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

By:

George W. Kamperman, P.E.
INCE Bd. Cert. Member Emeritus
Fellow Member Acoustical of America
National Council of Acoustical Consultants
Kamperman Associates Inc
Wisconsin Dells, Wisconsin
george@kamperman.com

Richard R. James, INCE
E-Coustic Solutions
rickjames@e-coustic.com

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

Introduction

One of the founding principles in the United States is encapsulated in the quote above. Today in a significant number of rural communities residents believe this principle is under challenge by the current push for renewable energy sources, especially those related to industrial-scale wind turbines (WTi). The U.S. is a latecomer to the wide spread use of wind turbines as an integral part of the electrical utility system. The construction of large WTi projects in the U.S. is a relatively recent phenomenon, with most of the projects occurring after 2002. Other countries, especially in Europe and the U.K., have been using wind energy systems since the early 1990's and in some cases even earlier. Wind energy in those countries where WTi locations are optimum for production of electricity, produce a substantial amount of electricity for internal use or export. These early projects were often installations of wind turbines with less than 1 MWatt generation capacity and with hub heights under 200 feet. Now, many of these early wind energy projects are near the end of their life cycle and are being replaced with the larger industrial grade WTi unit with capacities of 1.5MWatts to 3 or more MWatts. The concepts and recommendations of this article may be applicable outside the U.S. as older wind farms are upgraded to the larger 1.5 MWatt and larger WTi.

If one listens to the people who see industrial wind turbines as the answer to the energy concerns in the U.S. one would think that the wind turbines are perfectly compatible with rural communities. Our State and Federal Governments and their agencies make the same claims about compatibility. Some States have established guidelines and direct local county and township governments to adopt these draft ordinances for their own use.

[1] George S. Hawkins, Esq., "*One Page Takings Summary: U.S Constitution and Local Land Use,*" Stony Brook-Millstone Watershed Association
"…[N]or shall private property be taken for public use, without just compensation."
Fifth Amendment, US Constitution.

On the other hand, if one listens to the various community action groups that have been organized in almost every community where WTi projects have been announced the situation is just the opposite. The members of those groups believe there is ample reason to challenge criteria set in the State Draft Ordinances and actively petition their local governments to adopt stricter guidelines. To them, WTi will cause excessive noise at or in their homes. Other concerns include vibration and potential health risks to the community. Those who live the closest to the WTi host sites feel they are asked to bear the largest share of the burdens and risks of living near the industrial wind turbine project.

Who is correