL/TP-500-43521, June 2008 *(Jointly sponsored by DOE Office of Science, Office of Biological and Environmental Research and DOE Office of Energy Efficiency and Renewable Energy, Wind & Hydropower Technologies Program).*

> "Models routinely under-predict power performance likely due to; a misrepresentation of the vertical wind speed and turbulence profile, a lack of understanding of the impact of complex terrain on flow, fundamental errors in modeling of ray effects/wind turbine wakes and/or a combination of these effects" *(page 38).*
>
> "The utility in models... that are based upon linear formation... falls off rapidly when applied in relatively steep terrain or if the weather fluctuates much. Several non-linear formations have been developed... that allow for turbulence prediction in steeper terrain" *(page 47).*

In studying your draft EIS, we determined it does not demonstrate that any additional sound measurements were even conducted. It appears the limited data originally gathered by the SDS consultant was the only information utilized. **An Independent Qualified Acoustical Consultant (unbiased third party**

with no financial or other connection to SDS or related companies) should have performed (not just reviewed what was provided) all sound monitoring, simulations and projections.

It appears that no actual sound monitoring was conducted at any of the three closest residences. It is not depicted in the draft EIS and we must necessarily assume it was not done. "Measurement Location 2" sound monitoring appears to have been measured almost 2 miles distant from the affected residence. "Measurement Location 1" sound monitoring appears to have been measured approximately a ½ mile distant beyond both the planned and the current residence closest to the wind turbines. No dBC scale measurements were conducted at all.

Applying Kamperman and James methodology to even the current SDS application noise data for receiver ID3 (the closest residential property), shows that the noise level would increase from **26 dBA** (using Kamperman and James recommended L_{90}, rather than the L_{eq} depicted in draft EIS *Table 3.7–4*) **to 42-plus dBA** during nighttime operation *(draft EIS Table 3.7–9)* ...**an increase in excess of 16 dBA. This considerably exceeds (by more than 3 times) the 5 dBA recommended by Kamperman and James, as well as the Government of South Australia EPA Protection Authority Environmental Noise Guidelines** *(see attached)*, **in preventing health risks!** Further, it exceeds the 10 decibel EPA guidelines and is thereby considered "serious and warranting close attention". A 10 dB increase almost always causes adverse community response *(page 14 of the "How To" guide).*

This is a more accurate depiction of what people will be subjected to at 2 a.m. (when attempting to sleep) than what is presented in this draft EIS.

The need for the draft EIS to more accurately represent nighttime ambient background noise level is further supported by the U.S. Department of Transportation "Transit Noise and Vibration Impact Assessment", May 2006 (Chapter 5: General Noise Assessment, pages 5-14 & 15)...

> "In areas away from major roadways, noise from local streets or in neighborhoods is estimated using a relationship determined during a research program by the U.S. EPA.(2) EPA determined that ambient noise can be related to population density in locations away from transportation corridors, such as airports, major roads and railroad tracks, according to the following relation: $Ldn = 22 + 10\log(p)$ (indBA) where p = population density in people per square mile."

In the USDOT document **Table 5-7, Estimating Existing Noise Exposure for General Assessment,** it shows that the estimated *Leq* for nighttime is **25** decibels for a population density of 1–100 per square mile. The closest homesites certainly fall within this category. Given that the draft EIS did not include measurements at the closest residences, **a figure of 25 dB as estimated by EPA must be used**, rather than the convoluted and inaccurate estimate of 34-35 dB depicted in the draft EIS *(Table 3.7-9, page 3-128)*.

The draft EIS computer prediction model (Cadna/A) depicts on Table 3-7.7 that wind turbines were treated as "point" source with no information provided to suggest that the computer simulation treats each array as a "line" source – even though they are arrayed in a line. "Point" sources attenuate (drop) at a rate of 6 dB per doubling of distance. "Line" sources attenuate (drop) at a rate of 3 dB per doubling of distance. **There is ample scientifically proven evidence both from:**

NASA studies *(Prediction of the Far Field Noise from Wind Energy Farms, Shepherd, K. P. and Hubbard, H.H 1986, NASA-CR-177956)*

> "At intermediate distances the array acts like a line source for which the theoretical decay rate is 3 dB per doubling of distance or 10 dB per decade. Only at the extreme distances, greater than one row length or 900 m, does the decay rate approach the single source value of 6 dB per doubling of distance or 20 dB per decade"; *(page 4)*

and van den Berg's 2006 thesis *(The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise, Rijksuniversiteit Groningen)*, cited in your draft EIS, that demonstrates wind turbines arrayed in a line, as they are projected to be at the Whistling Ridge site, may operate as a "line" source.

This phenomenon is a well-documented fact by the US Department of Transportation *(May 2006 – Transit Noise and Vibration Impact Assessment)* that individual cars traveling on a highway can be treated as a "point" source, while multiple cars traveling in a line have to be treated as a "line" source. The same is true of railcar transportation. (That is why sound barriers are erected on heavily traveled highways – to protect nearby residents.)

We want to state this clearly. The draft EIS leads people to believe that the sound from the line of wind turbines will drop at a rate of 6 dB. *"As a general rule, at distances greater than 50 feet from a noise generator such as a wind turbine, SPL drops at a rate of 6dB with each doubling of distance."(Page 3-114).* This, in our opinion, **is inaccurate for wind turbines arrayed in a line on a ridge in mountainous, bowled and irregular terrain.** We feel the negative sound impact to be experienced by this community's residents **is grossly underestimated.**

The only way to mitigate this impact is to set the wind turbines back further from the closest non-participating properties.

The "How To" Guide referenced above clearly articulates how to go about setting such standards. Simple reliance on the Washington State Environmental Noise Levels, Chapter 173-60 WAC (enacted 35 years ago, before large industrial wind turbines were even developed), is not enough. The acoustical experts' "How To" Guide approach is to locate a wind turbine so as **to not increase preconstruction/operation background sound levels by more than 5 dBA along the property lines of the receiving non-participating property. And, such that it would not exceed a total of 35 dBA within 100 feet of any occupied structure.** (Page 15) Additionally, we refer you to the low-frequency sound limits also depicted on page 15. *NOTE: In previously provided expert testimony, Mr. James recommended* ***a minimum distance of 1.2 miles*** *between turbines and residences.*

Again, we reiterate that if industrial wind turbines are as "quiet" as represented, setting enhanced noise standards or requiring the meeting of standards used just across the river in Oregon should provide no difficulty for developers to meet. You now have an opportunity to make a strong statement illustrating BPA's and EFSEC's commitment to safeguarding the health of Washington's residents.

We formerly provided as part of our May 6, 2009 testimony, documentation of potential health risks from sound:

> *"Deputation (by Dr. Robert McMurtry M.D., F.R.C.S (C), F.A.C.S)* to the Standing Committee on General Government Regarding Bill C-150 April 22, 2009 www.wind-watch.org/documents/wp-content/uploads/mcmurtry-deputation-to-standing-committee.pdf); a news release (March 4, 2009 www.windaction.org/documents/20306) from the Medical Staff of Northern Maine Medical Center regarding "Health Concerns and the Need for Careful Siting of Wind Turbines"; *"Wind Turbine Syndrome A Report on a Natural Experiment" published by K-Selected Books;* and work of New York physician Nina Pierpont M.D., Ph.D. at www.windturbinesyndrome.com..

In late February 2009 the Office of Energy Security (OES), *[the equivalent to Washington's EFSEC]*, requested that the Minnesota Department of Health (MDH) **evaluate the possible health effects associated with low frequency vibrations and sound arising from large wind energy conversion systems to assist them in guiding decision-making for future wind energy projects.** MDH produced a **26–page white paper "Public Health Impacts of Wind Turbines"** on May 22, 2009 *(attached).*

The following quotes are a summary (of the 26-page white paper) with excerpts of salient points especially applicable to the draft EIS. **We feel** you must give serious consideration and take appropriate action in adequately addressing the environmental and health issues of the proposed Whistling Ridge Energy Project. *NOTE: Underlining that follows is our emphasis.*

Health Issues

"Noise originates from mechanical equipment inside the nacelles of the turbines (gears, generators, etc.) and from interaction of turbine blades with wind. ... The most problematic wind turbine noise is a broadband "whooshing" sound produced by interaction of turbine blades with the wind." *(Page 6)*

"The NRC (National Research Council of the National Academies) also notes that effects of low frequency (infrasound) vibration (less than 20 Hz) ... have been asserted to disturb some people." *(Page 6)*

Sound

"... low frequencies are not effectively attenuated by walls and windows of most homes or vehicles. (For example, one can typically hear the bass, low frequency music from a neighboring car at a stoplight, but not the higher frequencies.)" *(Page 9)*

"Rhythmic, low frequency pulsing of higher frequency noise (like the sound of an amplified heart beat) is one type of sound that can be caused by wind turbine blades under some conditions." *(Page 9)*

"The World Health Organization (WHO, 1999) suggests that A-weighting noise that has a large low frequency component is not reliable assessment of loudness." *(Page 11)*

Noise From Wind Turbines

"Aerodynamic noise from a wind turbine may be underestimated during planning. One source of error is that most meteorological wind speed measurements noted in wind farm literature are taken at 10 meters above the ground. Wind speed above this elevation, in the area of the wind turbine rotor, is then calculated using established modeling relationships. In one study... it was determined that the wind speeds at the hub at night were up to 2.6 times higher than modeled. Subsequently, it was found that noise levels were 15 dB higher than anticipated." *(Pages 11-12)*

"Rhythmic modulation of noise, especially low frequency noise, has been found to be more annoying than steady noise." *(Page 12)*

"Horizontal layers with different wind speeds or directions can form in the atmosphere. ... called shear. If the winds at the top and bottom of the blade rotation are different, blade noise will vary between the top and bottom of blade rotation, causing modulation of aerodynamic noise. *(Page 12)*

"... additional noise, or thumping, may occur as each blade passes through the transition between different wind speed (or wind direction) areas." *(Page 13)*

"... in the nighttime the atmosphere can stabilize (vertically), and layers form. .... Consequently, blade noise would be greater at night." *(Page 14)*

"A number of reports ... suggest that aerodynamic modulation is typically underestimated ... that detailed modeling of wind, terrain, land use and structures may be used to predict whether modulation of aerodynamic noise will be a problem at a proposed wind turbine site." *(Page 14)*

"... noise from a wind turbine farm may be greater than noise from the nearest turbine due to synchrony between noise from more than one turbine..." *(Page 14)*

Impacts of Wind Turbine Noise

"Some people are more sensitive to low frequency noise. The difference, in dB, between soft (acceptable) and loud (annoying) noise is much less at low frequency..." *(Page 16)*

"Two studies in Sweden... showed... when noise measurements were greater than 40 dB(A), about 50% of the people surveyed (22 of 45 people) reported annoyance. When noise measurements were between 35 and 40 dB(A) about 24% reported annoyance (67 of 276 people). Noise annoyance was more likely in areas that were rated as quiet and in areas where turbines were visible. In one of the studies, 64% respondents who reported noise annoyance also reported sleep disturbance; 15% of respondents reported sleep disturbance without annoyance." *(Page 17)*

"... reports have catalogued complaints of annoyance and some more severe health impacts ... The most common complaint is decreased quality of life, followed by sleep loss and headache. Complaints seem to be either from individuals with homes quite close to turbines, or individuals who live in areas subject to aerodynamic modulation and, possibly, enhanced sound propagation which can occur in hilly or mountainous terrain." *(Page 18)*

Noise Assessment and Regulation

"... lower noise levels (dB(A)) from wind turbines engenders annoyance similar to much higher levels of noise exposure from aircraft, road traffic and railroads." *(Page 20)*

"The World Health Organization (WHO) recommends that if dB(C) is greater than 10 dB more than dB(A), the low frequency components of the noise may be important and should be evaluated separately. In addition, WHO says "[i]t should be noted that a large proportion of low-frequency components in noise may increase considerably the adverse effects on health." *(Page 20)*

"... sound tends to propagate as if by spherical dispersion. This creates amplitude decay at a rate of about -6 dB per doubling of distance. However, low frequency noise from a wind turbine has been shown to follow more of a cylindrical decay at long distances, about -3 dB per doubling of distance in the downwind direction..." *(Page 23)*

"As one moves away from the noise source, loudness at higher frequencies decreases more rapidly (and extinguishes faster) than at lower frequencies. Measurement of A-weighted decibels... obscures this finding." *(Page 23)*

Conclusions

"Wind turbines generate a broad spectrum of low-intensity noise. At typical setback distances higher frequencies are attenuated. In addition, walls and windows of homes attenuate high frequencies, but their effect on low frequencies is limited. Low frequency noise is primarily a problem that may affect some people in their homes, especially at night." *(Page 25)*

"The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A)." *(Page 25)*

"The Minnesota nighttime standard of 50 dB(A) not to be exceeded more than 50% of the time in a given hour, appears to underweight penetration of low frequency noise into dwellings." *(Page 25)*

NOTE: Washington State noise standards, which rely on dB(A), do not adequately take into account the low frequency noise generated by wind turbines.

"For some projects, wind velocity for a wind turbine project is measured at 10 m and then modeled to the height of the rotor. These models may under-predict wind speed that will be encountered when the turbine is erected. Higher wind speed will result in noise exceeding model predictions." *(Page 25)*

"... if a turbine is subject to aerodynamic modulation because of shear caused by terrain (mountains, trees, buildings) or different wind conditions through the rotor plane, turbine noise may be heard at greater distances." *(Page 25)*

NOTE: the mountainous terrain and bowl topography of the Whistling Ridge Energy Project area will likely amplify the low frequency noise, more acutely impacting nearby residents than is suggested by the project's dB(A) modeling projections.

OUR THOUGHTS/COMMENTS

We feel this white paper is particularly relevant as it was produced by two Ph.D. Toxicologists for a public health state agency as requested by that state's agency equivalent to Washington's EFSEC.

It depicts how low frequency noise generated by wind turbine farms may indeed, be more pronounced at night, exacerbating sleep problems and related health issues.

It points out that the current methodology of most meteorological wind speed measurements and modeled projections can significantly underestimate the actual noise levels experienced.

In our opinion, this paper and its findings, reinforces the need for quality independent sound measurement and modeling, as well as the wisdom of using the Kamperman and James "How To" Guide to Siting Wind Turbines to Prevent Health Risks from Sound.

Our **second** area of concern relates to protecting the incredible scenic beauty of the Columbia River Gorge. This area is a local, national and even global treasure, recently rated in National Geographic as tied for number 6 in the world for it's natural and sustainable beauty. We see no evidence that the proposed mere "painting of the wind turbines a gray color" will adequately mitigate the profoundly detrimental effect on the truly unique and exceptional scenic and recreational resources wisely preserved and protected for the enjoyment of all through the Columbia Gorge National Scenic Area Act. "436" foot-tall wind turbines lining the scenic area would surely denigrate the scenic experience and we feel certain, was not remotely foreseen when determining the scenic area boundaries and thus, would undermine the intent of the Act.

The draft EIS constructed visual representations of the turbines depicted against backgrounds of haze and clouds obscures the significant adverse impact that will be experienced by viewers. This draft EIS and its simulated pictorial representations shamefully understates the actual impact.

We feel it is imperative that the final EIS include alternatives such as adjusted placement or outright removal of the proposed A-array or however many wind turbines might be necessary to prevent any negative aesthetic impact to the nationally and globally recognized scenic area and its view points in the Columbia River Gorge. **People come here to heal their souls and to escape from, not be impressed by, industrial complexes.**

The Third issue we raised was partially resolved, not due to your actions, but as a result of a decision rendered by DNR, which prevented, at least temporarily, the leasing of adjacent DNR land to SDS for placement of additional wind turbines.

We are still greatly concerned that this proposed project is reportedly the first of its kind in forested habitats in Washington. This begs the need for intelligent planning, caution and due consideration given the potentially profound impact on watersheds, wildfire risk, bats, avian species, mammals and humans.

We feel greatly disappointed that the current draft EIS appears to hide behind outdated and inadequate state regulations, and pray that EFSEC and BPA will yet demonstrate desperately needed leadership in adopting a quality and accurate model for wind turbine siting that is in harmony with the environment while providing ample protection for the health and quality of life of all Washington residents.

In summary, we specifically request:

- New sound impact determinations/predictions be conducted (not simply review the current estimates) by an Independent Qualified Acoustical Consultant, preferably by Kamperman and James;

- That a proven complex, 3-dimensional computerized sound propagation model, using both dBA and dBC scales and based on the most current and best available science, be used to more accurately predict sound impacts in this mountainous terrain in an effort to protect people's sleep, health and quality of life;

- and that the "How to" Guide to Siting Wind Turbines to Prevent Health Risks (or **minimally**, the EPA guidelines) be used in determining projected impact and that any predicted decibel increases over 10 be mitigated up front by effective set-backs or the outright elimination of selected wind turbines.

EFSEC... the very name indicates that you must evaluate appropriate siting for proposed energy facilities, but does it demand that you must site? Have you ever recommended against siting a wind energy facility?

This siting, if it occurs, will set a precedent with troubling and long-standing consequences for not only forested lands in Washington, but will also put at risk all other national and state treasures, parks, and scenic areas. History is replete with

disastrous consequences from forging ahead to achieve short-term financial windfalls without adequate regulatory oversight and caution. Big money interests and unfortunately, sometimes government, suppresses and ignores mounting scientific evidence that is contrary to its financial and political goals (as in the effects of tobacco, deforestation and most recently, deep-water drilling). Must we blindly go forward and ruin all that has been set aside? Once it is gone, it is gone. Employing wisdom and forethought, if there is ever a time for EFSEC and BPA to determine **"NO, the cost is too great!"** this is it.

Respectfully submitted,

Keith Brown, Ph.D. and Teresa Robbins
211 Malfait Tracts Rd.
Skamania County
Washougal, WA 98671

(6) Attachments:

Verbal Testimony of Keith Brown, Ph.D. and Teresa Robbins on the EFSEC/BPA draft EIS for Whistling Ridge Energy Project, Noise Impact Section – June 16, 2010

The "How To" Guide to Siting Wind Turbines to Prevent Health Risks from Sound, George W. Kamperman, P.E. and Richard R. James, INCE – October 2008

Environmental Noise Guidelines: Wind Farms, Environmental Protection Authority Government of South Australia, February 2003

Public Health Impacts of Wind Turbines, Carl Hebrandson, Ph.D., Toxicologist and Rita B. Messing, Ph.D. Toxicologist, Minnesota Department of Health Environmental Health Division – May 22, 2009

(State of Oregon Wind Energy Facilities) Noise Control Regulations for Industry and Commerce 340-035-0035

Wind Turbines, Health, Ridgelines, and Valleys, Michael A. Nissenbaum, M.D. – May 7, 2010

(3) Previously Provided Attachments:

Deputation to the Standing Committee on General Government Regarding Bill C-150, Robert McMurtry, M.D. – April 22,2009

Presentation to the Maine Medical Association, Michael A. Nissembaum, M.D. – March 2009

Health Concerns and the Need for Careful Siting of Wind Turbines...Medical Staff of Northern Maine Medical Center – March 4, 2009

KEITH BROWN, Ph.D.

Look, I'm not an expert on wind turbines, but I've taught program evaluation, advanced statistics and measurement techniques at Indiana and Boise State Universities. I was the assistant director of one of the top research and development centers in my field. My job was to find the truth. During the last two years I've spent hundreds and hundreds of hours researching probable impact of wind turbine noise.

The primary purpose of the noise portion of this draft EIS **should be to predict as accurately as possible and to fully describe potential adverse impacts of the probable and worst case noise scenarios** that would be inflicted upon the people who live, work, recreate and sleep in the Cook-Underwood, Mill A and surrounding communities.

This EFSEC/BPA draft EIS, in our opinion, **fails to do this**. Instead:

1) it **hides** behind outdated noise regulations never intended for industrial wind turbine complexes,

2) it **distorts** the comparison of the EPA to Washington noise guidelines,

3) it **ignores** guidelines specifically designed to reduce adverse wind turbine noise impacts,

4) it **collects inadequate data** on current noise levels at homes closest to the proposed industrial wind turbines

and finally,

5) it **uses a computer model too simple to accurately predict** noise levels at affected home locations in complex mountainous terrain and varied weather conditions.

1) What do we mean by "outdated" regulations? The Washington Noise Regulations were written in 1975 (that's **35 years ago**). This is well before the current large-scale industrial wind turbines were even developed!

This draft EIS **ignores the substantial work that has been done since 1996 in developing regulations and guidelines specific to appropriate and ecological siting of industrial wind turbines**. Simply using the outdated Washington Noise regulations will result in this community being subjected to significantly higher noise levels than to which Oregon communities, just across the river, are currently subjected.

(Typical **26** decibel "Background")

NIGHTTIME MAX

OREGON	EPA	DRAFT EIS
36	45	50
	(Increases allowed over "Background")	
10	**10** **serious, warrants close attention**	24

Just across the river, an industrial wind turbine complex is permitted to create noise levels only up to 10 decibels over existing ambient background noise (typically 26 decibels). So, total ambient background noise plus the wind energy facility operating at **maximum** capacity **is not to exceed a total of 36 decibels.**

How can BPA, which operates in Oregon as well, in good conscience, apply a more destructive standard to Washington? This draft EIS will allow the Whistling Ridge wind complex to increase total noise levels up to and exceeding 60 decibels during the day and 50 decibels during the night. **That's a difference of an additional 14 decibels during the night over the Oregon standard**... when people are attempting to sleep.

Even according to the inadequate sound measurements done for this draft EIS, measured nighttime ambient background noise **would be allowed to rise by 24 decibels**!

You might think 'That's not a lot'. The EPA Region X guidelines stated that an increase of **10-plus decibels** over existing background noise **will result in significant negative community reaction** and would be considered **serious, warranting close attention.** Further, the New York State Energy Research and Development Authority states "...A 10 dB increase is subjectively heard as an approximate doubling in loudness and almost always causes an adverse community response."

24 decibels? Really... That's okay?

2) 1974 EPA guidelines (for general noise, not wind turbine noise) specify a 10 decibel penalty for nighttime hours, which would effectively **limit noise levels to 45 decibels** during the night. In our opinion, this draft EIS skews even this distinction by averaging allowable daytime and nighttime levels, thereby boosting the suggested nighttime limit to **49 decibels**, then portraying it to be "generally consistent" with the 50 decibel outdated Washington standard. What should be compared is the EPA nighttime limit of 45 to the Washington nighttime 50, **which is not generally consistent** *(p.3-118, draft EIS).* Further, it makes no mention of the EPA guidelines just cited above regarding the impact of decibel increases of 10 or more over background noise.

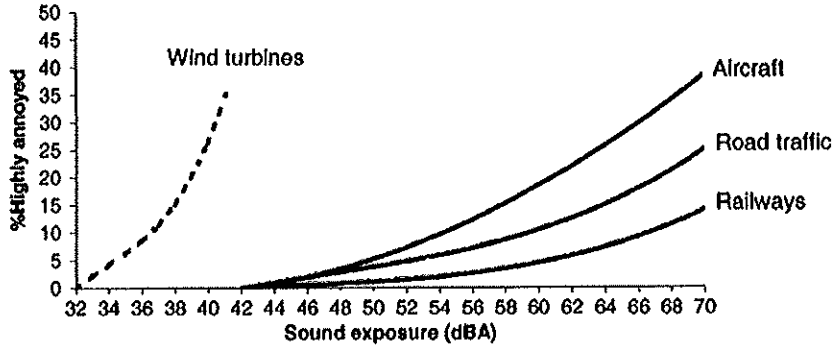
3) It is astounding that this draft EIS **makes no mention of the plethora of guidelines designed specifically to reduce the impact of industrial wind turbine complexes**. You wouldn't have had to go very far to get this information.

We've already mentioned the Oregon standards *(copy attached)*. Similar guidelines exist in country after country around the world, including Australia *(copy attached)*, Denmark, France, Germany, Holland, even the World Health Organization. We actually provided you in May of 2009, the extremely useful, recent research **and relevant** Kamperman and James "How to" Guide to Siting Wind Turbines to Prevent Health Risks from Sound. *(copy attached)*

What do all these guidelines have in common? They are based on research of what would be effective in limiting the impact of wind turbine complex noise on nearby residents. **They limit maximum noise levels to between 35 and 40 decibels.** Why do they do this? Based upon decades of extensive experience with wind turbines, they have determined the type and level of noise produced by industrial wind turbine complexes impacts people differently than other industrial noises.

The following chart taken from the **Public Health Impacts of Wind Turbines prepared by the Minnesota Department of Health Environmental Health Division in response to a request from the Minnesota Department of Commerce Office of Energy Security (equivalent to Washington State EFSEC)** demonstrates that the modulating sound wave noise wind turbines produce, results in significantly more annoyance than noises of traffic, railways, and aircraft.

Figure 6: Annoyance associated with exposure to different environmental noises



Reprinted with permission from Pedersen, E. and K.P. Waye (2004). Perception and annoyance due to wind turbine noise–a dose-response relationship. The Journal of the Acoustical Society of America 116: 3460. Copyright 2004, Acoustical Society of America.

What specifically does this show? **35+%** of people in rural areas **experience wind turbine noise at about 40 decibels as "highly annoying".** Conversely, at 40 decibels of aircraft, traffic or railway noise, **0%** of people report "high annoyance". It would take 70 decibels of aircraft noise, and far in excess of 70 decibels for road traffic and railway noise to create the same level of annoyance that wind turbines create at 40 decibels.

Noise standards used for aircraft, railway, and traffic noise **are inadequate** when applied to wind turbine noise impact. **Wind turbines are clearly in a different class of sound impact and require a different standard!**

4) We see no additional measurements other than the short-term and limited measurements originally provided by the consultant hired by SDS (three 10-minute readings at a site approximately a ½ mile beyond the home site closest to proposed wind turbine placement and three 10-minute readings from a site nearly 2 miles beyond the 3rd closest home site … and one 24-hour measurement from the site a ½ mile beyond the closest home site… all taken in January 2009). **Reported measurements were not even taken at the closest property lines or residences.**

Readings of such short duration prevented measurement of actual ambient noise levels at the home sites when the proposed wind turbines site was experiencing wind at the 6 and 9 meters per second level recommended for accurate projections *(see attached Wind Farms Environmental Noise Guidelines produced by Environmental Protection Authority – South Australia)*. For your convenience, 6 and 9 are the cut-in speed and rated power speed, respectively.

By the way, it is critical to take measurements at the right time – summer... and the right place – affected residences. The greatest potential adverse impact is during the summer when people are sleeping with windows open during an inversion when the ambient background noise is very low at the homesite and the wind turbines are operating at maximum speed. Measuring far away from the homes in winter utterly misrepresents what these residents will experience.

Further, the consultant reported that the SDS meteorological data was **potentially compromised due to ice-y conditions,** indicating we don't even know what the actual wind levels were at the wind turbine site during the limited readings provided!

5)

a. The home site closest to the proposed wind turbines is in an area where the wind turbine noise may reflect off of the amphitheater-like bowl terrain, thus the sound will not attenuate as it would in flatter terrain and will be louder. We see no evidence that this was built-in to the computer model. Research in complex mountainous terrain by Prospathopoulos, J. M. and Voutsinas, S. G. *(Application of a ray theory model to the prediction of noise emissions from isolated wind turbines and wind parks... in Wind Energy, Volume 10 Issue 2, Pages 103 – 119, published online: 6 Dec 2006, John Wiley & Sons,*

Ltd.) **proves** that the simple computer model employed in this draft EIS prediction is inadequate. **"In cases of complex terrain... simple projection models are no longer valid."**

b. The computer projection model utilized is based upon wind speeds measured at 10 meters height, which extensive research shows **will underestimate the wind speeds at the hub by a factor of as much as 2.6! This results in underestimating the wind turbine noise by as much as 15 decibels** during inversions when wind shears develop due to layering of air and the separation of wind currents. *(The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise, van den Berg, G. P. 2006, Rijksuniversiteit Groningen)*

While the draft EIS notes this phenomenon, it is once again, not built into the computer projection model used. This is important because, it is during these inversions (mostly at night) that people experience even greater sleep disturbance and what is described by van den Berg 2006 as "thumping", "pile driving", "a train coming and never arriving"... and that the most annoyance is reported.

c. The computer projection model appears to use each wind turbine as a "point source", with no information provided to suggest that the computer simulation treats each array as a "line" source.

There is ample scientifically proven evidence both from: NASA studies *(Prediction of the Far Field Noise from Wind Energy Farms, Shepherd, K. P. and Hubbard, H.H 1986, NASA-CR-177956)*

> "At intermediate distances the array acts like a line source for which the theoretical decay rate is 3 dB per doubling of distance or 10 dB per decade. Only at the extreme distances, greater than one row length or 900 m, does the decay rate approach the single source value of 6 dB per doubling of distance or 20 dB per decade"*(page 4)*;

and van den Berg's 2006 thesis, which you even cited in your EIS, that demonstrates wind turbines arrayed in a line, as they are projected to be at the Whistling Ridge site, may operate as a "line source". **This results in sound attenuation at 3 decibels per doubling of distance vs. the 6 decibels projected from a "point source".** (We recommend you actually read the whole thesis, as we did.)

The same thing happens with cars traveling in a line and it is why USDOT *(May 2006 – Transit Noise and Vibration Impact Assessment)* requires that the **3 decibel attenuation** be used in all assessment and designed mitigation of potentially heavy traffic impact.

We've thoroughly examined this draft EIS on noise impact and find it to be totally inadequate. It needs to be redone.

TERESA ROBBINS

SO...WHAT DOES ALL THIS MEAN TO THE PEOPLE OF THIS COMMUNITY?

We offer this recent study (with appropriate "control" group protocols) conducted by Medical Doctor Michael A. Nissenbaum (whole slew of qualifications) to provide some important insight and "sound" the alarm *(see attached: Wind Turbines, Health, Ridgelines, and Valleys, 2010)*.

"If industrial wind turbines installed in close proximity to human habitation result in sleep disturbance and stress, then it follows ... that wind turbines will, over the long term, result in... serious health effects (cardiovascular disease, chronic feelings of depression, anger, helplessness) and reduced quality of life."

He compared a group of "exposed" individuals, meaning living within 3500 feet of a ridgeline arrangement of 28 1.5 MW wind turbines... *(Note: the proposed Whistling Ridge will have more and larger turbines)*

And a group of similar age and occupation "not exposed" individuals, meaning living approximately 3 miles away from the industrial complex...
Here's what he found:

"EXPOSED"	NOT "EXPOSED"
New/worsened chronic sleep deprivation	
82%	4%
New chronic headaches	
41%	4%
Stress	
59%	0%
Persistent anger	
77%	0%
New/worsened depression	
33+%	0%
Perceived reduced quality of life	
95%	0%

New prescriptions offered	New/increased prescriptions
26 (15 accepted)	4

Type of prescriptions

Anti-hypertensives anti-hypertensives
Anti-depressants anti-arthritics
Anti-migraines

"There is absolutely no doubt that people living within 3500 feet of a ridgeline arrangement of turbines 1.5 MW or larger … in a rural environment will suffer negative effects."

Ridgeline industrial wind turbine complex "noise travels farther and hits homes and people at greater amplitude than it would from a lower elevation. Even though this is not rocket science, it was conclusively proven in a NASA funded study in 1990."

"The WHO says that 30dbA is ideal, and noise levels of above 40 dbA have definite health consequences. At Mars Hill, where affected homes are present at 3500 feet, sound levels have been measured at over 52.5 dbA…. The people who live within 3500 feet …are truly suffering."

And you are proposing to allow up to 60 decibels here? We fear this will lead to similar suffering as residents of Mars Hill.

The cutting edge equipment we have previously proposed you use for more accurate measurement, and according to Nissenbaum,

> …"revealed drastic short duration excesses over allowed sound levels, levels that set homes vibrating and rendering them unlivable, but also levels of lower frequency transient noise at the audible level, that demonstrates not only failure of preconstruction sound modeling as currently practiced, but also the

> inadequacy of the measuring tools in the toolkit of the everyday practicing acoustician-consultant who generates reports for industry and local government."

In addition to this study, we are providing you with a copy of the 26-page white paper Public Health Impacts of Wind Turbines prepared by the Minnesota Department of Health Environmental Health Division in response to a request from the Minnesota Department of Commerce Office of Energy Security (equivalent to Washington State EFSEC).

It is a recent review, **performed by two unbiased Ph.D. Toxicologists**, of all the relevant published studies. While we strongly insist you read the entire study, due to limited time to testify, we offer one quote from the white paper conclusions.

> "The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headaches are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dbA."

And if that is not enough, here are quotes from one of the experts you cited in the draft EIS ***(van den Berg, 2006).*** He has conducted one of the most comprehensive studies of what is causing the increased noise levels experienced above model predictions.

> "Recently Pedersen... found that annoyance was relatively high at calculated maximum sound immission levels below 40 dB(A) where one would not expect strong annoyance."

> "As wind turbines become taller, the discrepancy between real and expected levels grows and as more tall wind turbines are constructed complaints may become more widespread. … It may be that earlier discrepancies between real and projected sound immission were not sufficient to evoke strong community reactions, and **that only recently turbines have become so tall that the discrepancy now is intolerable."**(our emphasis)

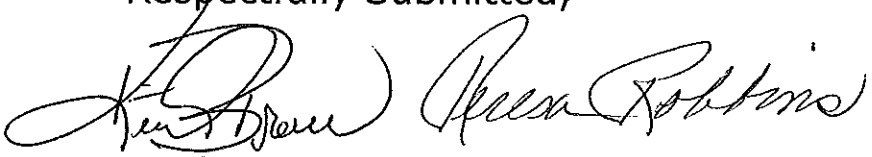
> "… in quiet nights the wind farm can be heard at distances up to several kilometers when the turbines rotate at high speed. In these nights, certainly at distances from 500 to a 1000 meters from the wind farm, one can hear a low-pitched thumping sound with a repetition rate of once a second… not unlike distant pile driving. A resident living a distance of 2.3 kilometers from the wind farm describes the sound as 'an endless train'."

And finally, this is your cited expert we quote

> **"… proponents must accept that wind turbine noise is not (always) benign, that the noise may affect people, and that people who are complaining are not always just a nuisance."**

Read his excellent 210-page dissertation. We have. Hence, we continue to be upset and very concerned.

Respectfully Submitted,



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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

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[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.

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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

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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.

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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

[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.

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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.

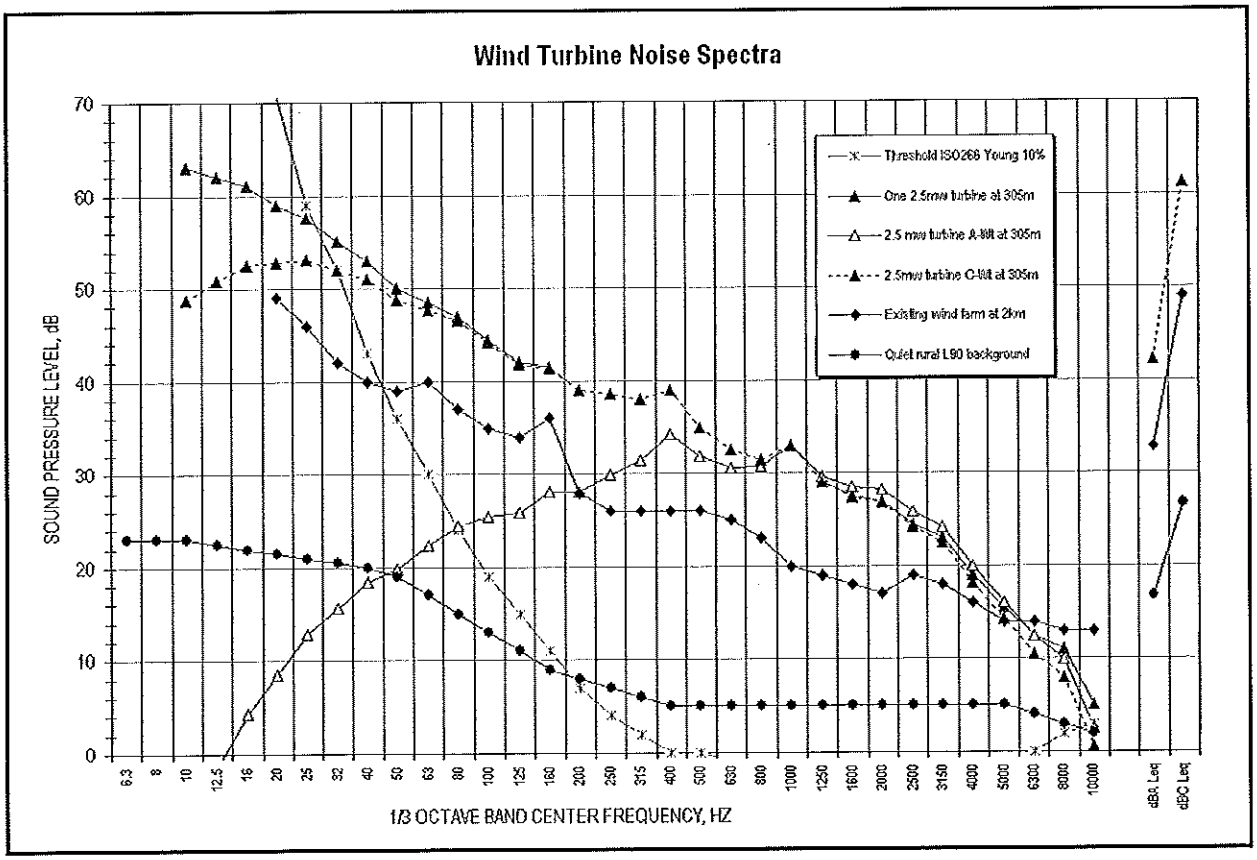

Figure 1-Graph Of Wind Turbine Sounds Vs. Rural Background And Threshold Of Perception

(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.

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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.

[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

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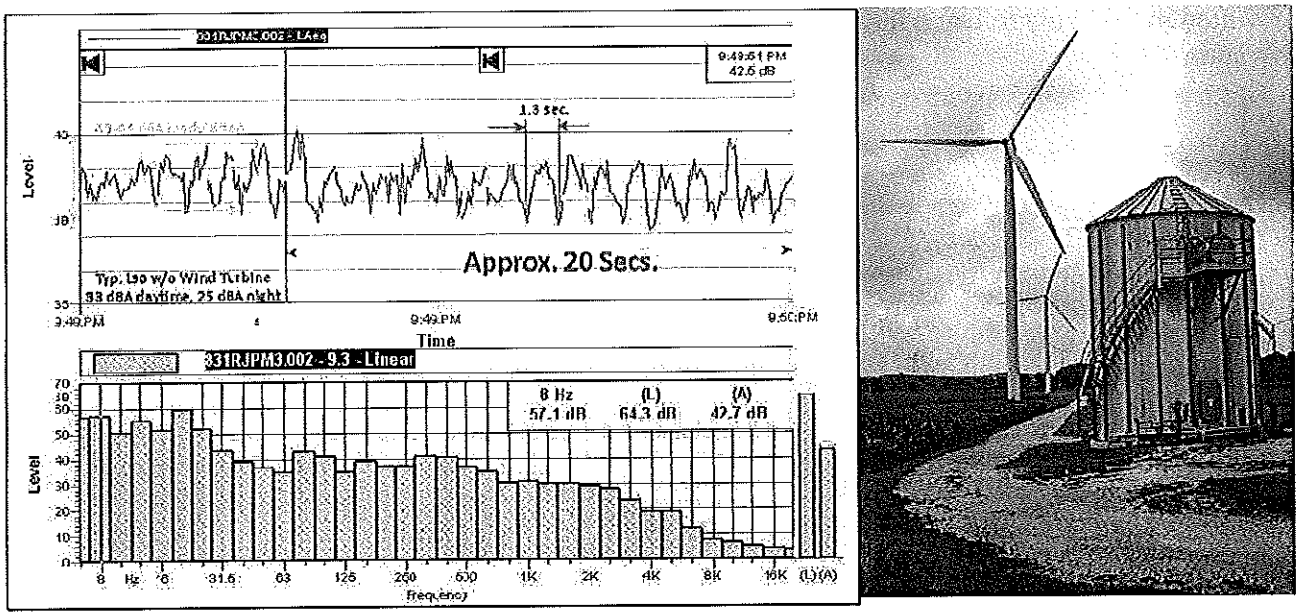

Figure 2 Amplitude Modulation at a farmhouse (Study sponsored by CCCRE, Calumet, Wisconsin)

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

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

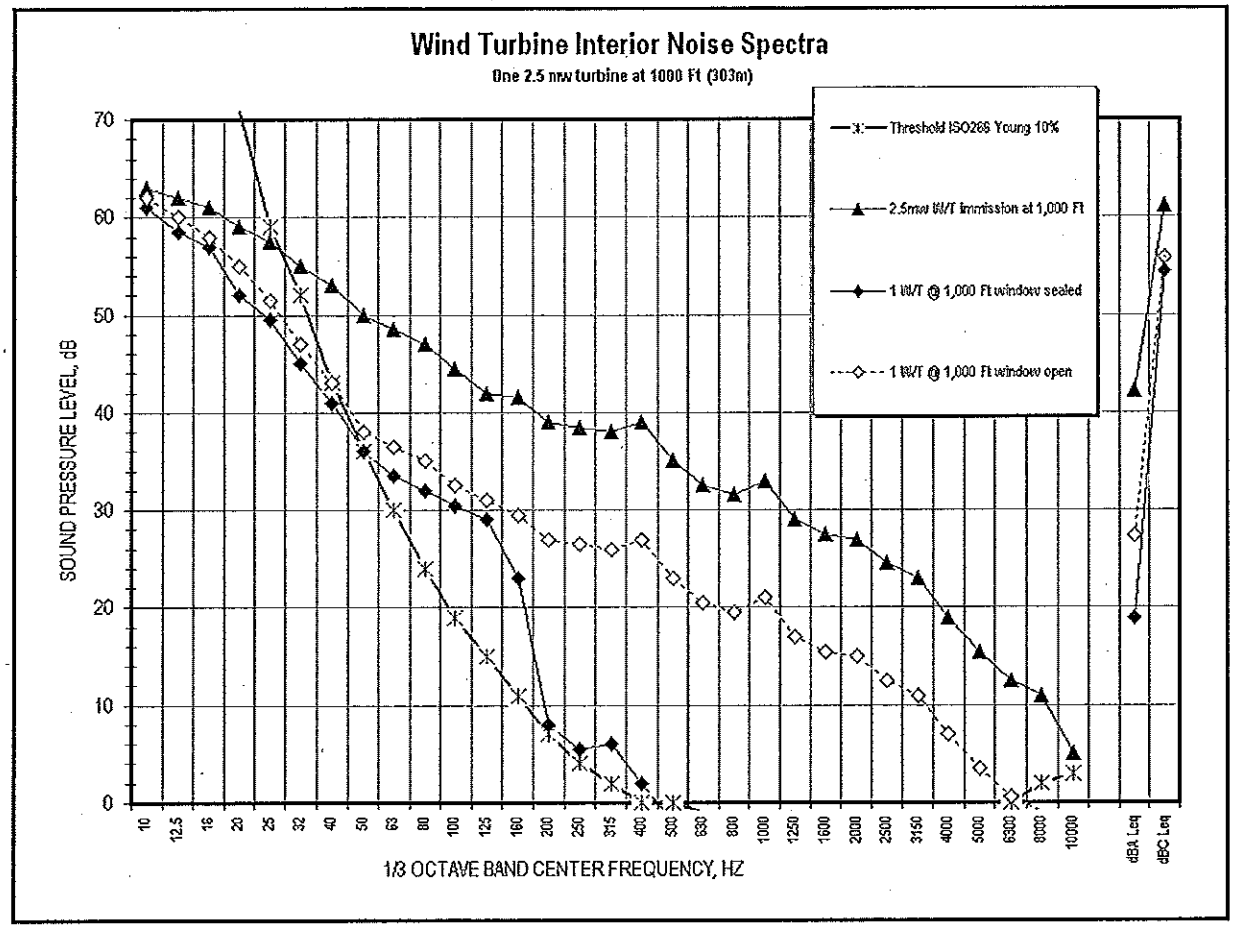

Figure 3-A Single Wind Turbine Sound Inside Home @ 1000 Feet

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).

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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.

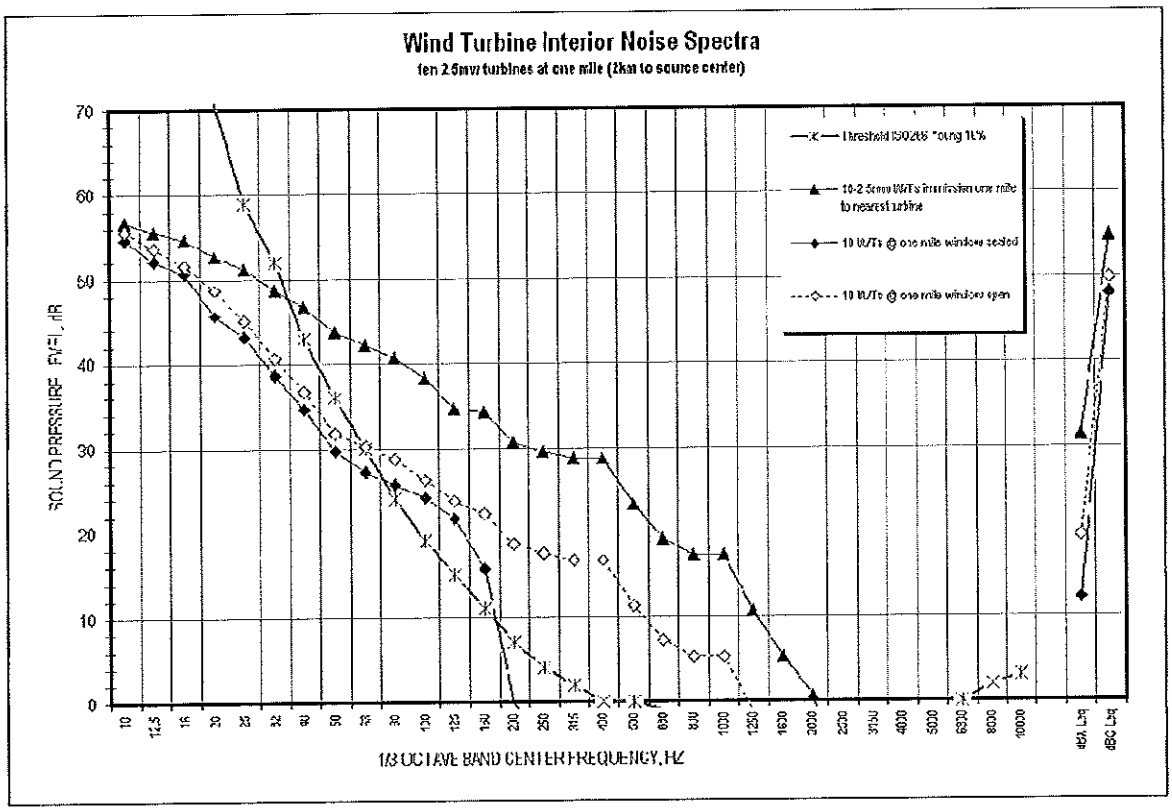

Figure 4-Sound from Ten (10) Wind Turbines inside home at One Mile

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

[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

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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.

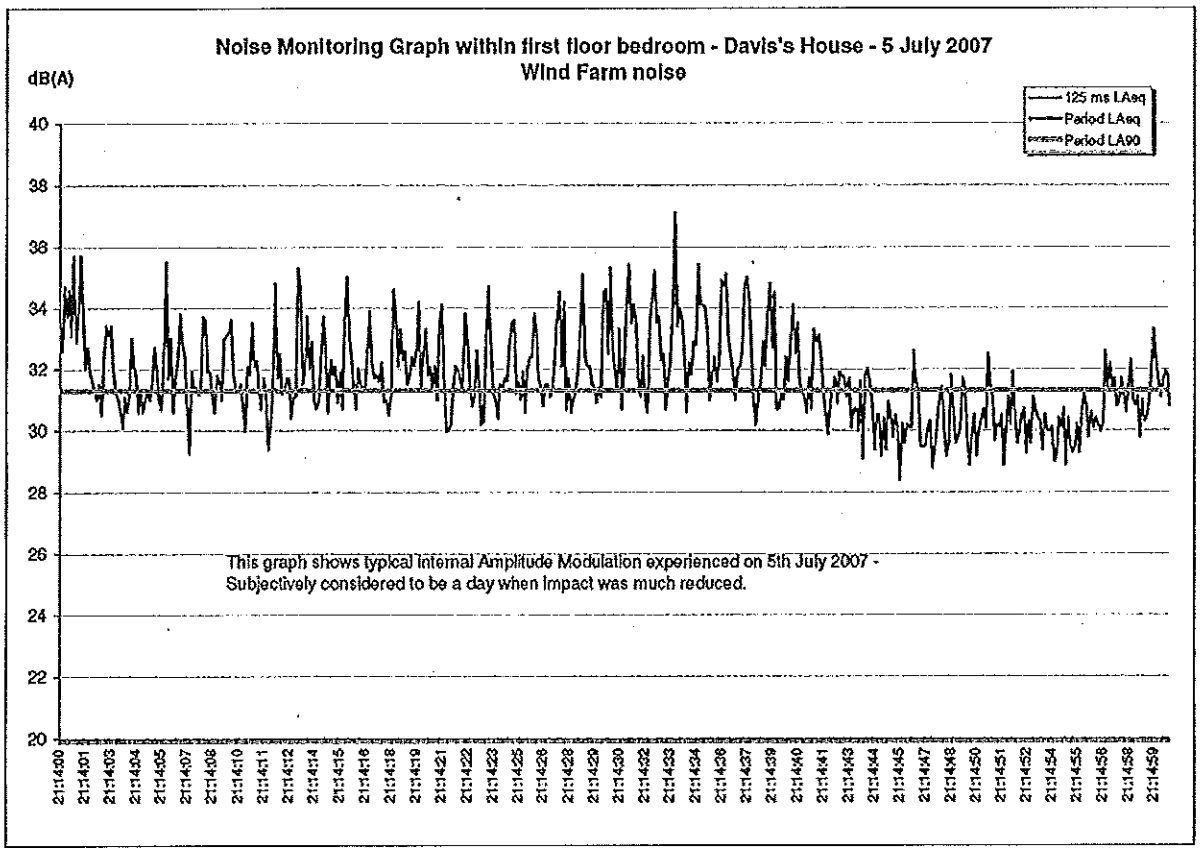

Figure 5- Amplitude modulation in a home 930 meters (3000 feet) from the nearest turbine.[19]

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.

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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

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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)

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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 <u>minimum</u> 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

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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.

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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*

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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.

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[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.

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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.

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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.

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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 not to be considered part of the long-term background sound.

"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.

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"**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 not 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

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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

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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.

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"**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.

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"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

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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-

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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:

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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.

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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

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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.

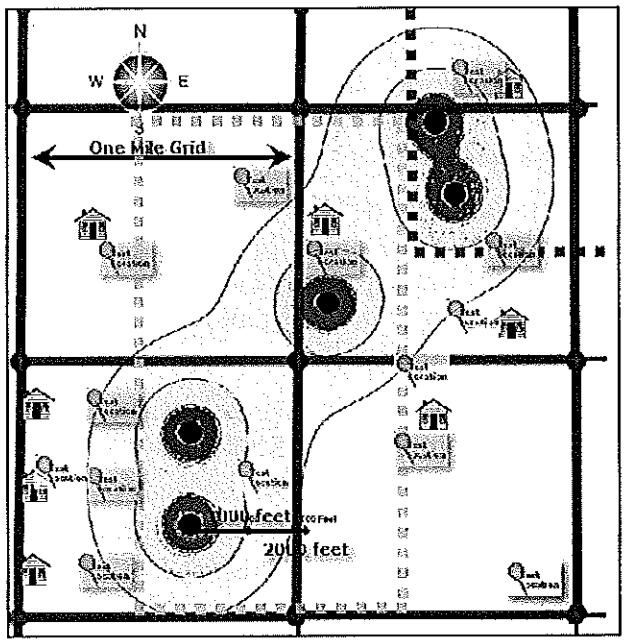
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors 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

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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.

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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

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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.

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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

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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

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VIII. Noise-Con 2008 Paper

Dearborn, Michigan

NOISE-CON 2008

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Simple guidelines for siting wind turbines to prevent health risks[30]

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Revision: 2.1[31]

Industrial scale wind turbines are a familiar part of the landscape in Europe, U.K. and other parts of the world. In the U.S., however, similar industrial scale wind energy developments are just beginning operation. The presence of industrial wind projects will increase dramatically over the next few years given the push by the Federal and state governments to promote renewable energy sources through tax incentives and other forms of economic and political support. States and local governments in the U.S. are promoting what appear to be lenient rules for how industrial wind farms can be located in communities, which are predominantly rural and often very quiet. Studies already completed and currently in progress describe significant health effects associated with living in the vicinity of industrial grade wind turbines. This paper reviews sound studies conducted by consultants for governments, the wind turbine owner, or the local residents for a number of sites with known health or annoyance problems. The purpose is to determine if a set of simple guidelines using dBA and dBC sound levels can serve as the 'safe' siting guidelines. Findings of the review and recommendations for sound limits will be presented. A discussion of how the proposed limits would have affected the existing sites where people have demonstrated pathologies apparently related to wind turbine sound will also be presented.

Background

A relatively new source of community noise is spreading rapidly across the rural U.S. countryside. Industrial grade wind turbines, a common sight in many European countries, are now being promoted by Federal and state governments as the way to minimize coal powered electrical energy and its effects on global warming. But, the initial developments using the newer 1.5 to 3 MWatt wind turbines here in the U.S. has also led to numerous complaints from

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[31] The criteria table at the end of this paper and portions of the narrative have been revised to reflect our current understanding of how to specify the sound limits with less ambiguity and to use the new format for presenting them.

residents who find themselves no longer in the quiet rural communities they were living in before the wind turbine developments went on-line. Questions have been raised about whether the current siting guidelines being used in the U.S. are sufficiently protective for the people living closest to the developments. Research being conducted into the health issues using data from established wind turbine developments is beginning to appear that supports the possibility there is a basis for the health concerns. Other research into the computer modeling and other methods used for determining the layout of the industrial wind turbine developments and the distances from residents in the adjacent communities are showing that the output of the models should not be considered accurate enough to be used as the sole basis for making the siting decisions.

The authors have reviewed a number of noise studies conducted in response to community complaints for wind energy systems sited in Europe, Canada, and the U.S. to determine if additional criteria are needed for establishing safe limits for industrial wind turbine sound immissions in rural communities. In several cases, the residents who filed the complaints have been included in studies by medical researchers who are investigating the potential health risks associated with living near industrial grade wind turbines 365 days a year. These studies were also reviewed by the authors to help in identifying what factors need to be considered in setting criteria for 'safe' sound limits at receiving properties. Due to concerns about medical privacy, details of these studies are not discussed in this paper. Current standards used in the U.S. and in most other parts of the world rely on not-to-exceed dBA sound levels, such as 50 dBA, or on not-to-exceed limits based on the pre-construction background sound level plus an adder (e.g. L_{90A} + 5 dBA).

Our review covered the community noise studies performed in response to complaints, research on health issues related to wind turbine noise, critiques of noise studies performed by consultants working for the wind developer, and research/technical papers on wind turbine sound immissions and related topics. The papers are listed in Tables 1-4.

Table 1-List of Studies Related to Complaints

Resource Systems Engineering, Sound Level Study – Ambient & Operations Sound Level Monitoring, Maine Department of Environmental Protection Order No. L-21635-26-A-N, June 2007
ESS Group, Inc., Draft Environmental Impact Statement For The Dutch Hill Wind Power Project – Town of Cohocton, NY, November 2006
David M. Hessler, Environmental Sound Survey and Noise Impact Assessment – Noble Wethersfield Wind park – Towns of Wethersfield and Eagle NY For: Noble Environmental Power, LLC January 2007
George Hessler, "Report Number 101006-1, Noise Assessment Jordanville Wind Power Project," October 2006
HGC Engineering, "Environmental Noise Assessment Pubnico Point Wind Farm, Nova Scotia, Natural Resources Canada Contract NRCAN-06-0046," August 23, 2006
John I. Walker, Sound Quality Monitoring, East Point, Prince Edward Island" by Jacques Whitford, Consultants for Prince Edward Island Energy Corporation, May 28, 2007

Table 2- List of Studies related to Health

Nina Pierpont, "Wind Turbine Syndrome – Abstract" from draft article and personal conversations. www.ninapierpont.com
Nina Pierpont, "Letter from Dr. Pierpont to a resident of Ontario, Canada, re: Wind Turbine Syndrome," Autumn 2007
Amanda Harry, "Wind Turbine Noise and Health" (2007)
Barbara J. Frey and Peter J. Hadden, "Noise Radiation from Wind Turbines Installed Near Homes, Effects on Health" (2007)
Eja Pedersen, "Human response to wind turbine noise – Perception, annoyance and moderating factors, Occupational and Environmental Medicine," The Sahlgrenska Academy, Gotenborg 2007
Robin Phipps, "In the Matter of Moturimu Wind Farm Application, Palmerston North, Australia," March 2007
WHO European Centre for Environment and Health, Bonn Office, "Report on the third meeting on night noise guidelines," April 2005

Table 3-List of Studies that review Siting Impact Statements

Richard H. Bolton, "Evaluation of Environmental Noise Analysis for 'Jordanville Wind Power Project,'" December 14, 2006 Rev 3.
Clifford P. Schneider, "Accuracy of Model Predictions and the Effects of Atmospheric Stability on Wind Turbine Noise at the Maple Ridge Wind Power Facility," Lowville, NY – 2007

Table 4-List of Research and Technical papers included in review process

Anthony L. Rogers, James F. Manwell, Sally Wright, "Wind Turbine Acoustic Noise," Renewable Energy Research Laboratory, Dept. of ME and IE, U of Mass, Amherst, amended June 2006
ISO. 1996. Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation. International Organization of Standardization. ISO 9613-2. p. 18.
G.P. van den Berg, "The Sounds of High Winds – the effect of atmospheric stability on wind turbine sound and microphone noise," Ph.D. thesis, 2006
Fritz van den Berg, "Wind Profiles over Complex Terrain," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
William K. G. Palmer, "Uncloaking the Nature of Wind Turbines-Using the Science of Meteorology," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Soren Vase Legarth, "Auralization and Assessment of Annoyance from Wind Turbines," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
Julian T. and Jane Davis, "Living with aerodynamic modulation, low frequency vibration

and sleep deprivation - how wind turbines inappropriately placed can act collectively and destroy rural quietitude," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
James D. Barnes, "A Variety of Wind Turbine Noise Regulations in the United States - 2007," Proceedings of Second International Meeting on Wind Turbine Noise, Lyons, France, Sept. 2007
M. Schwartz and D. Elliott, Wind Shear Characteristics at Central Plains Tall Towers, NREL 2006
IEC 61400 "Wind turbine generator systems, Part 11: Acoustic noise measurement techniques,".rev:2002

Discussion

After reviewing the materials in the tables; we have arrived at our current understanding of wind turbine noise and its impact on the host community and its residents. The review showed that some residents living as far as 3 km (two (2) miles) from a wind farm complain of sleep disturbance from the noise. Many residents living one-tenth this distance (300 m. or 1000 feet) from a wind farm are experiencing major sleep disruption and other serious medical problems from nighttime wind turbine noise. The peculiar acoustic characteristics of wind turbine noise immissions cause the sounds heard at the receiving properties to be more annoying and troublesome than the more familiar noise from traffic and industrial factories. Limits used for these other community noise sources do not appear to be appropriate for siting industrial wind turbines. The residents who are annoyed by wind turbine noise complain of the approximately one (1) second repetitive swoosh-boom-swoosh-boom sound of the turbine blades and "low frequency" noise. It is not apparent to these authors whether the complaints that refer to "low frequency" noise are about the audible low frequency part of the swoosh-boom sound, the one hertz amplitude modulation of the swoosh-boom sound, or some combination of both acoustic phenomena.

To assist in understanding the issues at hand, the authors developed the 'conceptual' graph for industrial wind turbine sound shown in Figure 1. This graph shows the data from one of the complaint sites plotted against the sound immission spectra for a modern 2.5 MWatt wind turbine; Young's threshold of perception for the 10% most sensitive population (ISO 0266); and a spectrum obtained for a rural community during a three hour, 20 minute test from 11:45 pm until 3:05 am on a windless June evening in near Ubly, Michigan a quiet rural community located in central Huron County. (Also called: Michigan's "Thumb.") It is worth noting that this rural community demonstrates how quiet a rural community can be when located at a distance from industry, highways, and airport related noise emitters.

During our review we posed a number of questions to ourselves related to what we were learning. The questions (italics) and our answers are:

Do National or International or local community Noise Standards for siting wind turbines near dwellings address the low frequency portion of the wind turbine's sound immissions?[32] No! State and Local governments are in the process of establishing wind farm noise limits and/or wind turbine

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

setbacks from nearby residents, but the standards incorrectly presume that limits based on dBA levels are sufficient to protect the residents.

Do wind farm developers have noise limit criteria and/or wind turbine setback criteria that apply to nearby residents? Yes! But the Wind Industry recommended residential wind turbine noise levels (typically 50-55 dBA) are too high for the quiet nature of the rural communities and may be unsafe for the nearest residents. An additional concern is that some of the methods for implementing pre-construction computer models may predict sound levels that are too low. These two factors combined can lead to post-construction complaints and health risks.

Are all residents living near wind farms equally affected by wind turbine noise? No, children, people with pre-existing medical conditions, especially sleep disorders, and the elderly are generally the most susceptible. Some people are unaffected while some nearby neighbors develop serious health effects caused by exposure to the same wind turbine noise.

How does wind turbine noise impact nearby residents? Initially, the most common problem is chronic sleep deprivation during nighttime. According to the medical research documents, this may develop into far more serious physical and psychological problems

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

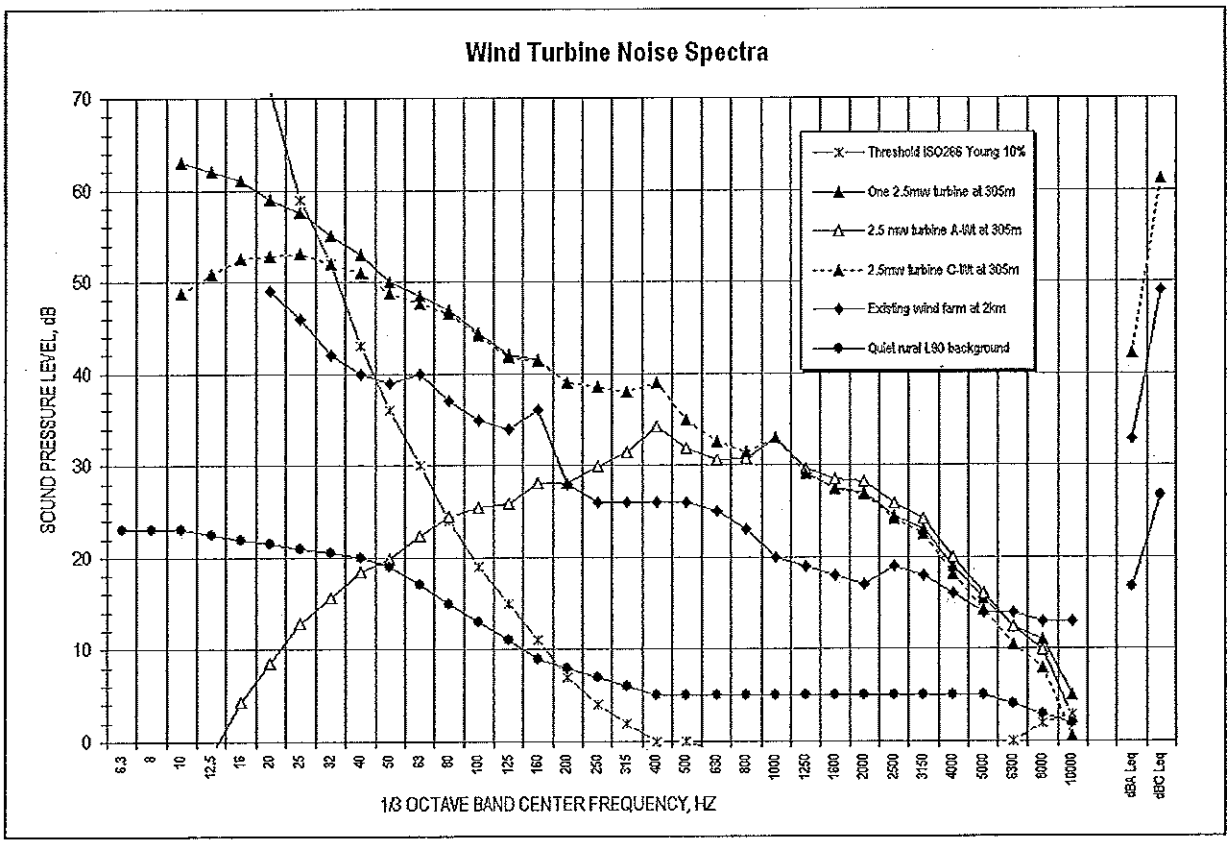

Figure 1-Generalized Sound Spectra vs. perception and rural community L_{90A} background 1/3 octave SPL

Is wind turbine noise at a residence much more annoying than traffic noise? Yes, researchers have found that "Wind turbine noise was perceived by about 85% of the respondents even when the calculated A-weighted SPL were as low as 35.0–37.5 dB. This could be due to the presence of

amplitude modulation in the noise, making it easy to detect and difficult to mask by ambient noise." [JASA 116(6), December 2004, pgs 3460-3470, "Perception and annoyance due to wind turbine noise-a dose-relationship" Eja Pedersen and Kerstin Persson Waye, Dept of Environmental Medicine, Goteborg University, Sweden]

Why do wind turbine noise immissions of only 35 dBA disturb sleep at night? This issue is now being studied by the medical profession. The affected residents complain of the middle to high frequency swooshing sounds of the rotating turbine blades at a constant repetitive rate of about 1 hertz plus low frequency noise. The amplitude modulation of the swooshing sound changes continuously. The short time interval between the blade's swooshing sounds described by residents as sometimes having a thump or low frequency banging sound that varies in amplitude up to 10 dBA. This may be a result of phase changes between turbine emissions, turbulence, or an operational mode.. The assumptions about wall and window attenuation being 15 dBA or more may not be sufficiently protective considering the relatively high amplitude of the wind turbine's low frequency immission spectra.

What are the typical wind farm noise immission criteria or standards? Limits are not consistent and may vary even within a particular country. Example criteria include: Australia-the lower of 35 dBA or L_{90} + 5 dBA, Denmark-40 dBA, France L_{90} + 3 (night) and L_{90} + 5 (day), Germany-40 dBA, Holland-40 dBA, United Kingdom-40 dBA (day) and 43 dBA (night) or L_{90} + 5 dBA, Illinois-55 dBA (day) and 51 dBA (night), Wisconsin-50 dBA and Michigan-55 dBA. Note: Illinois statewide limits are expressed only in nine contiguous octave frequency bands and no mention of A-weighting for the hourly l_{eq} limits. Typically, wind turbine noise just meeting the octave band limits would read 5 dB below the energy sum of the nine octave bands after applying A-weighting. So the Illinois limits are approximately 50 dBA (daytime 7 AM to 10 PM) and 46 dBA at night, assuming a wind farm is a Class C Property Line Noise Source.

What is a reasonable wind farm sound immission limit to protect the health of residences? We are proposing an immission limit of 35 dBA or L_{90A} + 5 dBA whichever is lower and also a C-weighted criteria to address the impacted resident's complaints of wind turbine low frequency noise: For the proposed criteria the dBC sound level at a receiving property shall not exceed L_{90A} + 20dB. In other words, the dBC operating immission limit shall not be more than 20 dB above the measured dBA (L_{90A}) pre-construction nighttime background sound level. A maximum not-to-exceed limit of 50 dBC is also proposed.

Why should the dBC immission limit not be permitted to be more than 20 dB above the background measured L_{90A}? The World Health Organization and others have determined a sound emitter's noise that results in a difference between the dBC and dBA value greater than 20 dB will be an annoying low frequency issue.

Is not L_{90A} the minimum dBA background noise level? This is not exactly correct. The L_{90} is the statistical descriptor representing the quietest 10% of the time. It may be understood as the sounds one hears when there are no nearby or short-term sounds from man-made or natural sources. It excludes sounds that are not part of the soundscape during all seasons. It is very important to establish the statistical average background noise environment outside a potentially impacted residence during the quietest (10 pm to 4 am) sleeping hours of the night. This nighttime sleep disturbance has generated the majority of the wind farm noise complaints throughout the world. The basis for a community's wind turbine sound immission limits would be the minimum 10 minute nighttime L_{90A} plus 5 dB for the time period of 10 pm to 7 am. This would become the Nighttime Immission Limits for the proposed wind farm. This can be accomplished with one or several ten (10) minute measurements during any night when the

atmosphere is classified stable with a light wind from the area of the proposed wind farm. The Daytime Limits (7 am to 7 pm) could be set 10 dB above the minimum nighttime L_{90A} measured noise, but the nighttime criteria will always be the limiting sound levels.

A nearby wind farm meeting these noise immission criteria will be clearly audible to the residents occasionally during nighttime and daytime. Compliance with this noise standard would be determined by repeating the initial nighttime minimum nighttime L_{90A} tests and adding the dBC (L_{eqC}) noise measurement with the turbines on and off. If the nighttime background noise level (turbines off) was found to be slightly higher than the measured background prior to the wind farm installation, then the results with the turbines on must be corrected to determine compliance with the pre-turbine established sound limits.

The common method used for establishing the background sound level at a proposed wind farm used in many of the studies in Table 1 was to use unattended noise monitors to record hundreds of ten (10) minute measurements to obtain a statistically significant sample over varying wind conditions or a period of weeks. The measured results for daytime and nighttime are combined to determine the statically average wind noise as a function of wind velocity measured at a height of ten (10) meters. This provides an enormous amount of data but the results have little relationship to the wind turbine sound immission or turbine noise impact in nearby residents. The purpose of this exhaustive exercise often only demonstrates how much noise is generated by the wind. In some cases it appears that the data is used to 'prove' that the wind noise masks the turbine's sound immissions.

The most glaring failure of this argument occurs during the frequent nighttime condition of a stable atmosphere. Then, the wind turbines operate at full or near full power and noise output while the wind at ground level is calm and the background noise level is low. This is the condition of maximum turbine noise impact on nearby residents. It is the condition which most directly causes chronic sleep disruption. Furthermore, the measurement methodology is usually faulty, as much of the wind noise measured by unattended sound monitors is the pseudo-wind noise generated by failure of the microphone's windscreen. This results in totally erroneous background sound levels being used for permitting and siting decisions. (See studies in Table 3, esp. Van den Berg)

Are there additional noise data to be recorded for a pre-wind turbine noise survey near selected dwellings? Yes, The measuring sound level meter(s) need document the L_{Aeq}, L_{A10}, L_{A90} and L_{Ceq}, L_{C10}, L_{C90} sound levels plus start time & date for each 10 minute sample. The L_{10} results will be utilized to help validate that conditions were appropriate for measuring the L_{90} long term background sound levels. For example, on a quiet night one would expect L_{A10} to be less than 10 dB higher than the L_{A90} long-term background sound level. On a windy night or day the difference may be more than 20 dB. There is a requirement for measurement of the wind velocity near the sound measurement microphone continuously throughout each ten (10) minute recorded noise sample. The ten (10) minute average of the wind speed near the microphone shall not exceed 2 m/s (4.5 mph) and the maximum wind speed for operational tests shall not exceed 4 m/s (9 mph). It is strongly recommended that observed samples be used for these tests.

Is there a need to record weather data during the background noise recording survey? One weather monitor is required at the proposed wind farm on the side nearest the residents. The weather station sensors are at standard ten (10) meter height above ground. It is critical the weather be recorded every ten (10) minutes synchronized with the clocks in the sound level recorders without ambiguity in the start and end time of each ten (10) minute period. The weather station should record wind speed and direction, temperature, humidity and rain.

Why do Canada and some other countries base the permitted wind turbine noise immission limits on the operational wind velocity at the 10m height wind speed instead of a maximum dBA or L_{A90} + 5 dBA immission level? First, it appears that the wind turbine industry will take advantage of every opportunity to elevate the maximum permitted noise immission level to reduce the setback distance from the nearby dwellings. Including wind as a masking source in the criteria is one method for elevating the permissible limits. Indeed the background noise level does increase with surface wind speed. When it does occur, it can be argued that the increased wind noise provides some masking of the wind farm turbine noise emission. However, in the middle of the night when the atmosphere is defined as stable (no vertical flow from surface heat radiation) the layers of the lower atmosphere can separate and permit wind velocities at the turbine hubs to be 2 to 4 times the wind velocity at the 10m high wind monitor but remain near calm at ground level. The result is the wind turbines can be operating at or close to full capacity while it is very quiet outside the nearby dwellings.

This is the heart of the wind turbine noise "problem" for residents within 3 km (approx. two miles) of a wind farm. When the turbines are producing the sound from operation it is quietest outside the surrounding homes. The PhD thesis of P.G. van den Berg "The Sounds of High Winds" is very enlightening on this issue. See also the letter by John Harrison in Ontario "On Wind Turbine Guidelines."

What sound monitor measurements would be needed for enforcement of the wind turbine sound ordinance? A similar sound and wind 10 minute series of measurements would be repeated at the pre-wind farm location nearest the resident registering the wind turbine noise complaint, with and without the operation of the wind turbines. An independent acoustics expert should be retained who reports to the County Board or other responsible governing body. This independent acoustics expert shall be responsible for all the acoustic measurements including instrumentation setup, calibration and interpretation of recorded results. An independent acoustical consultant shall also perform all pre-turbine background noise measurements and interpretation of results to establish the Nighttime (and Daytime if applicable) industrial wind turbine sound immission limits. At present the acoustical consultants are retained by, and work directly for, the wind farm developer.

This presents a serious problem with conflict of interest on the part of the consultant. The wind farm developer would like to show the significant amount of wind noise that is present to mask the sounds of the wind turbine immissions. The wind farm impacted community would like to know that wind turbine noise will be only barely perceptible and then only occasionally during the night or daytime.

Is frequency analysis required either during pre-wind farm background survey or for compliance measurements? Normally one-third octave or narrower band analysis would only be required if there is a complaint of tones immission from the wind farm.

Proposed Sound Limits

The simple fact that so many residents complain of low frequency noise from wind turbines is clear evidence that the single A-weighted (dBA) noise descriptor used in most jurisdictions for siting turbines is not adequate. The only other simple audio frequency weighting that is standardized and available on all sound level meters is C-weighting or dBC. A standard sound level meter set to measure dBA is increasingly less sensitive to low frequency below 500 Hz (one octave above middle-C). The same sound level meter set to measure dBC is equally sensitive to all frequencies above 32 Hz (lowest note on grand piano). It is well accepted that dBC readings

are more predictive of perceptual loudness than dBA readings if low frequency sounds are significant.

We are proposing to use the commonly accepted dBA criteria that is based on the pre-existing background sound levels plus a 5 dB allowance for the wind turbine's immissions (e.g. L_{90A} +5) for the audible sounds from wind turbines. In addition, to address the lower frequencies that are not considered in A-weighted measurements we are proposing to add limits based on dBC. The Proposed Sound Limits are presented in the text box at the end of this paper.

For the current industrial grade wind turbines in the 1.5 to 3 MWatt range, the addition of the dBC requirement will result in an increased distance between wind turbines and the nearby residents. For the generalized graphs shown in Figure 1, the distances would need to be approximately double the current distance. This will result in setbacks in the range of 1 km or greater for the current generation of wind turbines if they are to be located in rural areas where the L_{90A} background sound levels are 30 dBA or lower. When no man-made sounds are audible they can even be under 20 dBA. In areas with higher background sound levels, turbines could be located somewhat closer, but still at a distance greater than the 305 m (1000 ft.) or less setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

1. Establishing Long-Term Background Noise Level

a. Instrumentation: ANSI or IEC Type 1 Precision Integrating Sound Level Meter plus meteorological instruments to measure wind velocity, temperature and humidity near the sound measuring microphone. Measurement procedures must meet ANSI S12.9, Part 3.

b. Measurement location(s): Nearest property line(s) from proposed wind turbines representative of all non-participating residential property within 2.0 miles.

c. Time of measurements and prevailing weather: The atmosphere must be classified as stable with no vertical heat flow to cause air mixing. Stable conditions occur in the evening and middle of the night with a clear sky and very little wind near the surface. Sound measurements are only valid when the measured wind speed at the microphone does not exceed 2 m/s (4.5 mph).

d. Long-Term Background sound measurements: All data recording shall be a series of contiguous ten (10) minute measurements. The measurement objective is to determine the quietest ten minute period at each location of interest. Nighttime test periods are preferred unless daytime conditions are quieter. The following data shall be recorded simultaneously for each ten (10) minute measurement period: dBA data includes L_{A90}, L_{A10}, L_{Aeq} and dBC data includes L_{C90}, L_{C10}, and L_{Ceq}. The maximum wind speed at the microphone during the ten minutes, a single measurement of temperature and humidity at the microphone for each new location or each hour whichever is oftener shall also be recorded. A ten (10) minute measurement contains valid data provided: Both L_{A10} minus L_{A90} and L_{C10} minus L_{C90} are not greater than 10 dB and the maximum wind speed at the microphone did not exceed 2 m/s during the same ten (10) minute period as the acoustic data.

2. Wind Turbine Sound Immission Limits

No wind turbine or group of turbines shall be located so as to cause wind turbine sound immission at any location on non-participating property containing a residence in excess of the limits in the following table:

Table of Not-To-Exceed Property Line Sound Immission Limits [1]

Criteria	Condition	dBA	dBC
A	Immission above pre-construction background:	$L_{Aeq} = L_{A90} + 5$	$L_{Ceq} = L_{C90} + 5$
B	Maximum immission:	35 L_{Aeq}	55 L_{Ceq} for quiet[2] rural environment 60 L_{Ceq} for rural-suburban environment
C	Immission spectra imbalance	L_{Ceq} (immission) minus (L_{A90} (background)+5) $\leq$ 20 dB	
D	Prominent tone penalty:	5 dB	5 dB

Notes	
1	Each Test is independent and exceedances of any test establishes non-compliance Sound "immission" is the wind turbine noise emission as received at a property
2	A "Quiet rural environment" is a location 2 miles from a state road or other major transportation artery without high traffic volume during otherwise quiet periods of the day or night.
3	Prominent tone as defined in IEC 61400-11. This Standard is not to be used for any other purpose.

[1] Procedures provided in Section 7. Measurement Procedures (Appendix to Ordinance) of the most recent version of "**The How To Guide To Siting Wind Turbines To Prevent Health Risks From Sound**" by Kamperman and James apply to this table.

3. Wind Farm Noise Compliance Testing

All of the measurements outlined above in 1. Establishing the Long-Term Background Noise Level must be repeated to determine compliance with 2. Wind Turbine Sound Immission Limits. The compliance test location is to be the pre-turbine background noise measurement location nearest to the home of the complainant in line with the wind farm and nearer to the wind farm. The time of day for the testing and the wind farm operating conditions plus wind speed and direction must replicate the conditions that generated the complaint. Procedures of ANSI S12.9-Part 3 apply as amended. Instrumentation limits for wind and other factors must be recognized and followed.

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.

Wind Farms

Environmental Noise Guidelines

EPA South Australia

NOISE

Government of South Australia

Environmental Noise Guidelines: Wind Farms

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1 INTRODUCTION

This document aims to help developers, planning and enforcement authorities, other government agencies and the broader community assess environmental noise impacts from wind farms.

The core objective of these guidelines is to balance the advantage of developing wind energy projects in this State with protecting the amenity of the surrounding community from adverse noise impacts.

Wind farms need specific guidelines because wind turbines have unique noise generating characteristics and the environments surrounding wind farm sites usually have low ambient noise.

A workshop with approximately 40 participants was held to help develop these guidelines. A technical subgroup, formed from the workshop group, provided specific technical consultation during development. An earlier draft of these guidelines was distributed to the original workshop participants and their submissions were used to prepare this final document.

In addition, the Environment Protection Authority (EPA) has taken into consideration the documents listed in the Bibliography (Section 11).

Shaded boxes throughout this draft document contain explanatory comments.

Guidelines

The *Environment Protection Act 1993* requires a duty of care for the environment. This is specified under Section 25 of the Act and states:

A person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

Guidelines published by the EPA indicate the standard of care that is likely to be required to secure compliance with the general environmental duty as outlined in s. 25 of the Act.

They have the advantage of flexibility and can be adapted to a range of circumstances.

2 NOISE CRITERIA

The general approach in setting noise criteria for new developments is to require compliance with a base noise level.

This base noise level is typically 5 dB(A) lower than the level considered to reflect the amenity of the receiving environment. Designing new developments at a lower level accounts for the cumulative effect of noise from other similar development and for the increased sensitivity of receivers to a new noise source.

The impact of a given noise is also closely linked to the amount it exceeds the background noise. For example, the same noise in a quiet rural area will generally have a greater adverse impact than in a busy urban area because of the masking effect of high ambient noise environments.

If the noise generated does not exceed the background noise by more than 5 dB(A) the impact will be marginal and acceptable.

A unique characteristic of wind farms is that the noise level from each wind turbine generator (WTG) increases as the wind speed at the site increases. As an offset, the background noise also generally increases under these conditions and can mask the WTG noise.

Comparison with a base noise level alone will therefore not be sufficient to indicate the potential impact of a wind farm: a farm could comply with this base level at lower wind speeds but exceed it when the wind speed rises.

Most international and interstate jurisdictions (see examples below) set a base noise level for low wind speeds and also ensure that the wind farm noise does not exceed the background noise by more than 5 dB(A) as the wind speed increases.

This general approach recognises the unique noise generating characteristics of wind turbines and the particular ambient noise environments of most sites and is the one used by these guidelines.

The New Zealand Standard NZS 6808 sets the predicted base level (L_{Aeq}) at 40 dB(A). This is higher than the approach of these guidelines, but the specified propagation model to be used in accordance with that standard does not account for factors such as ground absorption and topography effects that can substantially reduce the noise level in practice. In addition, the New Zealand Standard requires the criteria to be met at all receivers, regardless of their relative amenity or relationship with the wind farm development.

A comprehensive publication developed by the wind farm industry for the UK Department of Trade and Industry (1996) sets the base level (L_{A90}) at 35-40 dB(A). The actual value chosen within this range depends on the number of dwellings affected, the effect on the capacity of the wind farm of meeting the standard, and the duration and level of exposure.

Wind turbines and wind farms have been being developed in Denmark for over 20 years. Denmark has set a base noise level only (and does not consider the influence of background noise). The base noise level (L_{Aeq}) is set at 40 dB(A) for a wind speed of V_{10m} = 8 m/s. These guidelines will provide a similar result given the expected influence of background noise.

The NSW EPA has not published specific guidelines for wind farms but has assessed a number of development applications using the same base noise level and background noise approach as these guidelines.

Most wind farm sites are within or next to areas where low ambient noise levels are a significant component of that area's amenity. These might include rural living zones or zones that are not intended to be subject to any other significant ambient noise sources from adjacent premises.

The criteria in these guidelines have been established for just such a scenario and have been developed in accordance with the objects of the *Environment Protection Act 1993* (the Act).

Where the wind farm sites are within or next to areas where more intensive activity is expected, the base noise level may also be increased commensurate with the amenity of that area. It is recommended that the developer discuss such a situation with the EPA and the relevant planning authority.

2.1 Determining wind farm operating criteria

The *Environment Protection (Industrial Noise) Policy 1994* limits the noise level from non-domestic noise sources including wind farms to 40 dB(A) or the lowest typical background noise level plus 5 dB(A) (whichever is the greater) in rural areas from 2200 hrs until 0700 hrs the following day.

This limit applies to existing noise sources and does not necessarily reflect the preferred noise criterion for new (planning) development. The general approach for new development applies a night time level of 35 dB(A) to significant development in a rural location.

To prevent adverse impacts from the increased noise of WTGs under high wind conditions, the increasing noise level must also be compared to the corresponding background noise at the relevant receiver.

2.2 Noise criteria—new wind farm development

The predicted equivalent noise level ($L_{Aeq,10}$), adjusted for tonality in accordance with these guidelines, should not exceed:

- 35 dB(A), or
- the background noise ($L_{A90,10}$) by more than 5 dB(A)

whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG.

The background noise should be as determined by the data collection and regression analysis procedure recommended under these guidelines (Section 3). It should be read from the resultant graph at the relevant integer wind speed.

2.3 Agreements with wind farm developers

Wind farm developers commonly enter into agreements with the owners of private land suitable for a wind farm site. The agreement provides the wind farm developers with the appropriate siting and generally provides the landowner with a level of compensation and diversity in their income stream.

The criteria have been developed to minimise the impact on the amenity of premises that do not have an agreement with wind farm developers.

Notwithstanding this, the EPA cannot ignore noise impacts on the basis that an agreement has been made between the developer and the landowner. Developers cannot absolve themselves of their obligations under the Act by entering into an agreement with a landowner.

If it is shown that a development is having an 'adverse effect on an amenity value of an area that ... unreasonably interferes with ... the enjoyment of the area' then appropriate action can be taken under the Act.

However, the existence of an agreement will affect the consideration of whether the interference is unreasonable in a given situation. It is unlikely that there will be *unreasonable* interference if:

- a formal agreement is documented between the parties
- the agreement clearly outlines to the landowner the expected impact of the noise from the wind farm and its effect upon the landowner's amenity
- the likely impact of exposure will not result in adverse health impacts (e.g. the level does not result in sleep disturbance).

A risk associated with relying on such agreements still remains where the criteria in these guidelines are exceeded. This is because an interpretation of 'unreasonable' is required in any future assessment of the impact of wind farm noise initiated by a complaint from the landowner (or future landowners).

2.4 Staged development

The procedure and criteria presented in these guidelines are for greenfield sites but a wind farm may be developed over a number of separate stages.

A previous stage of the wind farm that is installed and operating may raise the background noise level at the relevant receivers by up to 5 dB(A).

Any subsequent stage in the development of the wind farm site should meet the criteria using the background noise levels as they existed prior to the wind farm. Therefore, the noise generated by existing WTGs from a previous stage should not be considered as part of the background noise in determining criteria for subsequent stages.

2.5 Cumulative development

Separate wind farm developments in close proximity to each other may impact on the same relevant receiver.

Therefore, as for staged development, any additional wind farm that may impact on the same relevant receiver as an existing wind farm should meet the criteria using the background noise levels as they existed before the original wind farm site development. The noise generated by existing WTGs from another wind farm should not be considered as part of the background noise in determining criteria for subsequent development.

On occasion it will not be possible to determine the background noise levels as they existed before the original wind farm development.

This may result in subsequent developers of new wind farm sites needing to provide sufficient distance from a relevant receiver (who is common to an existing site) such that the base noise level is met at that receiver for all operating wind speeds of the WTGs (V_{10m})[1] up to 10 m/s.

[1] Refer to 3.1 – Background noise

3 MEETING THE CRITERIA

This section describes the steps to be taken to assess whether the wind farm noise reaching receivers at relevant locations will comply with the criteria of these guidelines.

Background noise is measured at relevant receiver locations over continuous 10-minute intervals and particularly over the range of wind speeds at which the WTGs operate. The data must adequately represent conditions at the site and cover approximately 2000 intervals.

Wind speed is measured at 10 m above the ground and in intervals that correlate with the background noise measurements. The wind speed data, together with the manufacturer's noise data for the WTG and using a suitable model, is then used to predict noise levels at each integer wind speed from cut-in to rated power, at relevant receiver locations.

The correlated wind speed and background noise data are plotted against each other to give a standard graph for background noise at each relevant receiver. This graph is then used in conjunction with the predicted noise levels to assess whether the wind farm will meet the criteria of these guidelines.

3.1 Background noise

What is background noise?

Background noise is the 'lull' in the ambient noise environment.

Intermittent noise events such as from aircraft flying over, dogs barking, mobile farm machinery and the occasional vehicle travelling along a nearby road are all part of the ambient noise environment but would not be considered part of the background noise unless they were present for at least 90% of the time.

Why is background noise important?

Background noise can mask the noise effects of new development such as a wind farm and the level of masking is a critical factor in assessing the impact of a wind farm.

Wind generated noise can provide a good masking effect, particularly as it has similar characteristics to wind farm generated noise.

Background noise measurement locations

Background noise measurements should be carried out at locations that are relevant for assessing the impact of WTG noise on nearby premises (relevant receivers).

Relevant receiver locations are premises:

- on which someone resides or has development approval to build a residential dwelling
- at which the predicted noise level exceeds the relevant base noise level for wind speeds (V_{10m}) of 10 m/s or less
- that are representative of the worst case situation when considering the range of premises, e.g. a house located among a group of nearby houses within a residential zone.

1. A proposed wind farm site with a zone in its vicinity that is primarily for residential land use and is yet to be fully developed should be discussed with the relevant planning authority and the EPA.

   These locations will probably also be considered relevant receivers and background noise levels will be required at the zone boundary.

   The relevant planning authority can then be informed about the potential impacts on any future residential development.

   Nearby areas for which the zoning intent is not clear should also be discussed with the relevant planning authority and the EPA.

2. Background noise generally increases at a greater rate than noise from WTGs at high wind speeds. If the wind farm is predicted to achieve the base noise level at the very high wind speed of 10 m/s, 10 m above the ground (V_{10m}; see Section 3.4) the wind farm noise at even higher wind speeds is expected to be masked by the increasing background noise. Therefore the impact will not be adverse and further investigation is not required.

   The only exception is a receiver within 1500 m of the wind farm site that is in an area unlikely to be exposed to a windy environment. This specific circumstance should be discussed with the EPA.

3. The worst case situation may not always be the closest receiver to the wind farm site. The closest receiver should always be a measurement position but other locations where the background noise environment may differ due to prevailing weather patterns and/or local topography should also be included as relevant receivers.

   Background noise environments likely to differ at receivers around a wind farm site should also be discussed with the EPA.

Background noise measurement position

All measurements should be made outdoors. The microphone should be positioned 1200–1500 mm above the ground and at least 5 m from any reflecting surface (other than the ground).

The property boundary of the receiving premises is not necessarily a valid measuring position (particularly for large rural properties) unless it is likely that someone would regularly be there or the Development Plan clearly envisages noise sensitive development at such a location.

In general, any area within 20 m of a house and in the direction of the wind farm would be a valid measuring position.

Background noise levels can be significantly affected by local conditions, such as the presence of trees nearby. Where this is expected then it is recommended that photographs be taken showing the noise measurement position and associated surroundings, such as buildings, trees and topography.

This will ensure that no significant physical changes have been made to the locations between the time of the initial background noise measurements and of compliance checking.

Data collection

Equipment

Background noise levels should be collected for continuous 10-minute time intervals using sound level meters or loggers of at least Type 2 certification in accordance with Australian Standard AS 1259–1990 or IEC-61672 (International Electrotechnical Commission 2002).

The meters or loggers must be calibrated on site immediately before and after any measurement period using a calibrator complying with IEC 942 and approved by the meter manufacturer.

> Type 2 certified monitoring equipment provides a sufficient level of accuracy for assessing the impact of wind farms under these guidelines.
>
> Type 1 certified monitoring equipment will probably become commercially available in South Australia in the future, possibly sooner if an Australian Standard is prepared dealing with measurement procedures for wind farm sites. The EPA intends to modify this guideline to suit technical advancements and relevant standards/policy development.

Wind

Microphones should be protected with windshields in accordance with the microphone manufacturer's instructions, and the protection should be sufficient to ensure the noise level threshold of the monitoring equipment does not adversely affect the data used in the analysis. If microphones cannot be appropriately protected then affected data should not be collected.

As part of the development application, developers may need to confirm that the reported noise levels aren't influenced by high wind speed across the microphone, particularly where average wind speeds at the noise measurement position are expected to exceed 5 m/s (a high wind speed for the purposes of noise level measurement conditions).

Affected data can be identified by monitoring the wind speed at the noise measurement position (1200–1500 mm above ground level at the relevant receiver) over 10-minute intervals that correspond with the noise level measurement intervals. This information would then be compared with both the collected data for that interval and the manufacturer's specifications for microphone performance under those conditions.

> The EPA is currently sponsoring a 12-month field trial, started in January 2003, to determine typical wind speeds at a background noise level measurement site and how these speeds relate to background noise level data. When the trials are complete the data collection procedure will be reviewed.

Rain

Rain periods during monitoring may also adversely affect the collected data. If rain was recorded in the vicinity during the collection period the developer must supply evidence that the affected data has not been used in the analysis.

The nearest weather station might not provide a sufficient indication of localised conditions in remote areas. A simple method might record rain using a local gauge or collection method that is regularly checked, and discard all data in periods where rain was detected. High sensitivity tipping rain gauges have been used overseas but they are not readily available.

Data

Data not adversely affected by the effects of wind or rain should be collected for a sufficient period to cover the range of wind speeds and directions generally expected at the wind farm site.

Particular emphasis should be placed on collecting background noise data corresponding to the operating wind speed range of the WTGs.

Sufficient data is considered to be approximately 2000 measurement intervals (or the equivalent of two weeks worth of data).

The EPA field trials will also evaluate the quantity of data required to provide reliable regression analysis and to adequately represent the expected range of conditions at the site. When the trials are complete the data collection procedure will be reviewed.

Compliance checking will require the background noise level data collection process to be repeated when the wind farm is operational (see Section 4).

Background noise varies naturally throughout the year, with different prevailing wind directions, foliage on trees, atmospheric conditions and the like.

A community concern is that the developer may measure during a limited (minimum 2 week) period that is not representative of the rest of the year.

This guideline recommends that compliance checking be repeated at different periods of the year where valid concerns exist.

The developer must collect representative background noise data. Non-compliance may result in one or a number of WTGs being stopped under certain conditions.

3.2 Wind speed measurements

Manufacturers of wind turbines publish noise level data for their machines derived through a comprehensive international measurement standard.

The noise level generated by a wind turbine increases as the wind speed driving it increases. Generally data is provided for at least each integer wind speed from cut-in speed up to rated power.

Wind speeds for the purposes of the WTG noise level data are measured at 10 m above ground level.

The noise level data for each WTG is used as the basis for predicting the total noise level from a wind farm.

Wind speed 10 m above the ground at the wind farm site and background noise at the relevant receiver must be correlated so that background noise and wind farm noise can be compared. Therefore, wind speed measurements must be made in 10-minute intervals that correlate/ synchronise with the background noise data collection.

Measurement height

The wind speed should be measured at 10 m above ground level.

A developer will often measure wind speed at different heights to determine whether wind conditions at the site are suitable for an economic wind farm development. It may be acceptable to

convert the results from a different measurement height to 10 m provided the wind shear model used to do this is clearly stated and is accepted by the EPA.

All wind speeds referred to in these guidelines and within any development application referred to a planning authority should be expressed at 10 m above ground level unless otherwise stated.

All predicted noise levels should be based on noise level data derived from wind speed measurements taken at 10 m above ground level.

Measurement location

The same location should be used for measuring wind speed and direction for all of the following procedures:

- background noise measurements
- compliance checking
- noise predictions.

Therefore the wind speed measurement location at the wind farm site should not:

- be significantly affected by the operation of the WTGs in their final location
- provide lower wind speed results than other locations on the wind farm site, where those locations will house WTGs that affect the noise level at a relevant receiver.

For large or topographically diverse wind farm sites, the suitability of the wind speed measurement location may need to be confirmed as part of the development assessment process.

3.3 Noise level prediction

Prediction locations

The noise level associated with the wind farm should be predicted at all locations identified as relevant receivers under these guidelines for each integer wind speed from cut-in speed to the speed of rated power.

> WTG manufacturers generally do not test or extrapolate tested results above wind speeds of rated power.
>
> The measurement of noise levels under high wind speeds (used to determine the sound power level of a turbine model) is difficult.
>
> Where wind farms comply with the noise level criteria in these guidelines up to rated power it is unlikely that adverse impacts will occur at higher wind speeds.

Propagation model

A suitable model must be selected (or developed) to predict the worst case noise level at all relevant receivers.

The following information should be provided as part of the development application:

- the propagation model, and any variation of the model, used for the prediction
- an estimate of the model accuracy in dB(A)

- the assumptions used as input to the model, including allowances for noise absorption due to air, ground, topographical and wind effects.

The noise level at the relevant receiver locations should be predicted allowing for the propagating effect of wind (the noise sounds louder downwind than upwind) in the direction from the wind farm to that receiver at each integer wind speed. This represents a worst case situation. (In most situations there will be different wind directions and wind speeds between each WTG on a wind farm site and the relevant receiver. These effects will reduce the actual noise level when compared to that predicted under worst case conditions.)

Noise levels should be predicted by an acoustic engineer defined for the purposes of these guidelines as an engineer who is eligible for membership of both the Australian Acoustical Society and the Institution of Engineers Australia.

The New Zealand Standard NZS 6808:1998 uses a simple propagation model that does not account for wind, ground or topographical effects, and uses a simplified approach to account for atmospheric effects.

The model is expected to predict higher than actual noise levels where topography (land rise or structure between receiver and wind farm) or ground effects (heavy foliage) are important. However, on other sites it may predict with similar accuracy to more complex propagation models because it does not account for the propagating effect of the wind.

This model can be used with limited background in acoustic engineering. If it, or a similar simple propagation model, is intended to be used, this should be discussed with the EPA. Use of such a model and input by someone other than an acoustic engineer may be acceptable where the predicted levels easily meet the criteria.

Sound power data

The sound power level can be thought of as the noise signature for the WTG model proposed for the wind farm.

The sound power level data at each integer wind speed from cut-in speed to the speed of rated power should be specified in the development application as determined in accordance with International Electrotechnical Standard IEC 61400-11.

Tonality is a characteristic that can increase the adverse impact of a given noise source and it can be determined by breaking the noise signature down into discrete frequency bands.

If tonality is a characteristic of the WTG noise, 5 dB(A) should be added to the predicted or measured noise level from the wind farm.

To help determine whether there is tonality, the method and results of testing (such as in accordance with IEC 61400-11) carried out on the proposed WTG model to determine the presence of tonality should also be specified in the development application.

At the time of development application, the contractual arrangements for which particular WTG model may not have been finalised between the developer and WTG supplier. If the WTG model to be installed differs from that assumed at the time of development application, the developer should assess and discuss the effect on the propagation model with the EPA.

The wind farm developer must also discuss changes to the type, location or operation of the WTGs with the relevant planning authority.

3.4 Data analysis

Background noise and wind speed data

At the completion of the data collection period there should be a minimum of 2000 pairs of synchronised background noise and wind speed measurements at wind speeds between the cut-in speed and the speed of rated power.

The background noise should be plotted against the corresponding wind speed measurement for each relevant receiver. It is common to plot the wind speed along the x axis and the background noise along the y axis.

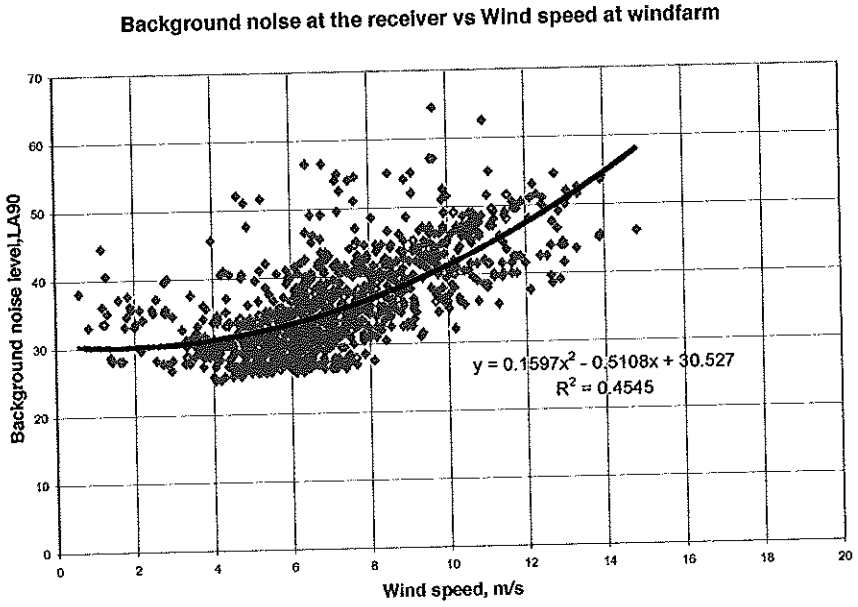
A best fit regression analysis should be carried out on the data. The polynomial order (from linear up to third order) providing the best correlation co-efficient should be used to provide the fitted regression line.

The correlation co-efficient should be specified for each polynomial order.

Data that has been collected at the extreme ends of the range of wind speeds (below and above the operating wind speeds of the WTG) can influence the slope of the fitted regression line and should not be included in the regression analysis.

The graph for each relevant receiver showing the plotted points, the fitted regression line, the polynomial describing that line and the correlation co-efficient should be included in the development application.

A typical graph is shown below for information. (In this example graph the operating speeds of the WTG are not known and thus, unlike real situations, data above and below the operating have not been removed.)



The predicted noise level should be overlaid on such a graph to determine compliance with the criteria.

4 COMPLIANCE CHECKING

It is unlikely that the worst case noise propagation conditions of the prediction procedure of these guidelines will often be repeated during operation of the wind farm. The actual impacts are therefore likely to be less than the predicted impacts.

Notwithstanding this, the prediction process relies on assumptions about a range of inputs, and the procedure given in this section for measuring the actual noise impacts is a means of confirming compliance or otherwise with the predicted impacts.

The measurement of wind farm noise is expected to be difficult due to the masking effect of the ambient noise and its influence on the base noise level descriptor (L_{Aeq}). The background noise descriptor (L_{A90}) is used to remove this effect.

In setting the compliance checking criteria, the cumulative pre-existing effect of the background noise and the wind farm noise, and the level of accuracy of the measurement procedure have been considered.

4.1 Procedure

Compliance checking follows a similar procedure to compliance prediction (Section 3).

Ambient noise levels with the wind farm operating are measured at relevant receiver locations, over continuous 10-minute intervals and over at least the range of wind speeds at which the WTGs operate. The data must cover approximately 2000 intervals.

Wind speed is measured at 10 m above the ground and in intervals that correlate with the ambient noise measurements.

Compliance checking should collect data associated with the worst case wind direction from the wind farm to the relevant receiver. A wind direction spread of 45 degrees either side of the direct line between the nearest WTG and the relevant receiver is considered acceptable (International Electrotechnical Commission 1998, 1(j) p9). This will not always be practical, given prevailing wind conditions.

Cases in which it appears to be impractical to collect 2000 data points under worst case wind direction conditions or in which all WTGs are not operating, should be discussed with the EPA.

4.2 Data analysis

Regression analysis should be repeated on the ambient noise and wind speed measurement data using the same polynomial order regression formula as for Section 3.5. The correlation co-efficient should be specified in the compliance checking report.

Data below the cut-in speed and above the speed for rated power should not be included (see Section 3.5).

A graph should be prepared for each relevant receiver showing the plotted points, the fitted regression line, the polynomial describing that line and the correlation co-efficient in the compliance checking report.

In addition, the graph should have the criteria determined in accordance with these guidelines superimposed.

4.3 Criteria

The ambient noise level ($L_{A90,10}$) measured in accordance with the compliance checking procedure and determined by the regression analysis procedure should be read from the resultant graph at

the relevant integer wind speed. It should then be adjusted for tonality in accordance with these guidelines and should not exceed:

- 35 dB(A), or
- the pre-existing background noise by more than 5 dB(A)

whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power.

4.4 Tonality

Where, in the opinion of an officer authorised under the Environment Protection Act, the wind farm exhibits tonality as a characteristic, the developer should conduct a tonality test in accordance with a procedure acceptable to the EPA.

An addition of 5 dB(A) should be made to the measured background noise level from a wind farm where tonality is shown to be a characteristic.

4.5 Annoying characteristics

These guidelines have been developed with the fundamental characteristics of noise from a wind farm taken into account. These include the aerodynamic noise from the passing blades (commonly termed 'swish') and the infrequent and short-term braking noise.

However, annoying characteristics that are not fundamental to a typical wind farm should be rectified. Such characteristics may include infrasound (low frequency noise below the audible frequency range that manifests as a rattle in lightweight materials such as glass) or adverse mechanical noise (perhaps generated as a failure of a component).

Infrasound was a characteristic of some early wind turbine models that has been attributed to early designs in which turbine blades were downwind of the main tower—the turbulence generated around the tower was cut through by the blades, generating this effect.

Modern designs generally have the blades upwind of the tower. Wind conditions onto the blades and improved blade design minimise the generation of the effect. The EPA has consulted the working group and completed an extensive literature search but is not aware of infrasound being present at any modern wind farm site.

4.6 Excessive noise

The operation of the wind farm should comply with the criteria at all relevant receivers[2]. The extent of relevant receivers should not be confined to those identified during the development assessment stage.

The EPA can require the developer to repeat the compliance checking procedure if it receives any complaint that may be valid about an unreasonable interference on those premises from noise impacts.

An Environment Protection Order as provided under s. 93 of the Environment Protection Act may be issued by the EPA to secure compliance with the criteria in these guidelines.

This may mean that the operation of certain WTGs would be restricted under certain wind speed conditions.

[2] See shaded panel

The EPA recognises that measurements in a windy environment are technically difficult and subject to variation. Exceeding the compliance checking criteria may be the result of varying background noise, rather than of excessive wind farm noise.

It is expected that there will be natural variations in background noise throughout the year[3], with different prevailing wind directions, foliage on trees, atmospheric conditions and possibly with changes to local conditions such as buildings, trees or topography that may affect compliance with the criteria. Where this may be the case, the onus of responsibility for proof resides with the developer.

A range of alternative compliance checking procedures, such as those detailed in the Clause 6 of the International Energy Agency recommended practices (1997), can remove the influence of background noise to accurately determine the wind farm noise in isolation.

[3] The EPA field trials are expected to provide information on the extent of variation of the background noise. When the trials are complete the compliance checking procedure will be reviewed.

5 DOCUMENTATION

Development applications for wind farms are often referred to the EPA by the relevant planning authority for assessment of the environmental noise impact.

The draft Planning SA Bulletin at the time of drafting these guidelines indicates that the referral may become formal by adding wind farm developments as a scheduled item in the *Development Act 1993*.

If it appears likely that the criteria under these guidelines will be approached, developers should discuss the development with the EPA before submitting the application to ensure they provide all relevant information.

All relevant information on the noise impacts must be included with the application. Possible information requirements are summarised below.

5.1 Predicted noise from the wind farm

(a) make and model of WTGs to be used, including hub height

(b) one third octave band sound power levels and associated wind speed of WTGs to be used

(c) positions of all WTGs

(d) positions of all affected premises within 1.5 km of any WTG, noting which premises are part of the development and which are not

(e) distance of all affected premises in d above from nearest WTG

(f) description of the zone category for all receivers in (d), as outlined in the relevant Development Plan under the *Development Act 1993*

(g) predicted noise levels for those premises in (d) for worst case wind direction and over the operating wind speed range of the WTGs

(h) the model used and the method for deriving the noise levels in (g)

(i) amount of noise reduction, if any, allowed for acoustic screening to estimate the levels in (g)

(j) topographical map of wind farm and affected premises showing contour lines

(k) location of wind measuring position(s) used for noise assessment and compliance purposes.

5.2 Measurement and assessment

(a) description of noise measuring equipment used, including make, model and type and including type and model of windscreen used for the microphone

(b) noise measurement position including height above ground, wind speed (at the noise measurement position) and distance to nearest building structure

(c) description and photograph of measurement position showing nearby trees and building structures

(d) atmospheric conditions at the wind farm including wind speed and direction

(e) time and duration of monitoring

(f) sampling time for wind and noise measurements

(g) number of data pairs measured (wind farm speed and background noise level)

(h) description of regression analysis method

(i) graphical plot of data in Section 5.1 (g) above and regression curve

(j) correlation co-efficient for regression curve

(k) graphical plot and corresponding tabulated data analysing predicted noise levels and criteria against integer wind speeds.

5.3 Compliance checking

(a) description of all noise monitoring equipment, including type of microphone wind protection used

(b) noise monitoring position(s)

(c) photographs of noise monitoring position taken before the wind farm was installed (at the noise modelling stage) and at the time of compliance checking, showing the noise measurement position and associated surroundings, such as buildings, trees and topography

(d) description of wind speed and direction measuring equipment used and the location on the wind farm, including height above ground level

(e) description of wind speed measuring equipment used for the purposes in Section 5.2

(f) details of which WTGs were operating during compliance check

(g) atmospheric conditions

(h) time and duration of monitoring period

(i) list of all monitored data showing wind speed, wind direction and noise level

(j) graphical plot and tabulated data overlaying line of best fit and criteria against integer wind speeds

(k) noise level at target and WTG cut-in speeds

(l) assessment of any audible annoying noise characteristics

6 GLOSSARY

A-weighted: frequency weighted as specified in Australian Standard AS 1259–1990 noise level meters or its replacement.

Authorised officer: a person appointed to be an authorised officer under Division 1 of Part 10 of the *Environment Protection Act 1993*.

Ambient noise: the total noise in a given environment.

Background noise: ambient noise, in the absence of the noise under investigation, measured using time weighting 'F', that is equalled or exceeded for 90% of the measurement time interval. Expressed as $L_{A90,T}$, where T refers to the measurement time interval in minutes.

Base noise level: means an $L_{Aeq,10}$ of 35 dB(A) unless otherwise stated.

dB(A): the noise level in decibels, obtained using the 'A' weighted network of a noise level meter as specified in Australian Standard AS 1259–1990 Noise Level Meters or its replacement.

EPA: Environment Protection Authority.

Equivalent noise level: the equivalent continuous A-weighted sound pressure level obtained using time weighting 'F', over the measurement time interval. Expressed as $L_{Aeq,T}$, where T refers to the measurement time interval in minutes.

Extraneous noise: noise from animals, excessive wind effects, insects, birds, aircraft or unusual traffic conditions or any other infrequently occurring component of the ambient noise.

Impulsive noise: noise containing impulse components as part of its characteristics, comprising a single pressure peak, or sequence of such peaks, or a single burst with multiple pressure peaks, whose amplitude decays with time, or a sequence of such bursts.

Low frequency noise: a noise with perceptible and definite content in the audible frequency range below 250 Hz.

Measurement place: a place at the receiver where the noise level is to be measured.

Noise source: premises at which an activity or process is undertaken that results in the emission of noise.

Predicted noise level: the $L_{Aeq,10}$ wind farm noise level at a receiver predicted in accordance with these guidelines.

Premises: any land, or the whole or part of a building or structure.

Prevailing background noise level: the background noise level derived from regression analysis of the background noise data.

Receiver: premises that may be affected by the noise source, other than premises on the same land as the noise source.

T: measurement time interval; taken to be 10 minutes unless stated otherwise.

Tonal noise: noise with perceptible and definite pitch or tone.

V_{10m}: wind speed measured in metres per second (m/s) at the wind farm site at 10 m above the ground.

WTG: wind turbine generator.

Wind farm: a group of WTGs installed in the same region and all operated by the same operator. It is not necessary that all WTGs are located on the same premises.

Zone: an area of land delineated as a zone, precinct or otherwise in the relevant Development Plan under the *Development Act 1993*, that is subject to a set of land use rules under that Plan.

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[Standards Australia provides access to Australian and New Zealand Standards, and standards and guidelines from the International Electrotechnical Commission and International Energy Agency.]

Public Health Impacts
of
Wind Turbines

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Office of Energy Security

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I. Introduction

In late February 2009 the Minnesota Department of Health (MDH) received a request from the Office of Energy Security (OES) in the Minnesota Department of Commerce, for a "white paper" evaluating possible health effects associated with low frequency vibrations and sound arising from large wind energy conversion systems (LWECS). The OES noted that there was a request for a Contested Case Hearing before the Minnesota Public Utilities Commission (PUC) on the proposed Bent Tree Wind Project in Freeborn County Minnesota; further, the OES had received a long comment letter from a citizen regarding a second project proposal, the Lakeswind Wind Power Plant in Clay, Becker and Ottertail Counties, Minnesota. This same commenter also wrote to the Commissioner of MDH to ask for an evaluation of health issues related to exposure to low frequency sound energy generated by wind turbines. The OES informed MDH that a white paper would have more general application and usefulness in guiding decision-making for future wind projects than a Contested Case Hearing on a particular project. (Note: A Contested Case Hearing is an evidentiary hearing before an Administrative Law Judge, and may be ordered by regulatory authorities, in this case the PUC, in order to make a determination on disputed issues of material fact. The OES advises the PUC on need and permitting issues related to large energy facilities.)

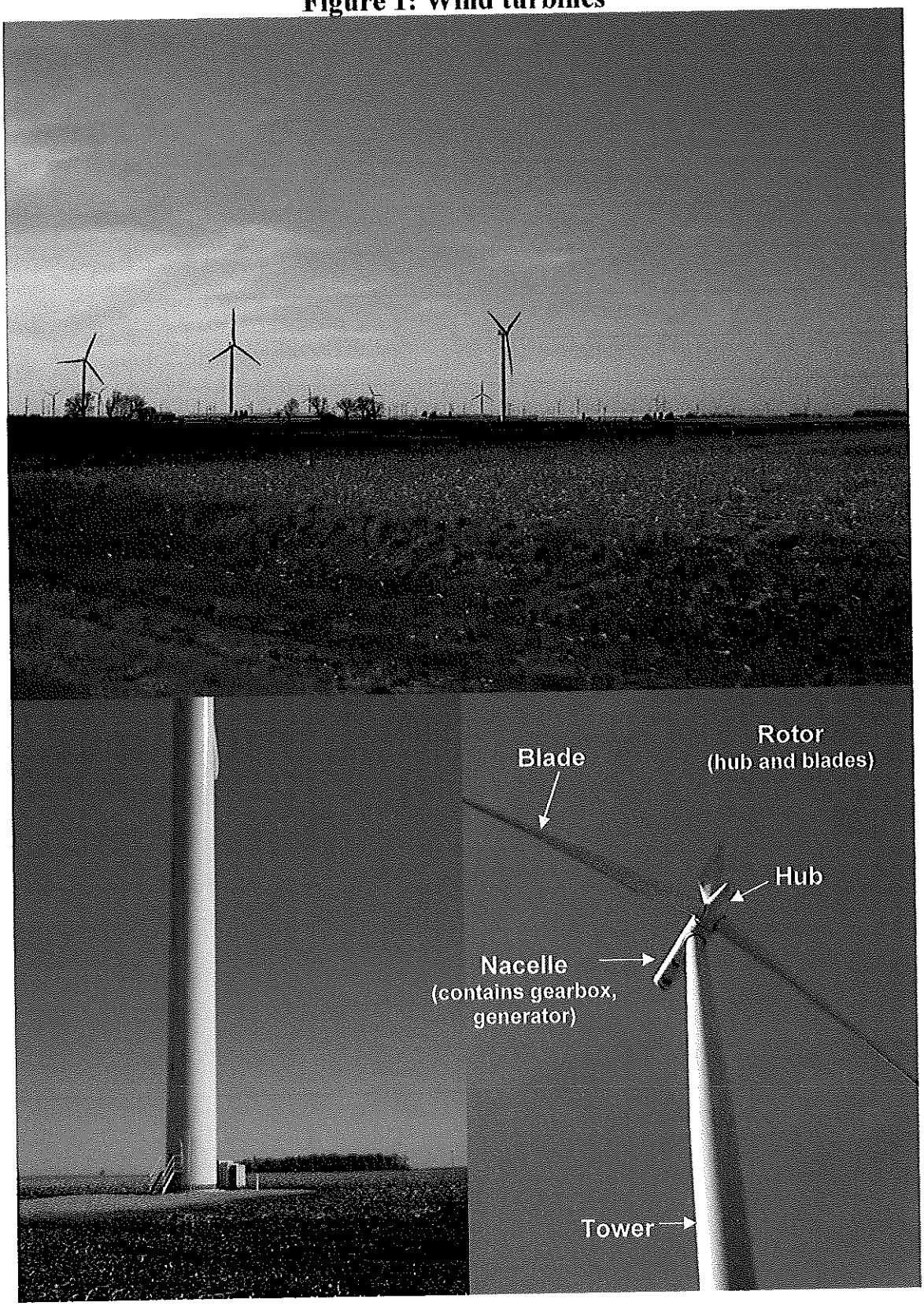
In early March 2009, MDH agreed to evaluate health impacts from wind turbine noise and low frequency vibrations. In discussion with OES, MDH also proposed to examine experiences and policies of other states and countries. MDH staff appeared at a hearing before the PUC on March 19, 2009, and explained the purpose and use of the health evaluation. The Commissioner replied to the citizen letter, affirming that MDH would perform the requested review.

A brief description of the two proposed wind power projects, and a brief discussion of health issues to be addressed in this report appear below.

A. Site Proposals

Wind turbines are huge and expensive machines requiring large capitol investment. Figure 1 shows some existing wind turbines in Minnesota. Large projects require control of extensive land area in order to optimize spacing of turbines to minimize turbulence at downwind turbines. Towers range up to 80 to 100 meters (260 to 325 feet), and blades can be up to 50 meters long (160 feet) (see Tetra Tech, 2008; WPL, 2008). Turbines are expected to be in place for 25-30 years.

Figure 1: Wind turbines



1. Bent Tree Wind Project in Freeborn County

This is a proposal by the Wisconsin Power and Light Company (WPL) for a 400 megawatt (MW) project in two phases of 200 MW each (requiring between 80 and 130 wind turbines). The cost of the first phase is estimated at $497 million. The project site area would occupy approximately 40 square miles located 4 miles north and west of the city of Albert Lea, approximately 95 miles south of Minneapolis (Figure 2) (WPL, 2008). The Project is a LWECS and a Certificate of Need (CON) from the PUC is required (*Minnesota Statutes 216B.243)*. The PUC uses the CON process to determine the basic type of facility (if any) to be constructed, the size of the facility, and when the project will be in service. The CON process involves a public hearing and preparation of an Environmental Report by the OES. The CON process generally takes a year, and is required before a facility can be permitted.

WPL is required to develop a site layout that optimizes wind resources. Accordingly, project developers are required to control areas at least 5 rotor diameters in the prevailing (north-south) wind directions (between about 1300 and 1700 feet for the 1.5 to 2.5 MW turbines under consideration for the project) and 3 rotor diameters in the crosswind (east-west) directions (between about 800 and 1000 feet). Thus, these are minimum setback distances from properties in the area for which easements have not been obtained. Further, noise rules promulgated by the Minnesota Pollution Control Agency (MPCA; *Minnesota Rules* Section 7030), specify a maximum nighttime noise in residential areas of 50 A-weighted decibels (dB(A). WPL has proposed a minimum setback of 1,000 feet from occupied structures in order to comply with the noise rule.

2. Noble Flat Hill Wind Park in Clay, Becker and Ottertail Counties

This is a LWECS proposed by Noble Flat Hill Windpark I (Noble), a subsidiary of Noble Environmental Power, based in Connecticut. The proposal is for a 201 MW project located 12 miles east of the City of Moorhead, about 230 miles northwest of Minneapolis (Figure 3) (Tetra Tech, 2008). The cost of the project is estimated to be between $382 million and $442 million. One hundred thirty-four GE 1.5 MW wind turbines are planned for an area of 11,000 acres (about 17 square miles); the site boundary encompasses approximately 20,000 acres. Setback distances of a minimum of 700 feet are planned to comply with the 50 dB(A) noise limit. However, rotor diameters will be 77 meters (250 feet). Therefore, setback distances in the prevailing wind direction of 1,300 feet are planned for properties where owners have not granted easements. Setbacks of 800 feet are planned in the crosswind direction.

Figure 2: Bent Tree Wind Project, Freeborn County

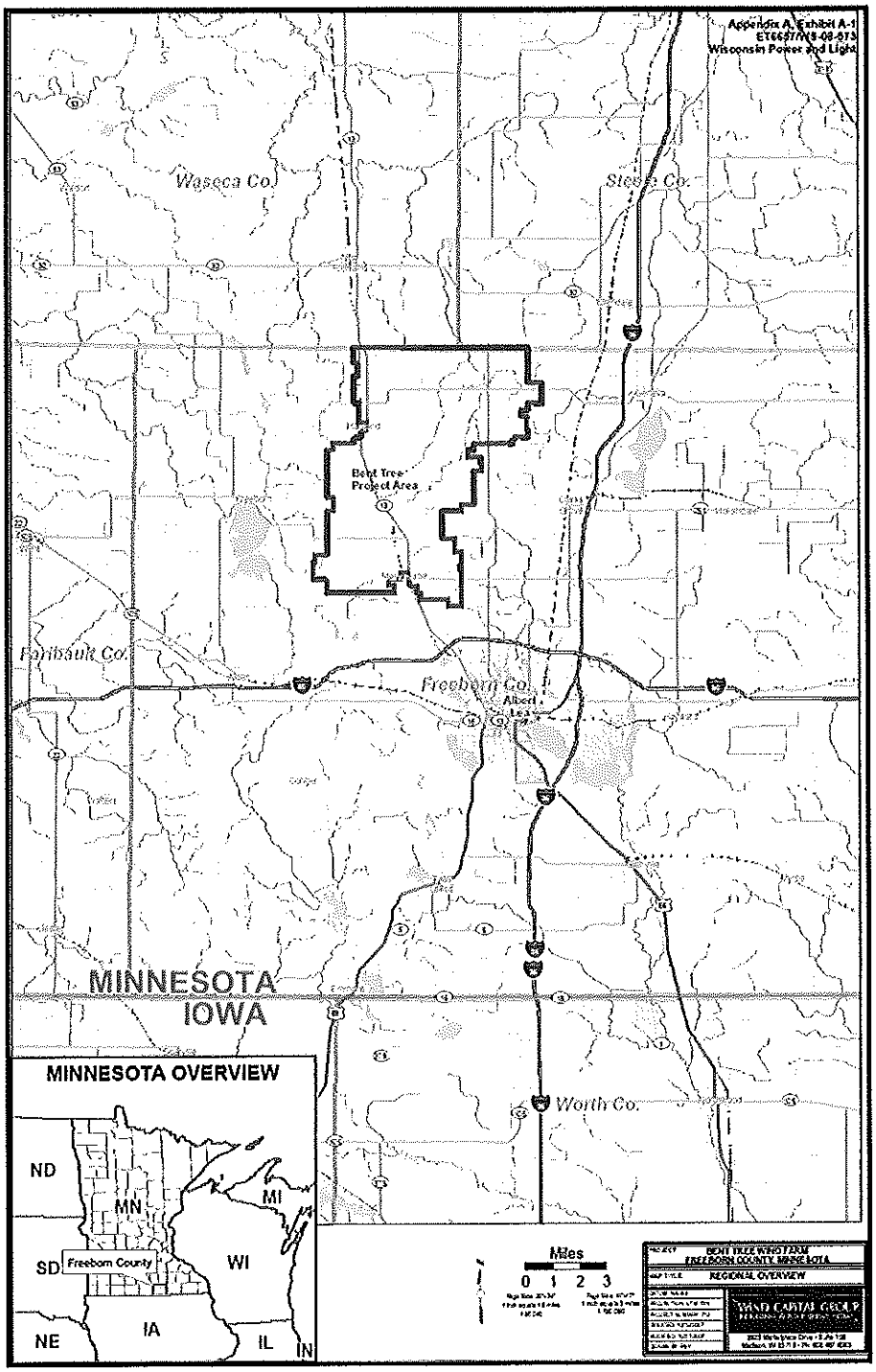
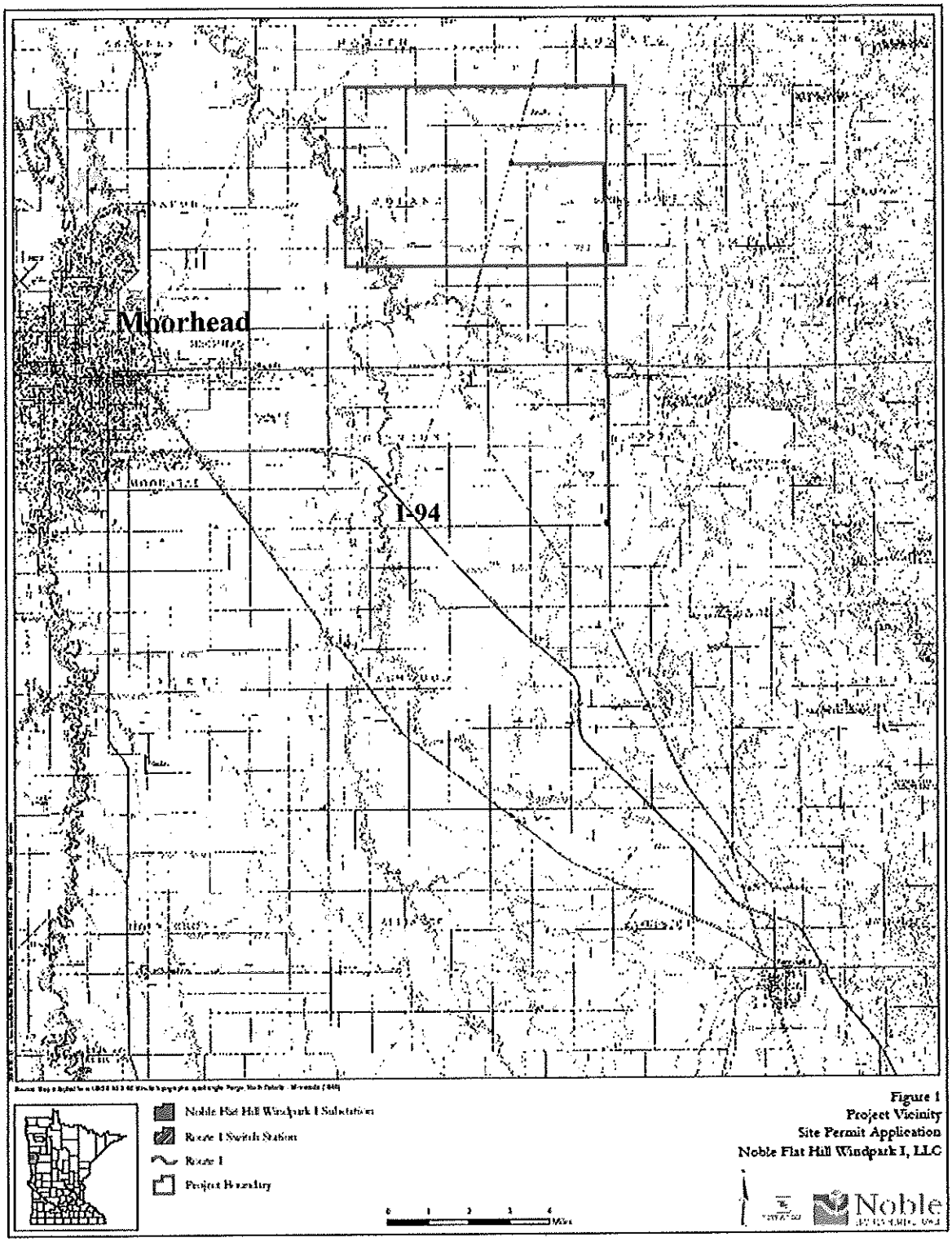


Figure 3: Noble Flat Hill Wind Park, Clay, Becker, Ottertail Counties



B. Health Issues

The National Research Council of the National Academies (NRC, 2007) has reviewed impacts of wind energy projects on human health and well-being. The NRC begins by observing that wind projects, just as other projects, create benefits and burdens, and that concern about impacts is natural when the source is near one's home. Further, the NRC notes that different people have different values and levels of sensitivity. Impacts noted by the NRC that may have the most effect on health include noise and low frequency vibration, and shadow flicker. While noise and vibration are the main focus of this paper, shadow flicker (casting of moving shadows on the ground as wind turbine blades rotate) will also be briefly discussed.

Noise originates from mechanical equipment inside the nacelles of the turbines (gears, generators, etc.) and from interaction of turbine blades with wind. Newer wind turbines generate minimal noise from mechanical equipment. The most problematic wind turbine noise is a broadband "whooshing" sound produced by interaction of turbine blades with the wind. Newer turbines have upwind rotor blades, minimizing low frequency "infrasound" (i.e., air pressure changes at frequencies below 20-100 Hz that are inaudible). However, the NRC notes that during quiet conditions at night, low frequency modulation of higher frequency sounds, such as are produced by turbine blades, is possible. The NRC also notes that effects of low frequency (infrasound) vibration (less than 20 Hz) on humans are not well understood, but have been asserted to disturb some people.

Finally, the NRC concludes that noise produced by wind turbines is generally not a major concern beyond a half mile. Issues raised by the NRC report and factors that may affect distances within which wind turbine noise may be problematic are discussed more extensively below.

II. Elementary Characteristics of Sensory Systems and Sound

A. Sensory Systems

1. Hearing

Sensory systems respond to a huge dynamic range of physical stimuli within a relatively narrow dynamic range of mechanical, chemical and/or neuronal (electrophysiological) output. Compression of the dynamic range is accomplished by systems that respond to logarithmic increases in intensity of physical stimuli with arithmetically increasing sensory responses. This general property is true for hearing, and has been recognized since at least the mid-19th century (see e.g., Woodworth and Schlosberg, 1964). "Loudness" is the sensory/perceptual correlate of the physical intensity of air pressure changes to which the electro-mechanical transducers in the ear and associated neuronal pathways are sensitive. Loudness increases as the logarithm of air pressure, and it is convenient to relate loudness to a reference air pressure (in dyne/cm^2 or pascals) in tenths of logarithmic units (decibels; dB). Further, the ear is sensitive to only a relatively narrow frequency range of air pressure changes: those between approximately 20 and 20,000 cycles per second or Herz (Hz). In fact, sensitivity varies within this range, so that the sound pressure level relative to a reference value that is audible in the middle of the range

(near 1,000 Hz) is about 4 orders of magnitude smaller than it is at 20 Hz and about 2 orders of magnitude smaller than at 20,000 Hz (Fig. 3). Accordingly, measurements of loudness in dB generally employ filters to equalize the loudness of sounds at different frequencies or "pitch." To approximate the sensitivity of the ear, A-weighted filters weigh sound pressure changes at frequencies in the mid-range more than those at higher or lower frequencies. When an A-weighted filter is used, loudness is measured in dB(A). This is explained in greater detail in Section B below.

The ear accomplishes transduction of sound through a series of complex mechanisms (Guyton, 1991). Briefly, sound waves move the eardrum (tympanic membrane), which is in turn connected to 2 small bones (ossicles) in the middle ear (the malleus and incus). A muscle connected to the malleus keeps the tympanic membrane tensed, allowing efficient transmission to the malleus of vibrations on the membrane. Ossicle muscles can also relax tension and attenuate transmission. Relaxation of muscle tension on the tympanic membrane protects the ear from very loud sounds and also masks low frequency sounds, or much background noise. The malleus and incus move a third bone (stapes). The stapes in turn applies pressure to the fluid of the cochlea, a snail-shaped structure imbedded in temporal bone. The cochlea is a complex structure, but for present purposes it is sufficient to note that pressure changes or waves of different frequencies in cochlear fluid result in bending of specialized hair cells in regions of the cochlea most sensitive to different frequencies or pitch. Hair cells are directly connected to nerve fibers in the vestibulocochlear nerve (VIII cranial nerve).

Transmission of sound can also occur directly through bone to the cochlea. This is a very inefficient means of sound transmission, unless a device (e.g. a tuning fork or hearing aid) is directly applied to bone (Guyton, 1991).

2. Vestibular System

The vestibular system reacts to changes in head and body orientation in space, and is necessary for maintenance of equilibrium and postural reflexes, for performance of rapid and intricate body movements, and for stabilizing visual images (via the vestibulo-ocular reflex) as the direction of movement changes (Guyton, 1991).

The vestibular apparatus, like the cochlea, is imbedded in temporal bone, and also like the cochlea, hair cells, bathed in vestibular gels, react to pressure changes and transmit signals to nerve fibers in the vestibulocochlear nerve. Two organs, the utricle and saccule, called otolith organs, integrate information about the orientation of the head with respect to gravity. Otoliths are tiny stone-like crystals, embedded in the gels of the utricle and saccule, that float as the head changes position within the gravitational field. This movement is translated to hair cells. Three semi-circular canals, oriented at right angles to each other, detect head rotation. Stimulation of the vestibular apparatus is not directly detected, but results in activation of motor reflexes as noted above (Guyton, 1991).

Like the cochlea, the vestibular apparatus reacts to pressure changes at a range of frequencies; optimal frequencies are lower than for hearing. These pressure changes can be caused by body movements, or by direct bone conduction (as for hearing, above) when vibration is applied directly to the temporal bone (Todd et al., 2008). These investigators

found maximal sensitivity at 100 Hz, with some sensitivity down to 12.5 Hz. The saccule, located in temporal bone just under the footplate of the stapes, is the most sound-sensitive of the vestibular organs (Halmagyi et al., 2004). It is known that brief loud clicks (90-95 dB) are detected by the vestibular system, even in deaf people. However, we do not know what the sensitivity of this system is through the entire range of sound stimuli.

While vestibular system activation is not directly felt, activation may give rise to a variety of sensations: vertigo, as the eye muscles make compensatory adjustments to rapid angular motion, and a variety of unpleasant sensations related to internal organs. In fact, the vestibular system interacts extensively with the "autonomic" nervous system, which regulates internal body organs (Balaban and Yates, 2004). Sensations and effects correlated with intense vestibular activation include nausea and vomiting and cardiac arrhythmia, blood pressure changes and breathing changes.

While these effects are induced by relatively intense stimulation, it is also true that A-weighted sound measurements attuned to auditory sensitivity, will underweight low frequencies for which the vestibular system is much more sensitive (Todd et al., 2008). Nevertheless, activation of the vestibular system *per se* obviously need not give rise to unpleasant sensations. It is not known what stimulus intensities are generally required for for autonomic activation at relatively low frequencies, and it is likely that there is considerable human variability and capacity to adapt to vestibular challenges.

B. Sound

1. Introduction

Sound is carried through air in compression waves of measurable frequency and amplitude. Sound can be tonal, predominating at a few frequencies, or it can contain a random mix of a broad range of frequencies and lack any tonal quality (white noise). Sound that is unwanted is called noise.

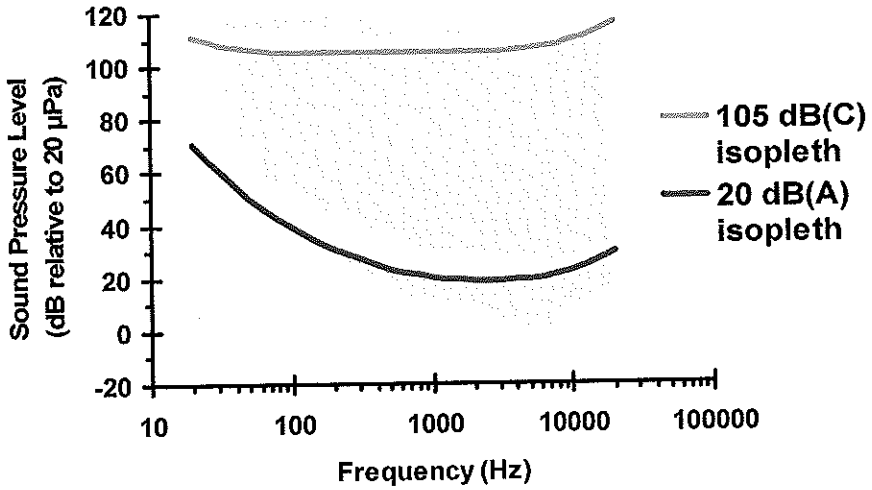
Audible Frequency Sound

Besides frequency sensitivity (between 20 and 20,000 Hz), humans are also sensitive to changes in the amplitude of the signal (compression waves) within this audible range of frequencies. Increasing amplitude, or increasing sound pressure, is perceived as increasing volume or loudness. The sound pressure level in air (SPL) is measured in micro Pascals (μPa). SPLs are typically converted in measuring instruments and reported as decibels (dB) which is a log scale, relative unit (see above). When used as the unit for sound, dBs are reported relative to a SPL of 20 μPa. Twenty μPa is used because it is the approximate threshold of human hearing sensitivity at about 1000 Hz. Decibels relative to 20 μPa are calculated from the following equation:

$$\text{Loudness (dB)} = \text{Log}\left((\text{SPL} / 20\ \mu\text{Pa})^2\right) * 10$$

Figure 4 shows the audible range of normal human hearing. Note that while the threshold sensitivity varies over the frequency range, at high SPLs sensitivity is relatively consistent over audible frequencies.

Figure 4: Audible Range of Human Hearing



Equivalence curves for different frequencies, when sound meter readings in dB are taken with A or C-weighting filters. (Adapted from EPD Hong Kong SAR, 2009)

Sub-Audible Frequency Sound

Sub-audible frequency sound is often called infrasound. It may be sensed by people, similar to audible sound, in the cochlear apparatus in the ear; it may be sensed by the vestibular system which is responsible for balance and physical equilibrium; or it may be sensed as vibration.

Resonance and modulation

Sound can be attenuated as it passes through a physical structure. However, because the wavelength of low frequency sound is very long (the wavelength of 40 Hz in air at sea level and room temperature is 8.6 meters or 28 ft), low frequencies are not effectively attenuated by walls and windows of most homes or vehicles. (For example, one can typically hear the bass, low frequency music from a neighboring car at a stoplight, but not the higher frequencies.) In fact, it is possible that there are rooms within buildings exposed to low frequency sound or noise where some frequencies may be amplified by resonance (e.g. ½ wavelength, ¼ wavelength) within the structure. In addition, low frequency sound can cause vibrations within a building at higher, more audible frequencies as well as throbbing or rumbling.

Sounds that we hear generally are a mixture of different frequencies. In most instances these frequencies are added together. However, if the source of the sound is not constant, but changes over time, the effect can be re-occurring pulses of sound or low frequency modulation of sound. This is the type of sound that occurs from a steam engine, a jack hammer, music and motor vehicle traffic. Rhythmic, low frequency pulsing of higher frequency noise (like the sound of an amplified heart beat) is one type of sound that can be caused by wind turbine blades under some conditions.

2. Human Response to Low Frequency Stimulation

There is no consensus whether sensitivity below 20 Hz is by a similar or different mechanism than sensitivity and hearing above 20 Hz (Reviewed by Møller and Pedersen, 2004). Possible mechanisms of sensation caused by low frequencies include bone conduction at the applied frequencies, as well as amplification of the base frequency and/or harmonics by the auditory apparatus (eardrum and ossicles) in the ear. Sensory thresholds are relatively continuous, suggesting (but not proving) a similar mechanism above and below 20 Hz. However, it is clear that cochlear sensitivity to infrasound (< 20 Hz) is considerably less than cochlear sensitivity to audible frequencies.

Møller and Pedersen (2004) reviewed human sensitivity at low and infrasonic frequencies. The following findings are of interest:

- When whole-body pressure-field sensitivity is compared with ear-only (earphone) sensitivity, the results are very similar. These data suggest that the threshold sensitivity for low frequency is through the ear and not vestibular.
- Some individuals have extraordinary sensitivity at low frequencies, up to 25 dB more sensitive than the presumed thresholds at some low frequencies.
- While population average sensitivity over the low frequency range is smooth, sound pressure thresholds of response for individuals do not vary smoothly but are inconsistent, with peaks and valleys or "microstructures". Therefore the sensitivity response of individuals to different low frequency stimulation may be difficult to predict.
- Studies of equal-loudness-levels demonstrate that as stimulus frequency decreases through the low frequencies, equal-loudness lines compress in the dB scale. (See Figure 4 as an example of the relatively small difference in auditory SPL range between soft and loud sound at low frequencies).
- The hearing threshold for pure tones is different than the hearing threshold for white noise at the same total sound pressure.

3. Sound Measurements

Sound measurements are taken by instruments that record sound pressure or the pressure of the compression wave in the air. Because the loudness of a sound to people is usually the primary interest in measuring sound, normalization schemes or filters have been applied to absolute measurements. dB(A) scaling of sound pressure measurements was intended to normalize readings to equal loudness over the audible range of frequencies at low loudness. For example, a 5,000 Hz (5 kHz) and 20 dB(A) tone is expected to have the same intensity or loudness as a 100 Hz, 20 dB(A) tone. However, note that the absolute sound pressures would be about 20,000 μPa and 40,000 μPa, respectively, or about a difference of 20 dB (relative to 20 μPa), or as it is sometimes written 20 dB(linear).

Most sound is not a single tone, but is a mixture of frequencies within the audible range. A sound meter can add the total SPLs for all frequencies; in other words, the dB readings over the entire spectrum of audible sound can be added to give a single loudness metric. If sound is reported as A-weighted, or dB(A), it is a summation of the dB(A) scaled sound pressure from 20 Hz to 20 kHz.

In conjunction with the dB(A) scale, the dB(B) scale was developed to approximate equal loudness to people across audible frequencies at medium loudness, and dB(C) was developed to approximate equal-loudness for loud environments. Figure 4 shows isopleths for 20 dB(A) and 105 dB(C). While dB(A), dB(B), dB(C) were developed from empirical data at the middle frequencies, at the ends of the curves these scales were extrapolated, or sketched in, and are not based on experimental or observational data (Berglund et al., 1996). As a result, data in the low frequency range (and probably the highest audible frequencies as well) cannot be reliably interpreted using these scales. The World Health Organization (WHO, 1999) suggests that A-weighting noise that has a large low frequency component is not reliable assessment of loudness.

The source of the noise, or the noise signature, may be important in developing equal-loudness schemes at low frequencies. C-weighting has been recommended for artillery noise, but a linear, unweighted scale may be even better at predicting a reaction (Berglund et al., 1996). A linear or equal energy rating also appears to be the most effective predictor of reaction to low frequency noise in other situations, including blast noise from mining. The implication of the analysis presented by Berglund et al. (1996) is that annoyance from non-tonal noise should not be estimated from a dB(A) scale, but may be better evaluated using dB(C), or a linear non-transformed scale.

However, as will be discussed below, a number of schemes use a modified dB(A) scale to evaluate low frequency noise. These schemes differ from a typical use of the dB(A) scale by addressing a limited frequency range below 250 Hz, where auditory sensitivity is rapidly changing as a function of frequency (see Figure 4).

III. Exposures of Interest

A. Noise From Wind Turbines

1. Mechanical noise

Mechanical noise from a wind turbine is sound that originates in the generator, gearbox, yaw motors (that intermittently turn the nacelle and blades to face the wind), tower ventilation system and transformer. Generally, these sounds are controlled in newer wind turbines so that they are a fraction of the aerodynamic noise. Mechanical noise from the turbine or gearbox should only be heard above aerodynamic noise when they are not functioning properly.

2. Aerodynamic noise

Aerodynamic noise is caused by wind passing over the blade of the wind turbine. The tip of a 40-50 meter blade travels at speeds of over 140 miles per hour under normal operating conditions. As the wind passes over the moving blade, the blade interrupts the laminar flow of air, causing turbulence and noise. Current blade designs minimize the amount of turbulence and noise caused by wind, but it is not possible to eliminate turbulence or noise.

Aerodynamic noise from a wind turbine may be underestimated during planning. One source of error is that most meteorological wind speed measurements noted in wind farm literature are taken at 10 meters above the ground. Wind speed above this elevation, in

much less than the difference at night (1.85 m/s (4.1 mph) and 4.5 m/s (10 mph), respectively). As a result one would expect that the blade angle can be better tuned to the wind speed during the daytime. Consequently, blade noise would be greater at night.

A number of reports have included discussion of aerodynamic modulation (van den Berg, 2005; UK Department of Transport and Industry, 2006; UK Department for Business Enterprise and Regulatory Reform, 2007; van den Berg, 2008). They suggest that aerodynamic modulation is typically underestimated when noise estimates are calculated. In addition, they suggest that detailed modeling of wind, terrain, land use and structures may be used to predict whether modulation of aerodynamic noise will be a problem at a proposed wind turbine site.

4. Wind farm noise

The noise from multiple turbines similarly distant from a residence can be noticeably louder than a lone turbine simply through the addition of multiple noise sources. Under steady wind conditions noise from a wind turbine farm may be greater than noise from the nearest turbine due to synchrony between noise from more than one turbine (van den Berg, 2005). Furthermore, if the dominant frequencies (including aerodynamic modulation) of different turbines vary by small amounts, an audible beat or dissonance may be heard when wind conditions are stable.

B. Shadow Flicker

Rhythmic light flicker from the blades of a wind turbine casting intermittent shadows has been reported to be annoying in many locations (NRC, 2007; Large Wind Turbine Citizens Committee, 2008). (Note: Flashing light at frequencies around 1 Hz is too slow to trigger an epileptic response.)

Modeling conducted by the Minnesota Department of Health suggests that a receptor 300 meters perpendicular to, and in the shadow of the blades of a wind turbine, can be in the flicker shadow of the rotating blade for almost 1½ hour a day. At this distance a blade may completely obscure the sun each time it passes between the receptor and the sun. With current wind turbine designs, flicker should not be an issue at distances over 10 rotational diameters (~1000 meters or 1 km (0.6 mi) for most current wind turbines). This distance has been recommended by the Wind Energy Handbook (Burton et al., 2001) as a minimum setback distance in directions that flicker may occur, and has been noted in the Bent Tree Permit Application (WPL, 2008).

Shadow flicker is a potential issue in the mornings and evenings, when turbine noise may be masked by ambient sounds. While low frequency noise is typically an issue indoors, shadow flicker can be an issue both indoors and outdoors when the sun is low in the sky. Therefore, shadow flicker may be an issue in locations other than the home.

Ireland recommends wind turbines setbacks of at least 300 meters from a road to decrease driver distraction (Michigan State University, 2004). The NRC (2007) recommends that shadow flicker is addressed during the preliminary planning stages of a wind turbine project.

IV. Impacts of Wind Turbine Noise

A. Potential Adverse Reaction to Sound

Human sensitivity to sound, especially to low frequency sound, is variable. Individuals have different ranges of frequency sensitivity to audible sound; different thresholds for each frequency of audible sound; different vestibular sensitivities and reactions to vestibular activation; and different sensitivity to vibration.

Further, sounds, such as repetitive but low intensity noise, can evoke different responses from individuals. People will exhibit variable levels of annoyance and tolerance for different frequencies. Some people can dismiss and ignore the signal, while for others, the signal will grow and become more apparent and unpleasant over time (Moreira and Bryan, 1972; Bryan and Tempest, 1973). These reactions may have little relationship to will or intent, and more to do with previous exposure history and personality.

Stress and annoyance from noise often do not correlate with loudness. This may suggest, in some circumstances, other factors impact an individual's reaction to noise. A number of reports, cited in Staples (1997), suggest that individuals with an interest in a project and individuals who have some control over an environmental noise are less likely to find a noise annoying or stressful.

Berglund et al. (1996) reviewed reported health effects from low frequency noise. Loud noise from any source can interfere with verbal communication and possibly with the development of language skills. Noise may also impact mental health. However, there are no studies that have looked specifically at the impact of low frequency noise on communication, development of language skills and mental health. Cardiovascular and endocrine effects have been demonstrated in studies that have looked at exposures to airplane and highway noise. In addition, possible effects of noise on performance and cognition have also been investigated, but these health studies have not generally looked at impacts specifically from low frequency noise. Noise has also been shown to impact sleep and sleep patterns, and one study demonstrated impacts from low frequency noise in the range of 72 to 85 dB(A) on chronic insomnia (Nagai et al., 1989 as reported in Berglund et al., 1996).

Case studies have suggested that health can be impacted by relatively low levels of low frequency noise. But it is difficult to draw general conclusions from case studies. Feldmann and Pitten (2004)) describe a family exposed during the winter to low frequency noise from a nearby heating plant. Reported health impacts were: "indisposition, decrease in performance, sleep disturbance, headache, ear pressure, crawl parästhesy [crawling, tingling or numbness sensation on the skin] or shortness of breath."

Annoyance, unpleasant sounds, and complaints

Reported health effects from low frequency stimulation are closely associated with annoyance from audible noise. "There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects" (WHO, 1999). It has not been shown whether annoyance is a symptom or an accessory in the causation of

health impacts from low frequency noise. Studies have been conducted on some aspects of low frequency noise that can cause annoyance.

Noise complaints are usually a reasonable measure of annoyance with low frequency environmental noise. Leventhall (2004) has reviewed noise complaints and offers the following conclusions:

> " 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 throb or rumble 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 descriptors of low frequency noise problems."

These observations are consistent with what we know about the propagation of low intensity, low frequency noise. Some people are more sensitive to low frequency noise. The difference, in dB, between soft (acceptable) and loud (annoying) noise is much less at low frequency (see Figure 4 audible range compression). Furthermore, during the daytime, and especially outdoors, annoying low frequency noise can be masked by high frequency noise.

The observation that "the noise was typically audible indoors and not outdoors" is not particularly intuitive. However, as noted in a previous section, low frequencies are not well attenuated when they pass through walls and windows. Higher frequencies (especially above 1000 Hz) can be efficiently attenuated by walls and windows. In addition, low frequency sounds may be amplified by resonance within rooms and halls of a building. Resonance is often characterized by a throbbing or a rumbling, which has also been associated with many low frequency noise complaints.

Low frequency noise, unlike higher frequency noise, can also be accompanied by shaking, vibration and rattling. In addition, throbbing and rumbling may be apparent in some low frequency noise. While these noise features may not be easily characterized, numerous studies have shown that their presence dramatically lowers tolerance for low frequency noise (Berglund et al., 1996).

As reviewed in Leventhall (2003), a study of industrial exposure to low frequency noise found that fluctuations in total noise averaged over 0.5, 1.0 and 2.0 seconds correlated with annoyance (Holmberg et al., 1997). This association was noted elsewhere and led (Broner and Leventhall, 1983) to propose a 3dB "penalty" be added to evaluations of annoyance in cases where low frequency noise fluctuated.

In another laboratory study with test subjects controlling loudness, 0.5 – 4 Hz modulation of low frequency noise was found to be more annoying than non-modulated low

frequency noise. On average test subjects found modulated noise to be similarly annoying as a constant tone 12.9 dB louder (Bradley, 1994).

B. Studies of Wind Turbine Noise Impacts on People

1. Swedish Studies

Two studies in Sweden collected information by questionnaires from 341 and 754 individuals (representing response rates of 68% and 58%, respectively), and correlated responses to calculated exposure to noise from wind farms (Pedersen and Waye, 2004; Pedersen, 2007; Pedersen and Persson, 2007). Both studies showed that the number of respondents perceiving the noise from the wind turbines increased as the calculated noise levels at their homes increased from less than 32.5 dB(A) to greater than 40 dB(A). Annoyance appeared to correlate or trend with calculated noise levels. Combining the data from the two studies, when noise measurements were greater than 40 dB(A), about 50% of the people surveyed (22 of 45 people) reported annoyance. When noise measurements were between 35 and 40 dB(A) about 24% reported annoyance (67 of 276 people). Noise annoyance was more likely in areas that were rated as quiet and in areas where turbines were visible. In one of the studies, 64% respondents who reported noise annoyance also reported sleep disturbance; 15% of respondents reported sleep disturbance without annoyance.

2. United Kingdom Study

Moorhouse et al. (UK Department for Business Enterprise and Regulatory Reform, 2007) evaluated complaints about wind farms. They found that 27 of 133 operating wind farms in the UK received formal complaints between 1991 and 2007. There were a total of 53 complainants for 16 of the sites for which good records were available. The authors of the report considered that many complaints in the early years were for generator and gearbox noise. However, subjective analyses of reports about noise ("like a train that never gets there", "distant helicopter", "thumping", "thudding", "pulsating", "thumping", "rhythmical beating", and "beating") suggested that aerodynamic modulation was the likely cause of complaints at 4 wind farms. The complaints from 8 other wind farms may have had "marginal" association with aerodynamic modulation noise.

Four wind farms that generated complaints possibly associated with aerodynamic modulation were evaluated further. These wind farms were commissioned between 1999 and 2002. Wind direction, speed and times of complaints were associated for 2 of the sites and suggested that aerodynamic modulation noise may be a problem between 7% and 25% of the time. Complaints at 2 of the farms have stopped and at one farm steps to mitigate aerodynamic modulation (operational shutdown under certain meteorological conditions) have been instituted.

3. Netherlands Study

F. van den Berg et al. (2008) conducted a postal survey of a group selected from all residents in the Netherlands within 2.5 kilometers (km) of a wind turbine. In all, 725 residents responded (37%). Respondents were exposed to sound between 24 and 54 dB(A). The percentage of respondents annoyed by sound increased from 2% at levels of 30 dB(A) or less, up to 25% at between 40 and 45 dB. Annoyance decreased above 45 dB. Most residents exposed above 45 dB(A) reported economic benefits from the

turbines. However, at greater than 45 dB(A) more respondents reported sleep interruption. Respondents tended to report more annoyance when they also noted a negative effect on landscape, and ability to see the turbines was strongly related to the probability of annoyance.

4. Case Reports

A number of un-reviewed reports have catalogued complaints of annoyance and some more severe health impacts associated with wind farms. These reports do not contain measurements of noise levels, and do not represent random samples of people living near wind turbines, so they cannot assess prevalence of complaints. They do generally show that in the people surveyed, complaints are more likely the closer people are to the turbines. The most common complaint is decreased quality of life, followed by sleep loss and headache. Complaints seem to be either from individuals with homes quite close to turbines, or individuals who live in areas subject to aerodynamic modulation and, possibly, enhanced sound propagation which can occur in hilly or mountainous terrain. In some of the cases described, people with noise complaints also mention aesthetic issues, concern for ecological effects, and shadow flicker concerns. Not all complaints are primarily about health.

Harry (2007) describes a meeting with a couple in Cornwall, U.K. who live 400 meters from a wind turbine, and complained of poor sleep, headaches, stress and anxiety. Harry subsequently investigated 42 people in various locations in the U.K. living between 300 meters and 2 kilometers (1000 feet to 1.2 miles) from the nearest wind turbine. The most frequent complaint (39 of 42 people) was that their quality of life was affected. Headaches were reported by 27 people and sleep disturbance by 28 people. Some people complained of palpitations, migraines, tinnitus, anxiety and depression. She also mentions correspondence and complaints from people in New Zealand, Australia, France, Germany, Netherlands and the U.S.

Phipps (2007) discusses a survey of 619 households living up to 10 kilometers (km; 6 miles) from wind farms in mountainous areas of New Zealand. Most respondents lived between 2 and 2.5 km from the turbines (over 350 households). Most respondents (519) said they could see the turbines from their homes, and 80% of these considered the turbines intrusive, and 73% considered them unattractive. Nine percent said they were affected by flicker. Over 50% of households located between 2 and 2.5 km and between 5 and 9.5 km reported being able to hear the turbines. In contrast, fewer people living between 3 and 4.5 km away could hear the turbines. Ninety-two households said that their quality of life was affected by turbine noise. Sixty-eight households reported sleep disturbances: 42 of the households reported occasional sleep disturbances, 21 reported frequent sleep disturbances and 5 reported sleep disturbances most of the time.

The Large Wind Turbine Citizens Committee for the Town of Union (2008) documents complaints from people living near wind turbines in Wisconsin communities and other places in the U.S. and U.K. Contained in this report is an older report prepared by the Wisconsin Public Service Corporation in 2001 in response to complaints in Lincoln County, Wisconsin. The report found essentially no exceedances of the 50 dB(A) requirement in the conditional use permit. The report did measure spectral data

accumulated over very short intervals (1 minute) in 1/3 octave bands at several sites while the wind turbines were functioning, and it is of interest that at these sites the sound pressure level at the lower frequencies (below 125 Hz) were at or near 50 dB(A).

Pierpont (2009) postulates wind turbine syndrome, consisting of a constellation of symptoms including headache, tinnitus, ear pressure, vertigo, nausea, visual blurring, tachycardia, irritability, cognitive problems and panic episodes associated with sensations of internal pulsation. She studied 38 people in 10 families living between 1000 feet and slightly under 1 mile from newer wind turbines. She proposes that the mechanism for these effects is disturbance of balance due to "discordant" stimulation of the vestibular system, along with visceral sensations, sensations of vibration in the chest and other locations in the body, and stimulation of the visual system by moving shadows. Pierpont does report that her study subjects maintain that their problems are caused by noise and vibration, and the most common symptoms reported are sleep disturbances and headache. However, 16 of the people she studied report symptoms consistent with (but not necessarily caused by) disturbance of equilibrium.

V. Noise Assessment and Regulation

1. Minnesota noise regulation

The Minnesota Noise Pollution Control Rule is accessible online at: https://www.revisor.leg.state.mn.us/rules/?id=7030 . A summary of the Minnesota Pollution Control Agency (MPCA) noise guidance can be found online at: http://www.pca.state.mn.us/programs/noise.html . The MPCA standards require A-weighting measurements of noise; background noise must be at least 10 dB lower than the noise source being measured. Different standards are specified for day and night, as well as standards that may not be exceeded for more than 10 percent of the time during any hour (L10) and 50 percent of the time during any hour (L50). Household units, including farm houses, are Classification 1 land use. The following are the Class 1 noise limits:

Table 1: Minnesota Class 1 Land Use Noise Limits

Daytime		Nighttime	
L50	L10	L50	L10
60 dB(A)	65 dB(A)	50 dB(A)	55 dB(A)

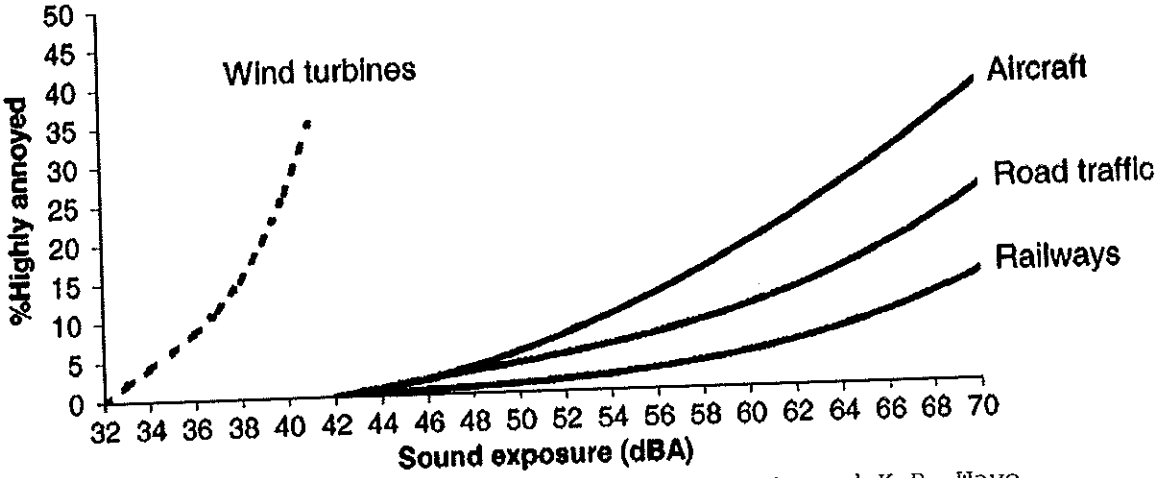
These noise limits are single number limits that rely on the measuring instrument to apply an A-weighting filter over the entire presumed audible spectrum of frequencies (20 Hz to 20 KHz) and then integrating that signal. The result is a single number that characterizes the audible spectrum noise intensity.

2. Low frequency noise assessment and regulation

Pedersen and Waye (2004) looked at the relationship between total dB(A) sound pressure and the annoyance of those who are environmentally exposed to noise from different sources. Figure 6 demonstrates the difficulty in using total dB(A) to evaluate annoyance. Note how lower noise levels (dB(A)) from wind turbines engenders annoyance similar to

much higher levels of noise exposure from aircraft, road traffic and railroads. Sound impulsiveness, low frequency noise and persistence of the noise, as well as demographic characteristics may explain some of the difference.

Figure 6: Annoyance associated with exposure to different environmental noises



Reprinted with permission from Pedersen, E. and K.P. Waye (2004). Perception and annoyance due to wind turbine noise–a dose-response relationship. The Journal of the Acoustical Society of America 116: 3460. Copyright 2004, Acoustical Society of America.

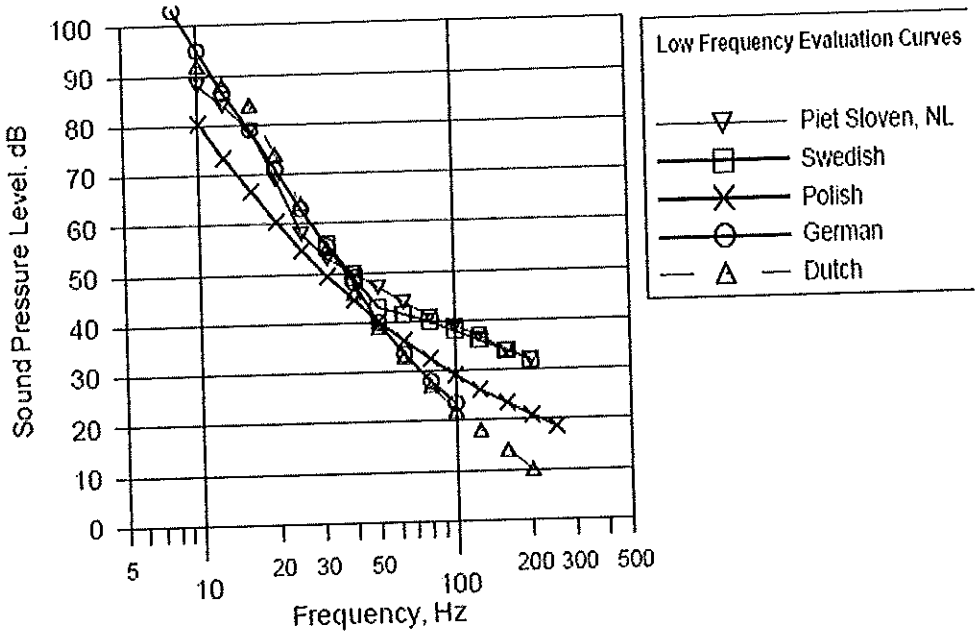
Kjellberg et al. (1997) looked at the ability of different full spectrum weighting schemes to predict annoyance caused by low frequency audio noise. They found that dB(A) is the worst predictor of annoyance of available scales. However, if 6 dB ("penalty") is added to dB(A) when dB(C) – dB(A) is greater than 15 dB, about 71% of the predictions of annoyance are correct. It is important to remember that integrated, transformed measurements of SPL (e.g. dB(A), dB(C)) do not measure frequencies below 20 Hz. While people detect stimuli below 20 Hz, as discussed in above sections, these frequencies are not measured using an A-weighted or C-weighted meter.

The World Health Organization (WHO) recommends that if dB(C) is greater than 10 dB more than dB(A), the low frequency components of the noise may be important and should be evaluated separately. In addition, WHO says "[i]t should be noted that a large proportion of low-frequency components in noise may increase considerably the adverse effects on health." (WHO, 1999)

Many governments that regulate low frequency noise look at noise within bands of frequencies instead of summing the entire spectrum. A study by Poulsen and Mortensen (Danish Environmental Protection Agency, 2002) included a summary of low frequency noise guidelines. German, Swedish, Polish, and Dutch low frequency evaluation curves were compared (see Figure 7). While there are distinctions in how the evaluation curves are described, generally, these curves are sound pressure criterion levels for 1/3 octaves from about 8 Hz to 250 Hz. Exceedance in any 1/3 octave measurement suggests that the noise may be annoying. However, note that regulations associated with low frequency

noise can be quite complex and the regulatory evaluations associated with individual curves can be somewhat different.

Figure 7: 1/3 Octave Sound Pressure Level Low frequency Noise Evaluation Curves



(Danish Environmental Protection Agency, 2002)

The Danish low frequency evaluation requires measuring noise indoors with windows closed; SPL measurements are obtained in 1/3 octave bands and transformed using the A-weighting algorithm for all frequencies between 10 and 160 Hz. These values are then summed into a single metric called $L_{pA,LF}$. A 5 dB "penalty" is added to any noise that is "impulsive". Danish regulations require that 20 dB $L_{pA,LF}$ is not exceeded during the evening and night, and that 25 dB $L_{pA,LF}$ is not exceeded during the day.

Swedish guidance recommends analyzing 1/3 octave bands between 31.5 and 200 Hz inside a home, and comparing the values to a Swedish assessment curve. The Swedish curve is equal to the United Kingdom (UK) Department of Environment, Food and Rural Affairs (DEFRA) low frequency noise criterion curve for overlapping frequencies (31.5 – 160 Hz).

The German "A-level" method sums the A-weighted equivalent levels of 1/3 octave bands that exceed the hearing threshold from 10 – 80 Hz. If the noise is not tonal, the measurements are added. The total cannot exceed 25 dB at night and 35 dB during the day. A frequency-dependent adjustment is applied if the noise is tonal.

In the Poulsen and Mortensen, Danish EPA study (2002), 18 individuals reported annoyance levels when they were exposed through earphones in a controlled environment to a wide range of low frequency environmental noises, all attenuated down to 35 dB, as depicted in Table 2. Noise was simulated as if being heard indoors, filtering out noise at

higher frequencies and effectively eliminating all frequencies above 1600 Hz. Noise levels in 1/3 octave SPLs from 8 Hz to 1600 Hz were measured and low frequencies (below 250 Hz) were used to predict annoyance using 7 different methods (Danish, German A-level, German tonal, Swedish, Polish, Sloven, and C-level). Predictions of annoyance were compared with the subjective annoyance evaluations. Correlation coefficients for these analyses ranged from 0.64 to 0.94, with the best correlation in comparison with the Danish low frequency noise evaluation methods.

As would be expected, at 35 dB nominal (full spectrum) loudness, every low frequency noise source tested exceeded all of the regulatory standards noted in the Danish EPA report. Table 2 shows the Danish and Swedish regulatory exceedances of the different 35 dB nominal (full spectrum) noise.

Table 2: 35 dB(A) (nominal, 8 Hz-20KHz) Indoor Noise from Various Outdoor Environmental Sources

	Traffic Noise	Drop Forge	Gas Turbine	Fast Ferry	Steel Factory	Generator	Cooling Compressor	Discotheque
Noise	67.6 dB(lin)	71.1 dB(lin)	78.4 dB(lin)	64.5 dB(lin)	72.7 dB(lin)	60.2 dB(lin)	60.3 dB(lin)	67.0 dB(lin)
Noise ≥ 20 Hz	35.2 dB(A)	36.6 dB(A)	35.0 dB(A)	35.1 dB(A)	33.6 dB(A)	36.2 dB(A)	36.6 dB(A)	33.6 dB(A)
	62.9 dB(C)	67.3 dB(C)	73.7 dB(C)	61.7 dB(C)	66.0 dB(C)	58.6 dB(C)	59.0 dB(C)	57.8 dB(C)
Danish Environmental Protection Agency	14.5 dB	21.5 dB *	14.8 dB	15.0 dB	13.1 dB	16.1 dB	14.0 dB	18.0 dB *
Swedish National Board of Health and Welfare	14.1 dB	19.7 dB	15.9 dB	16.8 dB	15.5 dB	18.3 dB	16.0 dB	10.0 dB

* includes 5 dB "penalty"

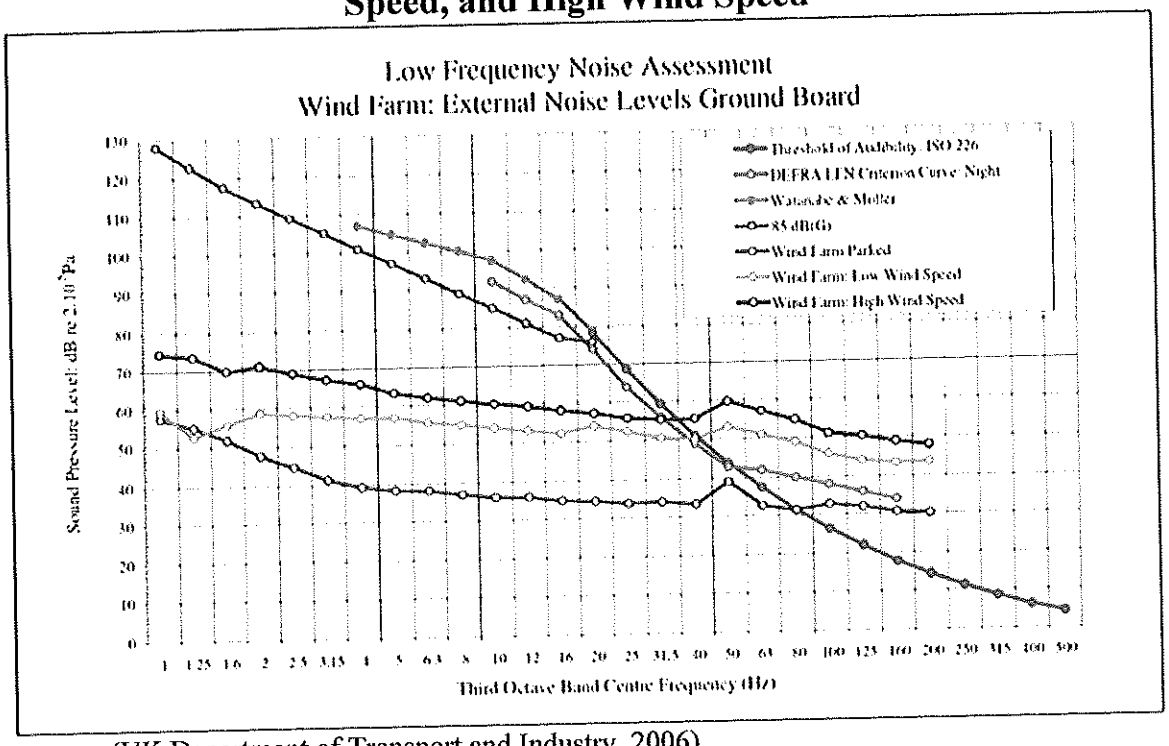
Noise adjusted to dB(lin), dB(A), dB(C) scales. Calculated exceedances of Danish and Swedish indoor criteria. (data from Danish Environmental Protection Agency, 2002)

In their noise guidance, the WHO (1999) recommends 30 dB(A) as a limit for "a good night's sleep". However, they also suggest that guidance for noise with predominating low frequencies be less than 30 dB(A).

3. Wind turbine sound measurements

Figure 8 shows examples of the SPLs at different frequencies from a representative wind turbine in the United Kingdom. Sound pressure level measurements are reported for a Nordex N-80 turbine at 200 meters (UK Department of Transport and Industry, 2006) when parked, at low wind speeds, and at high wind speeds. Figure 8 also includes, for reference, 3 sound threshold curves (ISO 226, Watanabe & Moller, 85 dB(G)) and the DEFRA Low Frequency Noise Criterion Curve (nighttime).

Figure 8: Low Frequency Noise from Wind Farm: Parked, Low Wind Speed, and High Wind Speed

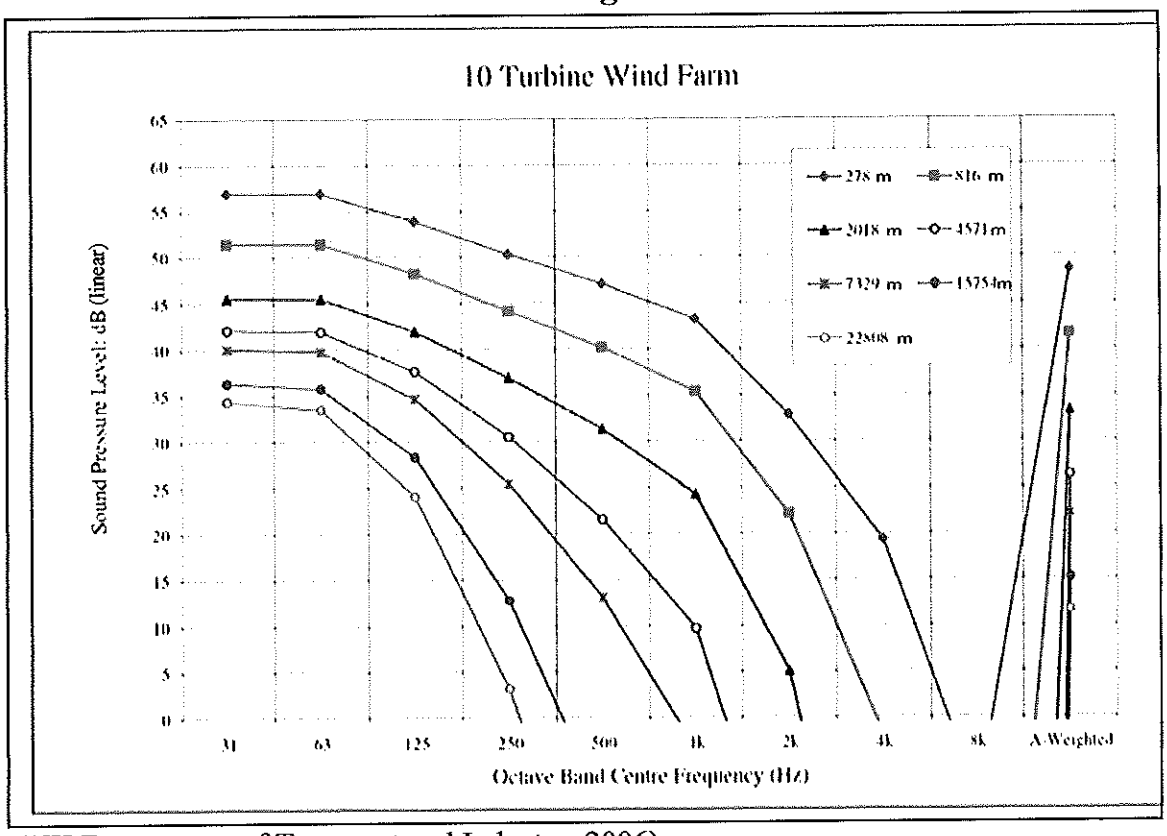


(UK Department of Transport and Industry, 2006)

In general, sound tends to propagate as if by spherical dispersion. This creates amplitude decay at a rate of about -6 dB per doubling of distance. However, low frequency noise from a wind turbine has been shown to follow more of a cylindrical decay at long distances, about -3 dB per doubling of distance in the downwind direction (Shepherd and Hubbard, 1991). This is thought to be the result of the lack of attenuation of low frequency sound waves by air and the atmospheric refraction of the low frequency sound waves over medium to long distances (Hawkins, 1987).

Figure 9 shows the calculated change in spectrum for a wind farm from 278 meters to 22,808 meters distant. As one moves away from the noise source, loudness at higher frequencies decreases more rapidly (and extinguishes faster) than at lower frequencies. Measurement of A-weighted decibels, shown at the right of the figure, obscures this finding.

Figure 9: Change in Noise Spectrum as Distance from Wind Farm Changes



(UK Department of Transport and Industry, 2006)

Thus, although noise from an upwind blade wind turbine is generally broad spectrum, without a tonal quality, high frequencies are efficiently attenuated by both the atmosphere, and by walls and windows of structures, as noted above. As a result, as one moves away from a wind turbine, the low frequency component of the noise becomes more pronounced.

Kamperman and James (2008) modeled indoor noise from outdoor wind turbine noise measurements, assuming a typical vinyl siding covered 2X4 wood frame construction. The wind turbine noise inside was calculated to be 5 dB less than the noise outside. Model data suggested that the sound of a single 2.5 MW wind turbine at 1000 feet will likely be heard in a house with the windows sealed. They note that models used for siting turbines often incorporate structure attenuation of 15dB. In addition, Kamperman and James demonstrate that sound from 10 2.5 MW turbines (acoustically) centered 2 km (1¼ mile) away and with the nearest turbine 1 mile away will only be 6.3 dB below the sound of a single turbine at 1000 feet (0.19 mile).

4. Wind turbine regulatory noise limits

Ramakrishnan (2007) has reported different noise criteria developed for wind farm planning. These criteria include common practices (if available) within each jurisdiction for estimating background SPLs, turbine SPLs, minimum setbacks and methods used to

assess impacts. Reported US wind turbine noise criteria range from: ambient + 10 dB(A) where ambient is assumed to be 26 dB(A) (Oregon); to 55 dB(A) or "background" + 5 dB(A) (Michigan). European criteria range from 35 dB(A) to 45 dB(A), at the property. US setbacks range from 1.1 times the full height of the turbine (consenting) and 5 times the hub height (non-consenting; Pennsylvania); to 350 m (consenting) and 1000 m (non-consenting; Oregon). European minimum setbacks are not noted.

VI. Conclusions

Wind turbines generate a broad spectrum of low-intensity noise. At typical setback distances higher frequencies are attenuated. In addition, walls and windows of homes attenuate high frequencies, but their effect on low frequencies is limited. Low frequency noise is primarily a problem that may affect some people in their homes, especially at night. It is not generally a problem for businesses, public buildings, or for people outdoors.

The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A). It has been hypothesized that direct activation of the vestibular and autonomic nervous system may be responsible for less common complaints, but evidence is scant.

The Minnesota nighttime standard of 50 dB(A) not to be exceeded more than 50% of the time in a given hour, appears to underweight penetration of low frequency noise into dwellings. Different schemes for evaluating low frequency noise, and/or lower noise standards, have been developed in a number of countries.

For some projects, wind velocity for a wind turbine project is measured at 10 m and then modeled to the height of the rotor. These models may under-predict wind speed that will be encountered when the turbine is erected. Higher wind speed will result in noise exceeding model predictions.

Low frequency noise from a wind turbine is generally not easily perceived beyond ½ mile. However, if a turbine is subject to aerodynamic modulation because of shear caused by terrain (mountains, trees, buildings) or different wind conditions through the rotor plane, turbine noise may be heard at greater distances.

Unlike low frequency noise, shadow flicker can affect individuals outdoors as well as indoors, and may be noticeable inside any building. Flicker can be eliminated by placement of wind turbines outside of the path of the sun as viewed from areas of concern, or by appropriate setbacks.

Prediction of complaint likelihood during project planning depends on: 1) good noise modeling including characterization of potential sources of aerodynamic modulation noise and characterization of nighttime wind conditions and noise; 2) shadow flicker modeling; 3) visibility of the wind turbines; and 4) interests of nearby residents and community.

VII. Recommendations

To assure informed decisions:

- Wind turbine noise estimates should include cumulative impacts (40-50 dB(A) isopleths) of all wind turbines.
- Isopleths for dB(C) - dB(A) greater than 10 dB should also be determined to evaluate the low frequency noise component.
- Potential impacts from shadow flicker and turbine visibility should be evaluated.

Any noise criteria beyond current state standards used for placement of wind turbines should reflect priorities and attitudes of the community.

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340-035-0035

Noise Control Regulations for Industry and Commerce

(1) Standards and Regulations:

(a) Existing Noise Sources. No person owning or controlling an existing industrial or commercial noise source shall cause or permit the operation of that noise source if the statistical noise levels generated by that source and measured at an appropriate measurement point, specified in subsection (3)(b) of this rule, exceed the levels specified in Table 7, except as otherwise provided in these rules.

(b) New Noise Sources:

(A) New Sources Located on Previously Used Sites. No person owning or controlling a new industrial or commercial noise source located on a previously used industrial or commercial site shall cause or permit the operation of that noise source if the statistical noise levels generated by that new source and measured at an appropriate measurement point, specified in subsection (3)(b) of this rule, exceed the levels specified in Table 8, except as otherwise provided in these rules. For noise levels generated by a wind energy facility including wind turbines of any size and any associated equipment or machinery, subparagraph (1)(b)(B)(iii) applies.

(B) New Sources Located on Previously Unused Site:

(i) No person owning or controlling a new industrial or commercial noise source located on a previously unused industrial or commercial site shall cause or permit the operation of that noise source if the noise levels generated or indirectly caused by that noise source increase the ambient statistical noise levels, L10 or L50, by more than 10 dBA in any one hour, or exceed the levels specified in Table 8, as measured at an appropriate measurement point, as specified in subsection (3)(b) of this rule, except as specified in subparagraph (1)(b)(B)(iii).

(ii) The ambient statistical noise level of a new industrial or commercial noise source on a previously unused industrial or commercial site shall include all noises generated or indirectly caused by or attributable to that source including all of its related activities. Sources exempted from the requirements of section (1) of this rule, which are identified in subsections (5)(b) - (f), (j), and (k) of this rule, shall not be excluded from this ambient measurement.

(iii) For noise levels generated or caused by a wind energy facility:

(I) The increase in ambient statistical noise levels is based on an assumed background L50 ambient noise level of 26 dBA or the actual ambient background level. The person owning the wind energy facility may conduct measurements to determine the actual ambient L10 and L50 background level .

(II) The "actual ambient background level" is the measured noise level at the appropriate measurement point as specified in subsection (3)(b) of this rule using generally accepted noise engineering measurement practices. Background noise measurements shall be obtained at the appropriate measurement point, synchronized with windspeed measurements of hub height conditions at the nearest wind turbine location. "Actual ambient background level" does not include noise generated or caused by the wind energy facility.

(III) The noise levels from a wind energy facility may increase the ambient statistical noise levels L10 and L_{50} by more than 10 dBA (but not above the limits specified in Table 8), if the person who owns the noise sensitive property executes a legally effective easement or real covenant that benefits the property on which the wind energy facility is located. The easement or covenant must authorize the wind energy facility to increase the ambient statistical noise levels, L_{10} or L_{50} on the sensitive property by more than 10 dBA at the appropriate measurement point.

(IV) For purposes of determining whether a proposed wind energy facility would satisfy the ambient noise standard where a landowner has not waived the standard, noise levels at the appropriate measurement point are predicted assuming that all of the proposed wind facility's turbines are operating between cut-in speed and the wind speed corresponding to the maximum sound power level established by IEC 61400-11 (version 2002-12). These predictions must be compared to the highest of either the assumed ambient noise level of 26 dBA or to the actual ambient background L10 and L50 noise level, if measured. The facility complies with the noise ambient background standard if this comparison shows that the increase in noise is not more than 10 dBA over this entire range of wind speeds.

(V) For purposes of determining whether an operating wind energy facility complies with the ambient noise standard where a landowner has not waived the standard, noise levels at the appropriate measurement point are measured when the facility's nearest wind turbine is operating over the entire range of wind speeds between cut-in speed and the windspeed corresponding to the maximum sound power level and no turbine that could contribute to the noise level is disabled. The facility complies with the noise ambient background standard if the increase in noise over either the assumed ambient noise level of 26 dBA or to the actual ambient background L10 and L50 noise level, if measured, is not more than 10 dBA over this entire range of wind speeds.

(VI) For purposes of determining whether a proposed wind energy facility would satisfy the Table 8 standards, noise levels at the appropriate measurement point are predicted by using the turbine's maximum sound power level following procedures established by IEC 61400-11 (version 2002-12), and assuming that all of the proposed wind facility's turbines are operating at the maximum sound power level.

(VII) For purposes of determining whether an operating wind energy facility satisfies the Table 8 standards, noise generated by the energy facility is measured at the appropriate measurement point when the facility's nearest wind turbine is operating at the windspeed corresponding to the maximum sound power level and no turbine that could contribute to the noise level is disabled.

(c) Quiet Areas. No person owning or controlling an industrial or commercial noise source located either within the boundaries of a quiet area or outside its boundaries shall cause or permit the operation of that noise source if the statistical noise levels generated by that source exceed the levels specified in Table 9 as measured within the quiet area and not less than 400 feet (122 meters) from the noise source.

(d) Impulse Sound. Notwithstanding the noise rules in Tables 7 through 9, no person owning or controlling an industrial or commercial noise source shall cause or permit the operation of that noise source if an impulsive sound is emitted in air by that source which exceeds the sound pressure levels specified below, as measured at an appropriate measurement point, as specified in subsection (3)(b) of this rule:

(A) Blasting. 98 dBC, slow response, between the hours of 7 a.m. and 10 p.m. and 93 dBC, slow response, between the hours of 10 p.m. and 7 a.m.

(B) All Other Impulse Sounds. 100 db, peak response, between the hours of 7 a.m. and 10 p.m. and 80 dB, peak response, between the hours of 10 p.m. and 7 a.m.

(f) Octave Bands and Audible Discrete Tones. When the Director has reasonable cause to believe that the requirements of subsection (1)(a), (b), or (c) of this rule do not adequately protect the health, safety, or welfare of the public as provided for in ORS Chapter 467, the Department may require the noise source to meet the following rules:

(A) Octave Bands. No person owning or controlling an industrial or commercial noise source shall cause or permit the operation of that noise source if such operation generates a median octave band sound pressure level which, as measured at an appropriate measurement point, specified in subsection (3)(b) of this rule, exceeds applicable levels specified in Table 10.

(B) One-third Octave Band. No person owning or controlling an industrial or commercial noise source shall cause or permit the operation of that noise source if such operation generates a median one-third octave band sound pressure level which, as measured at an appropriate measurement point, specified in subsection (3)(b) of this rule, and in a one-third octave band at a preferred frequency, exceeds the arithmetic average of the median sound pressure levels of the two adjacent one-third octave bands by:

(i) 5 dB for such one-third octave band with a center frequency from 500 Hertz to 10,000 Hertz, inclusive. Provided: Such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band; or

(ii) 8 dB for such one-third octave band with a center frequency from 160 Hertz to 400 Hertz, inclusive. Provided: Such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band; or

(iii) 15 dB for such one-third octave band with a center frequency from 25 Hertz to 125 Hertz, inclusive. Provided: Such one-third octave band sound pressure level exceeds the sound pressure level of each adjacent one-third octave band;

(iv) This rule shall not apply to audible discrete tones having a one-third octave band sound pressure level 10 dB or more below the allowable sound pressure levels specified in Table 10 for the octave band which contains such one-third octave band.

(2) Compliance. Upon written notification from the Director, the owner or controller of an industrial or commercial noise source operating in violation of the adopted rules shall submit a compliance schedule acceptable to the Department. The schedule will set forth the dates, terms, and conditions by which the person responsible for the noise source shall comply with the adopted rules.

(3) Measurement:

(a) Sound measurements procedures shall conform to those procedures which are adopted by the Commission and set forth in Sound Measurement Procedures Manual (NPCS-1), or to such other procedures as are approved in writing by the Department;

(b) Unless otherwise specified, the appropriate measurement point shall be that point on the noise sensitive property, described below, which is further from the noise source:

(A) 25 feet (7.6 meters) toward the noise source from that point on the noise sensitive building nearest the noise source;

(B) That point on the noise sensitive property line nearest the noise source.

(4) Monitoring and Reporting:

(a) Upon written notification from the Department, persons owning or controlling an industrial or commercial noise source shall monitor and record the statistical noise levels and operating times of equipment, facilities, operations, and activities, and shall submit such data to the Department in the form and on the schedule requested by the Department. Procedures for such measurements shall conform to those procedures which are adopted by the Commission and set forth in Sound Measurement Procedures Manual (NPCS-1);

(b) Nothing in this rule shall preclude the Department from conducting separate or additional noise tests and measurements. Therefore, when requested by the Department, the owner or operator of an industrial or commercial noise source shall provide the following:

(A) Access to the site;

(B) Reasonable facilities, where available, including but not limited to, electric power and ladders adequate to perform the testing;

(C) Cooperation in the reasonable operation, manipulation, or shutdown of various equipment or operations as needed to ascertain the source of sound and measure its emission.

(5) Exemptions: Except as otherwise provided in subparagraph (1)(b)(B)(ii) of this rule, the rules in section (1) of this rule shall not apply to:

(a) Emergency equipment not operated on a regular or scheduled basis;

(b) Warning devices not operating continuously for more than 5 minutes;

(c) Sounds created by the tires or motor used to propel any road vehicle complying with the noise standards for road vehicles;

(d) Sounds resulting from the operation of any equipment or facility of a surface carrier engaged in interstate commerce by railroad only to the extent that such equipment or facility is regulated by pre-emptive federal regulations as set forth in Part 201 of Title 40 of the Code of Federal Regulations, promulgated pursuant to Section 17 of the Noise Control Act of 1972, 86 Stat. 1248, Public Law 92-576; but this exemption does not apply to any standard, control, license, regulation, or restriction necessitated by special local conditions which is approved by the Administrator of the EPA after consultation with the Secretary of Transportation pursuant to procedures set forth in Section 17(c)(2) of the Act;

(e) Sounds created by bells, chimes, or carillons;

(f) Sounds not electronically amplified which are created by or generated at sporting, amusement, and entertainment events, except those sounds which are regulated under other noise standards. An event is a noteworthy happening and does not include informal, frequent, or ongoing activities such as, but not

limited to, those which normally occur at bowling alleys or amusement parks operating in one location for a significant period of time;

(g) Sounds that originate on construction sites.

(h) Sounds created in construction or maintenance of capital equipment;

(i) Sounds created by lawn care maintenance and snow removal equipment;

(j) Sounds generated by the operation of aircraft and subject to pre-emptive federal regulation. This exception does not apply to aircraft engine testing, activity conducted at the airport that is not directly related to flight operations, and any other activity not pre-emptively regulated by the federal government or controlled under OAR 340-035-0045;

(k) Sounds created by the operation of road vehicle auxiliary equipment complying with the noise rules for such equipment as specified in OAR 340-035-0030(1)(e);

(l) Sounds created by agricultural activities;

(m) Sounds created by activities related to the growing or harvesting of forest tree species on forest land as defined in subsection (1) of ORS 526.324.

(6) Exceptions: Upon written request from the owner or controller of an industrial or commercial noise source, the Department may authorize exceptions to section (1) of this rule, pursuant to rule 340-035-0010, for:

(a) Unusual and/or infrequent events;

(b) Industrial or commercial facilities previously established in areas of new development of noise sensitive property;

(c) Those industrial or commercial noise sources whose statistical noise levels at the appropriate measurement point are exceeded by any noise source external to the industrial or commercial noise source in question;

(d) Noise sensitive property owned or controlled by the person who controls or owns the noise source;

(e) Noise sensitive property located on land zoned exclusively for industrial or commercial use.

[ED. NOTE: The Table(s) referenced in this rule are not printed in the OAR Compilation. Copies are available from the agency.]

[Publication: The Publication(s) referred to or incorporated by reference in this rule are available from the agency.]

Stat. Auth.: ORS 467
Stats. Implemented: ORS 467.030
Hist.: DEQ 77, f. 9-5-74, ef. 9-25-74; DEQ 135, f. & ef. 6-7-77; DEQ 8-1980, f. & ef. 3-11-80; DEQ 7-1983, f. & ef. 4-22-83

Wind Turbines, Health, Ridgelines, and Valleys

Montpelier, VT, May 7 2010

It is a medical fact that sleep disturbance and perceived stress result in ill effects, including and especially cardiovascular disease, but also chronic feelings of depression, anger, helplessness, and, in the aggregate, the banishment of happiness and reduced quality of life.

Cardiovascular disease, as we all now, leads to reduced life expectancy. Try and get reasonably priced life insurance if you are hypertensive or have suffered a heart attack.

If industrial wind turbines installed in close proximity to human habitation result in sleep disturbance and stress, then it follows as surely as day follows night that wind turbines will, over the long term, result in these serious health effects and reduced quality of life.

The question is, then, do they?

In my investigation of Mars Hill, Maine, 22 out of about 30 adults ('exposed') who live within 3500 feet of a ridgeline arrangement of 28 1.5 MW wind turbines were evaluated to date, and compared with 27 people of otherwise similar age and occupation living about 3 miles away (Not Exposed).

Here is what was found:

82% (18/22) of exposed subjects reported new or worsened chronic sleep deprivation, versus 4% (1 person) in the non-exposed group. 41% of exposed people reported new chronic headaches vs 4% in the control group. 59% (13/22) of the exposed reported 'stress' versus none in the control group, and 77% (17/22) persistent anger versus none in the people living 3 miles away. More than a third of the study subjects had new or worsened depression, with none in the control group. 95% (21/22) of the exposed subjects perceived reduced quality of life, versus 0% in the control group. Underlining these findings, there were 26 new prescription medications offered to the exposed subjects, of which 15 were accepted, compared to 4 new or increased prescriptions in the control group. The prescriptions ranged

from anti-hypertensives and antidepressants to anti migraine medications among the exposed. The new medications for the non exposed group were anti-hypertensives and anti-arthritics.

The Mars Hill study will soon be completed and is being prepared for publication. Preliminary findings have been presented to the Chief Medical Officer for Ontario, and have been presented to Health Canada, by invitation. Earlier partial results were presented to the Maine Medical Association, which passed a Resolution calling for caution, further study, and appropriate modification of siting regulations, at its annual meeting in 2009.

There is absolutely no doubt that people living within 3500 feet of a ridgeline arrangement of turbines 1.5 MW or larger turbines in a rural environment will suffer negative effects.

The study was undertaken as a pilot project to evaluate for a cluster of symptoms after numerous media reports, in order to present data to the Maine Medical Association, after the Maine CDC failed to more fully investigate.

While the study is not perfect, it does suggest a real problem that warrants not only further more detailed investigation, but the tenderest caution, in the meantime, when decisions on how to site industrial wind turbines are made.

What is it about northeast USA ridgelines that contribute to these ill effects, and how can they be avoided?

Consider, the Northeast is prone to icing conditions. Icing will increase the sound coming off of 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 wind industry claims.

Sound is amplified coming off of ridgelines into valleys. This is because the background noise in rural valleys is low to begin with, increasing the sensitivity to changes, particularly the beating, pulsatile nature of wind turbine noise, and sound sources at elevation do not undergo the same attenuation that occurs from groundcover when noise sources are at ground level. The noise travels farther and hits homes and people at greater

amplitude that it would from a lower elevation. Even though this is not rocket science, it was conclusively proven in a NASA funded study in 1990.

Snow pack and ice contribute to increased noise transmission. Vermont valleys have both, I believe.

Preconstruction sound modeling fails to take the tendency of the homes that people live in to respond and vibrate perceptibly to sound at frequencies that the occupants of the dwellings cannot necessarily hear. They hear, and feel, the walls and windows rattle, and the floors vibrate, in a pulsing manner at a frequency or the turbine rpm.

When pre construction modeling fails to take the pulsatile nature, propensity for icing, and ridgeline elevation into account, as well as a linear as opposed to point source of noise, problems can be expected. What distance is safe? It depends on the terrain, the climate, the size of the project and the turbines themselves. Accurate preconstruction modeling with safe targets in mind is critical. The WHO says that 30dbA is ideal, and noise levels of above 40dbA have definite health consequences. At Mars Hill, where affected homes are present at 3500 feet, sound levels have been measured at over 52.5dbA. The fiasco there has been acknowledged by the local wind energy company, and by a former Maine governor.

Vermont would do well to learn from the affected people in Mars Hill.

I have seen the preliminary plans for the planned Deerfield Wind Facility, and have particular concerns regarding the dwellings to the north and northeast of the northernmost extension of the turbine layout. These homes are well within a mile, generally downwind, and downhill from what I am told may well be 2 MW turbines (or larger?), in a snowy and icy part of the Northeast.

The parallels to Mars Hill are striking.

We know that preconstruction sound modeling failed at Mars Hill. No matter what the preconstruction modeling at Deerfield shows, the real world experiment at Mars Hill suggests that there will be problems for homes at the setbacks that seem to be planned for Deerfield on the attached image.

The people who live within 3500 feet at Mars Hill are truly suffering. Learn from Mars Hill. It is not a matter of not having wind turbines. It is a matter of putting them where they will not affect people's health.

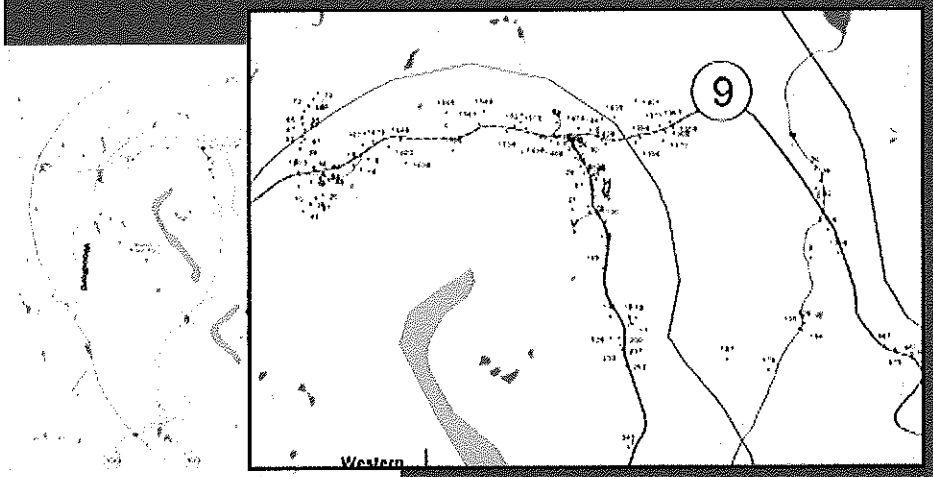
Newer technology to accurately measure sound at a quantum level improvement in temporal, frequency and amplitude resolution over commonly used acoustician's equipment now exists, though it is costly and not readily available. But it will be widespread, soon, well within the tenure of the individuals responsible for making siting decisions today.

Avail yourselves of these findings and familiarize yourselves with the new technologies. You will not only be future proofing your current decisions, you will also be helping people who would otherwise end up too close to industrial wind turbines escape the fate of the exposed residents of Mars Hill, and many other sites in North America (Mars Hill, Maine, merely represents the first small 'controlled' study).

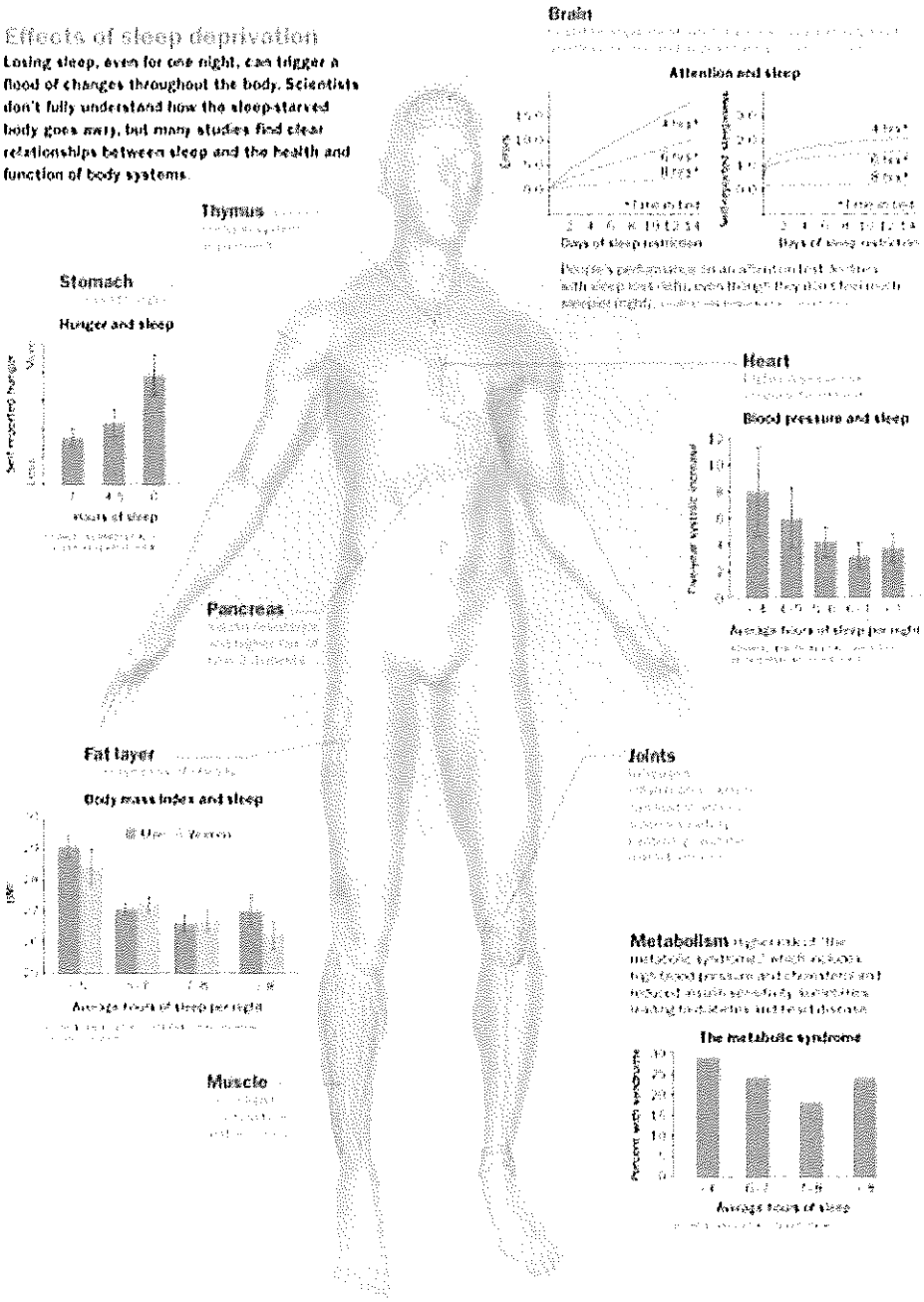
I have seen the results of this cutting edge equipment, and how it has revealed drastic short duration excesses over allowed sound levels, levels that set homes vibrating and rendering them unlivable, but also levels of lower frequency transient noise at the audible level, that demonstrates not only failure of preconstruction sound modeling as currently practiced, but also the inadequacy of the measuring tools in the toolkit of the everyday practicing acoustician-consultant who generates reports for industry and local government.

Michael A. Nissenbaum, MD
University of Toronto (MD), McGill University (Specialty Diagnostic Imaging),
University of California (Fellowship)
Harvard University Medical School (junior faculty, Associate Director of MRI, BIH)
Currently, Radiologist, NMMC, Ft. Kent, Maine

Deerfield Wind Project, Vermont



2 MW turbines?


Effects of sleep deprivation
Losing sleep, even for one night, can trigger a flood of changes throughout the body. Scientists don't fully understand how the sleep-starved body goes awry, but many studies find clear relationships between sleep and the health and function of body systems.
Brain
Attention and sleep
Days of sleep restriction
Days of sleep restriction
Thymus
Stomach
Hunger and sleep
Hours of sleep
Heart
Blood pressure and sleep
Average hours of sleep per night
Pancreas
Fat layer
Body mass index and sleep
Average hours of sleep per night
Joints
Metabolism
The metabolic syndrome
Average hours of sleep
Muscle

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

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

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

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

My presentation is in four parts:

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

Regulations in Canada

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

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

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

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

Low Frequency Noise

Human auditory range is from 20 – 20,000 HZ. LFN is about 20-200 HZ. (1) It is an area of growing interest and for example there are 15,400,000 hits on Google (accessed April 20 2009) for "Low Frequency Noise". However there appears to be a variance of opinion

in recognizing its significance. For example the wind developer IPC Energy contracted Avalon Consulting to do Environmental Screening. I contacted Avalon who indicated to me on 2 occasions that it is "not necessary" to monitor for LFN. The wind industry at large agrees as they also deny the need to monitor for LFN. The Ministry of the Environment of Ontario concurs as all its regulations are based on dBA (Decibels with A weighting) which is relatively insensitive to LFN. dBA however is adequate for higher frequency noises such as the characteristic "swoosh, swoosh, swoosh" of turbine blades which are in the mid-frequency range.

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

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

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

Others disagree.

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

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

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

Adverse Health Events

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A Proposal

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

There is a way out of this dilemma. Authoritative guidelines must be established based on sound science. A well-designed epidemiological study conducted by arms-length

investigators, mutually agreeable to all sides, must be done. In addition and far more simply is to engage sound engineers, (again mutually agreeable) to determine the presence or absence of LFN near existing wind farms in Ontario.

In the meantime listen to and help the victims.

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

Summary

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

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

Respectfully Submitted

R.Y. McMurtry MD FRCSC FACS

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

2 ibid

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

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

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

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

7. http://www.windturbinesyndrome.com

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

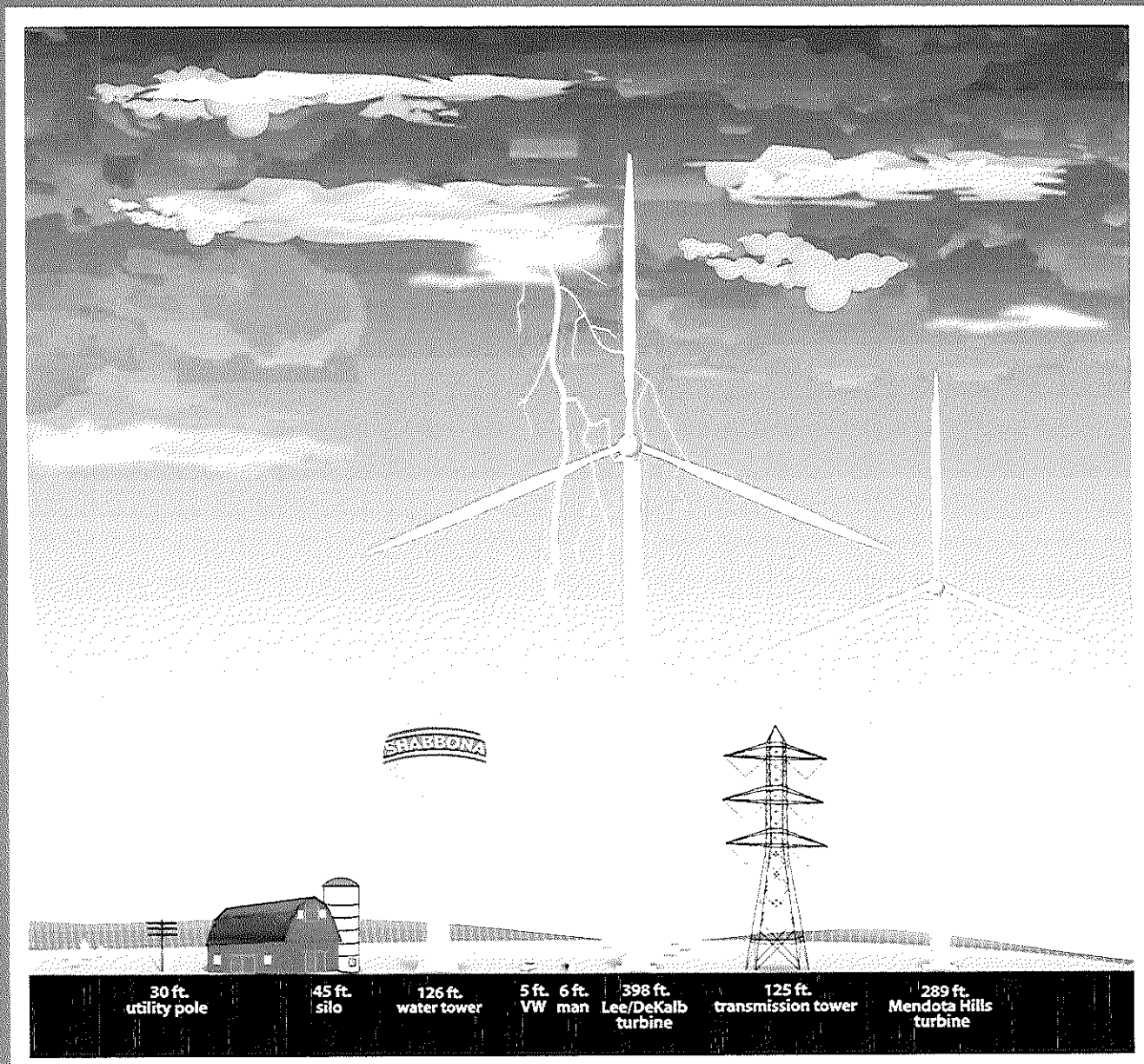
9. http://www.epaw.org/

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

Mars Hill Wind Turbine Project
Health Effects – Preliminary Findings

- 28 turbines, 389 ft tall
- Online Dec 06, Complete Mar 07
- 20 homes North and East of turbines
- 35 adults, 16 children live within 3400 feet
- 15 people interviewed (13 face to face Mar 12, 2009) to date

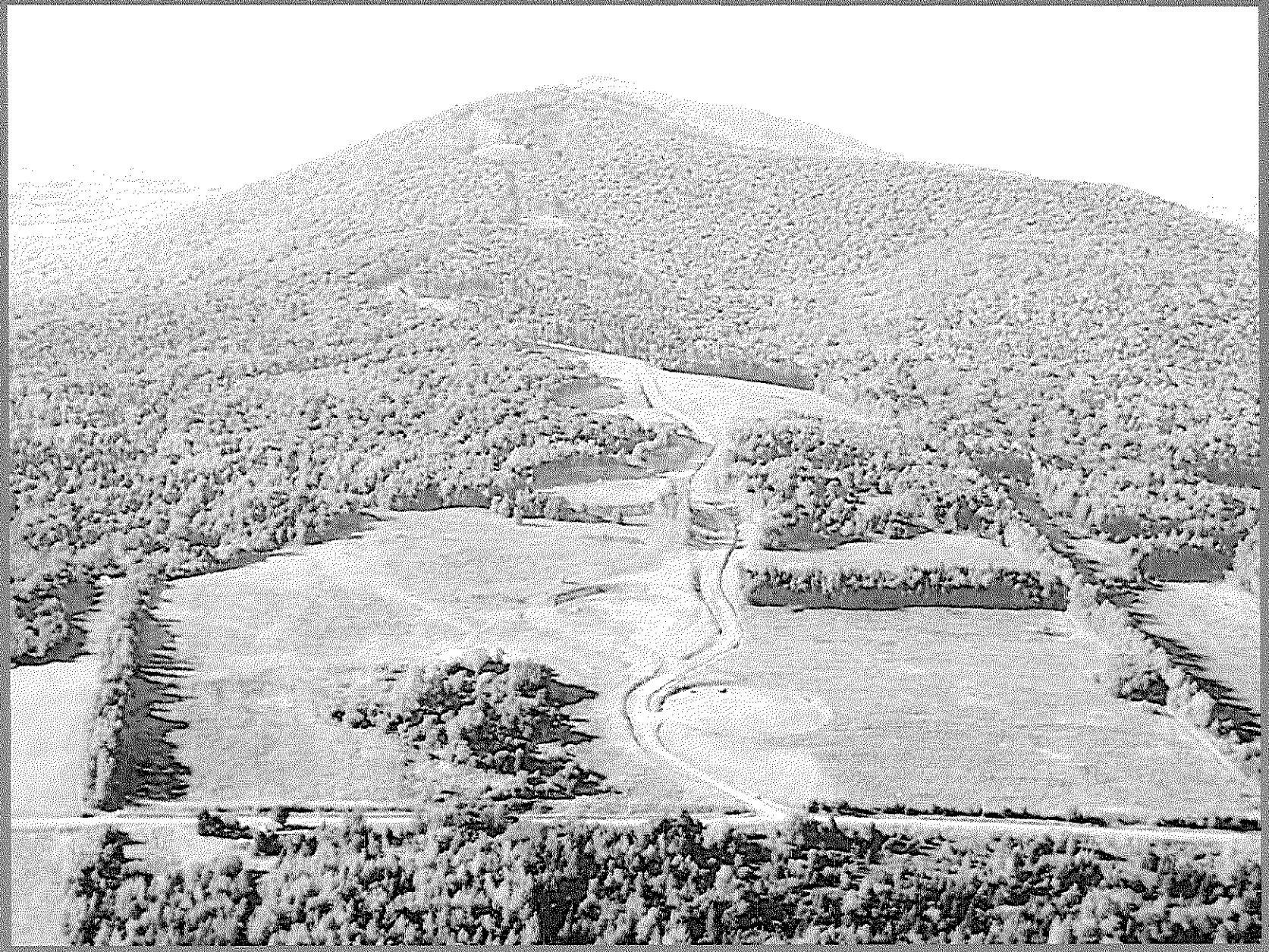
Michael A. Nissenbaum, MD, *presentation to Maine Medical Association March 2009*


SHABBONA
30 ft.
utility pole
45 ft.
silo
126 ft.
water tower
5 ft.
VW
6 ft.
man
398 ft.
Lee/DeKalb
turbine
125 ft.
transmission tower
289 ft.
Mendota Hills
turbine

Locations of 28 wind turbines (red dots) and 2 meteorological towers (gold dots), based on coordinates included in the FAA's 7460-1 database for the Mars Hill windplant, Aroostook County, ME.

wind turbine #9

Courtesy Dan Boone



Mars Hill's North End - East Ridge Road

Michael A. Nissenbaum, MD. March 2009

Aerial photo of Mars Hill taken during Summer of 2006

www.windaction.org/pictures/5919

Mars Hill Experience

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings

Questionnaire Used

Name	Age	Turbine Dist.	Years here	Occupation	Telephone #	email

Information provided by: Address:

Pre existing medical conditions or diagnoses:				
Medications prior to WTP:				
New medical conditions or diagnoses since WTP:				
New medications or dose changes since WTP:				

Sign/Symptom	Frequency/Severity	Freq/Sev PRIOR to WTP	Improves when away?	Seen a doc? New Rx or Tx?	Comment
Sleep disturbance:					
Difficulty falling asleep:					
Waking up mid. of night:					
Headaches ☐ Migraines ☐					
Dizziness					
Ears ringing					
Balance probs					
Unusual body sensations (specify):					
Weight: gain ☐ loss ☐					
Palpitations					
Changes in appetite (spec):					
Feelings of 'Stress'					
Feelings of 'Anger'					
Feelings of 'hopelessness'					
Feelings of 'anxiety'					
Feelings of 'irritability'					
Feelings of 'Depression'					
Other					

1. Has your quality of life been altered in any way since the wind turbine project went online?

2. How so?

3. Have you considered moving away?

4. Why haven't you moved away?

I understand and consent to this information being collected as part of a medical investigation. I understand no names shall be used in any report generated with this information, and that no patient names will be released at any time. The report or excerpts from the report may be presented to government or to other bodies such as the Maine Medical Association, and may be published in journals or other media.

_____ signature _____ date

_____ print name

Michael A. Nissenbaum, MD. March 2009

Michael A. Nissenbaum, MD. March 2009

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings

Population Sample - Demographics

- 20 homes in affected area
- Members of 9 homes interviewed
- ***None of 16 children interviewed***

Interviewed:

- 7 females, age range 41-73, mean 59 years
- 8 males, age range 47-75, mean 61 years

- Distance to nearest turbine ranges 1200 – 3400 ft
  Mean distance 2500 feet

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings

Population Sample - Demographics

Sex	Age	Occupation	Distance to nearest turbine (ft)
F	confidential	confidential	3400
F	confidential	confidential	2400
F	confidential	confidential	2500
F	confidential	confidential	3000
F	confidential	confidential	3200
F	confidential	confidential	1200
F	confidential	confidential	2300
F	confidential	confidential	3400
M	confidential	confidential	2400
M	confidential	confidential	3000
M	confidential	confidential	3200
M	confidential	confidential	1200
M	confidential	confidential	2100
M	confidential	confidential	2400
M	confidential	confidential	2300
M	confidential	confidential	

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

SLEEP DISTURBANCES **(new onset)**

Sleep Disturbance (total)	**14**	**93%**
Waking up middle of night:	13	87%
Difficulty falling asleep:	7	47%
1-2/WK	3	20%
3-4/WK	2	13%
5-7/WK	9	60%
Discussed with MD:	**13**	**87%**
Offered Rx:	12	80%
Accepted Rx:	5	33%
Offered & Declined Rx:	7	47%

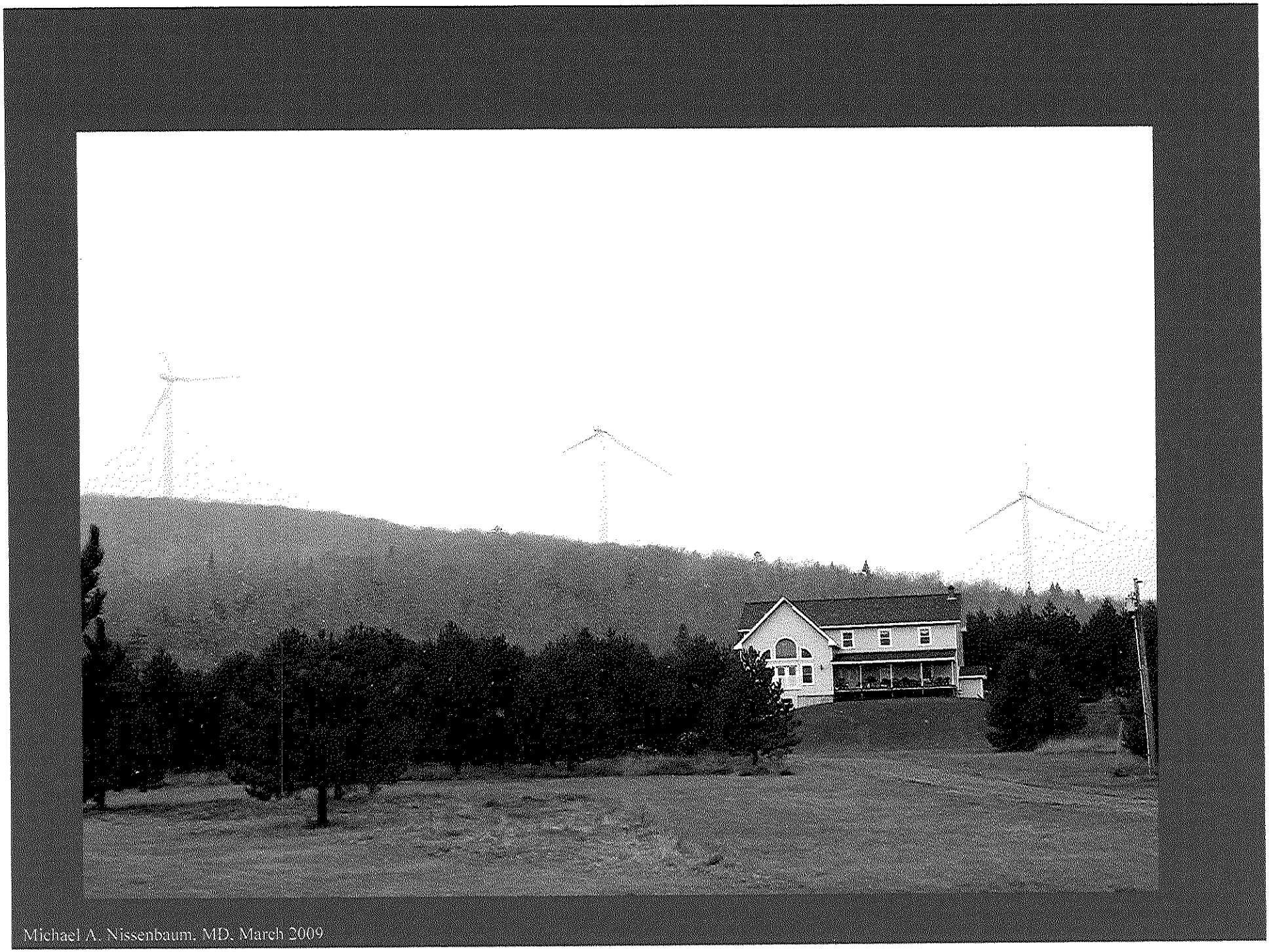
Michael A. Nissenbaum, MD. March 2009

Michael A. Nissenbaum, MD. March 2009.

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Headache

Increased Headache:	**8**	**53%**
New onset headaches:	6	40%
Increased migraine frequency:	2	13%
New Rx	**2**	**13%**
Increased Migraine Rx	**1**	**6%**



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Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Dizziness	**3**	**20%**
Tinnitus	**1**	**6%**
Unsteadiness	**1**	**6%**
Unusual Body sensations:	**3**	**20%**
Chest pulsations	**2**	
Pulsatile ear pressure	**1**	

Michael A. Nissenbaum. MD. March 2009

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Hypertension

New Dx Hypertension	3	20%
Worsened BP	1	6%
New Rx offered or increased:	4	27%
New Rx accepted or increased:	3	20%
New Rx declined:	1	

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Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Troubled by Shadow Flicker

Troubled by Shadow Flicker:	**5**	**33%**
nausea & dizziness	*2*	
dizziness alone	*2*	
triggers migraine	*1*	

" like turning a light switch on and off, on and off '

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Weight Change

Weight changes since turbines online:	**6**	**40%**
Weight gain:	**5**	**33%**
Weight loss:	**1**	**6%**

Michael A. Nissenbaum, MD. March 2009

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Psychiatric Symptomatology

Feelings of:

"Stress"	11	73%
"Anger"	13	87%
"Anxiety"	6	40%
"Irritability"	4	27%
"Hopelessness"	11	73%
"Depression"(total)	8	53%
new:	7	
increased:	1	

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Anger

" Absolute rage – you feel you want to kill someone, and don't know who to kill " *(67 y.o. woman)*

" So angry I could kill " *(65 y.o. man)*

" Makes my blood boil " *(65 y.o. woman)*

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Hopelessness

" Nobody will help us "

" No options – can't leave, and can't live here "

" This is an awful thing to have happen to you "

" People don't believe us – (our complaints) fall on deaf ears "

" No one cares. No one listens."

" They just tread on us "

" It's very hard watching my child suffer "

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Depression

7 new subjective symptom complexes **47%**
1 worsened prior Dx

4 New Rx offered
1 declined (incompatible with job license)
3 New Rx: Cymbalta, Lexapro, Mirtazepine **20%**

1 prior Dx, Rx increased/changed: Zoloft, Trazodone

Tearful at points during interview: 4 27%
2 women, 2 men

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

New Prescriptions

Total Number of New and Increased Prescriptions: 15

New Rx	12
Increased	3

Cymbalta	*Lexapro*
Mirtazepine	*Zoloft*
Trazodone	*Meloxicam*
Hydrocodone	*Tylenol III*
Benazepril	*Topamax*
Anxiolytics (2)	
BP meds (3)	

10 Rx offered and declined

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Has your quality of life been affected? 15 100%

"Loss of joy in living . . .put a lot of life's plans on hold"
"No desire to go outside"
"Feel trapped"
"Dreams have been dashed"
"Was our dream home . . . it's all been stolen from us"
"We have no peace and quiet"
"My husband's (who has advanced MS) only pleasure in life was to see the wild animals. They are gone."
"No sleep"
"Sinking feeling every night when I (come home) and see them."
"I used to be able to hear it snow, before. Now, I do not look forward to going home."

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Have you considered moving away?

Yes	**15**	**100%**

Why have you not moved away?

Can't afford to:	**11**	**73%**

Recent professional appraisal with loss of home value perceived as enough to make it impossible to move away: 8/9 homes ***90%***

Mars Hill Wind Turbine Project Health Effects – Preliminary Findings
Symptoms Survey Results

Current survey weaknesses:

- Small sample
- Case Series structure
- Retrospective
- No study control
- No analysis for statistical significance as yet

- **Preliminary findings nonetheless alarming**
- **Do we have a right to subject the non coastal population of Maine to a 30 year prospective study?**

Mars Hill ME DEP Nightime Noise Variance 45=>50 dbA

"There are 4 protected locations were the noise level would be above 45 dBA, but less than 50 dBA, **which is approximately equivalent to the noise that songbirds make . . .** the Department finds that the applicants' project will not have an unreasonable adverse impact . . . and therefore grants a variance from the noise standards for the windpower farm."

DONE AND DATED AT AUGUSTA, MAINE, THIS 1ST DAY OF JUNE, 2004.

DEPARTMENT OF ENVIRONMENTAL PROTECTION

By: Dawn R. Gallagher
DAWN R. GALLAGHER, COMMISSIONER

PLEASE NOTE THE ATTACHED SHEET FOR GUIDANCE ON APPEAL PROCEDURES

Date of initial receipt of application January 12, 2004
Date of application acceptance January 22, 2004

Date filed with Board of Environmental Protection
RC/L21635AN/BN

FILED
JUN - 2 2004
BOARD OF ENVIRONMENTAL PROT.
STATE OF MAINE

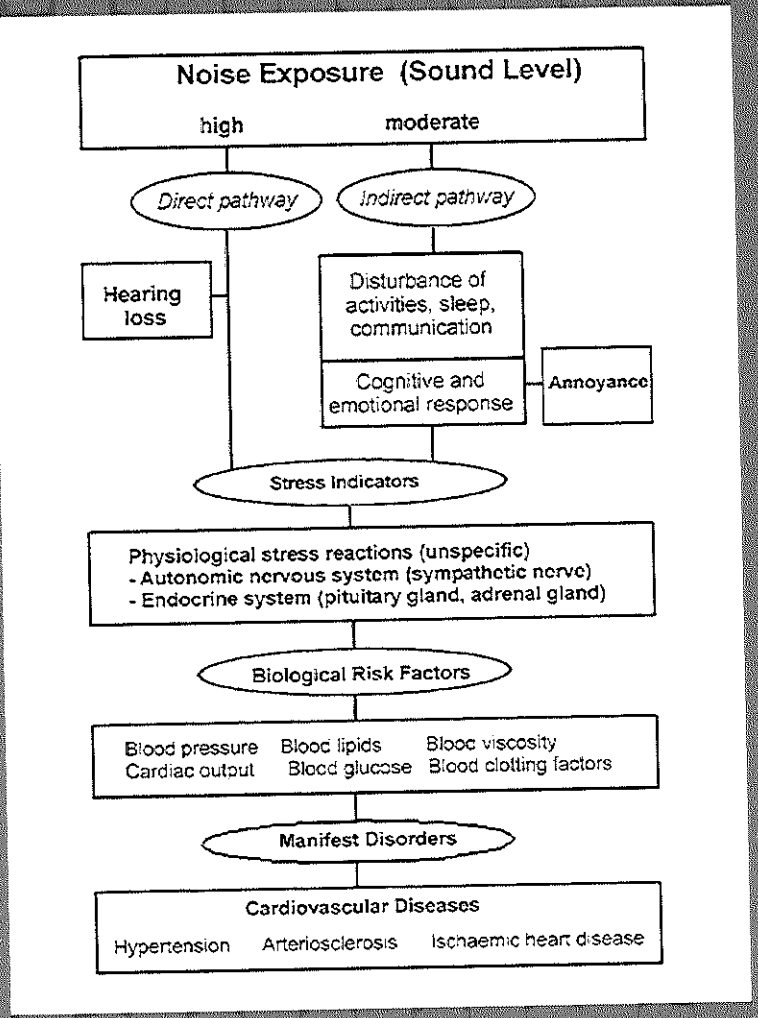
Michael A. Nissenbaum. MD. March 2009

Mars Hill ME DEP Nightime Noise Variance 45=>50 dbA

In fact, the turbines at Mars Hill produce night time readings 52.5 dBA, which Andrew Fisk of MDEP has characterized as 'substantially in compliance', and has issued a letter of compliance to First Wind/UPC.

He acknowledged, during a recent meeting in Fort Kent, that this reflected an average measurement which included downtime, though the statute is meant to regulate sound sources during operation.

Is this the Mars Hill Experience?



Preliminary findings are alarming

More detailed studies are required:

- Diurnal cortisol studies
- Larger population sample
- Detailed cardiovascular studies
- Detailed psychiatric assessments

*****16 Children*** MUST be studied.**

Health Aspects of Extra-Aural Noise Research. W. Babisch. German Federal Environmental Agency
Noise and Health 2004, 6:22, 69-81

Michael A. Nissenbaum, MD, March 2009

DO NO HARM

In light of these growing, serious medical concerns, we propose a moratorium on the building of any such "wind farms" until more research is done on the health impact that such facilities will have on the communities surrounding such technology. These communities and the Maine DEP and Health Services must be allowed time to study and learn from the European and Canadian experiences, as well as from the many affected families in Mars Hill, Maine, and put into place appropriate regulations and ordinances, prior to expanding the wind industry in the State of Maine.

Excerpt, Statement of the Medical Staff of NMMC, March 2009

DO NO HARM

The State of Maine has a vast, unpopulated hinterland. There is little need to site industrial wind developments in proximity to residential communities if there is a risk of negative health effects. Quality of life, quality of place, and a healthful environment should be the right of all residents of Maine, including those of the rural north.

Excerpt, Statement of the Medical Staff of NMMC, March 2009

Preliminary Findings are Alarming
In the Meantime, DO NO HARM

Options:

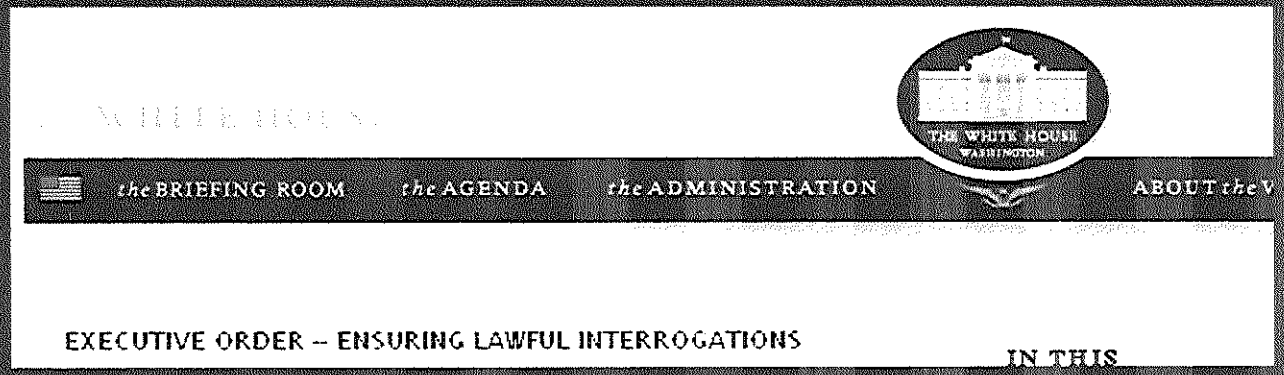
- Request moratorium until more extensive medical studies are done and current state of knowledge is fully understood by authorities and regulations reflecting risks and hazards put into place

- Request siting setbacks reflecting current state of knowledge and non US jurisdictions' best practices (France, Germany, Australia) – including use of db(C) calibration

- Request a Wind Developer "Code of Conduct" be established and enforced by the State's Attorney General's Office (similar to NY State)

Further Studies Must be Done NOW

How is any medical scientist going to conduct an epidemiological study of wind turbine health effects when 'Good Neighbor' and lease-holder gag clauses exist in land lease contracts?



Effective immediately, an individual in the custody or under the effective control of an officer, employee, or other agent of the United States Government, or detained within a facility owned, operated, or controlled by a department or agency of the United States, in any armed conflict, **shall not be subjected to any interrogation technique or approach, or any treatment related to interrogation, that is not authorized by and listed in Army Field Manual 2 22.3**

BARACK OBAMA
THE WHITE HOUSE,
January 22, 2009

Sleep Deprivation is not permitted in Army Field Manual 2 22.3

WHO 2000 *Guidelines: Community Noise*

- When low frequency components are present, noise measures based on dBA measurements are inappropriate - dBC is a better measure when health effects are to be minimized

- It should be noted that a large proportion of low frequency components may increase considerably the adverse effects on health and the evidence on low frequency noise is sufficiently strong to warrant immediate concern

Berglund et al., 2000

Wednesday, March 4, 2009
For Immediate Release:

At its monthly meeting held Tuesday, March 3, 2009, the Medical Staff of Northern Maine Medical Center unanimously approved the release of the following statement:

Health Concerns and the Need for Careful Siting of Wind Turbines

Members of Northern Maine Medical Center's medical staff endorse the use of alternative energies.

We echo the concerns of the Medical Staff of Rumford Community Hospital as regards an increasing body of literature and reports from Canada, the USA, and particularly from Europe suggesting that the deployment of industrial wind facilities in close proximity to places where people live, work or attend schools results in negative health effects, including and especially sleep deprivation and stress.

We know, as physicians, that sleep deprivation and chronic stress can result in many consequential negative health effects, some of them serious, over the long term.

These effects arise not only from audible noise frequencies but also from persistent inaudible low frequency noise waves of a cyclical nature which are felt, but not heard. There are a growing number of scientific observations and studies suggesting that people living up to 2 miles away from these industrial wind farms may be affected.

Many European nations with more than two decades of experience with industrial wind factories have now implemented regulations stipulating setbacks of 1-1.5 miles.

In light of these growing, serious medical concerns, we propose a

moratorium on the building of any such "wind farms" until more research is done on the health impact that such facilities will have on the communities surrounding such technology. These communities and the Maine DEP and Health Services must be allowed time to study and learn from the European and Canadian experiences, as well as from the many affected families in Mars Hill, Maine, and put into place appropriate regulations and ordinances, prior to expanding the wind industry in the State of Maine.

The State of Maine has a vast, unpopulated hinterland. There is little need to site industrial wind developments in proximity to residential communities if there is a risk of negative health effects. Quality of life, quality of place, and a healthful environment should be the right of all residents of Maine, including those of the rural north.

We also encourage the residents of Fort Kent, Maine, to exercise their rights and vote 'YES' at the next annual Town Meeting on March 23rd to a proposal to establish a moratorium in Fort Kent on the permitting of industrial wind development until such time as an ordinance to govern their siting is in place.

Signed,

Medical Staff, Northern Maine Medical Center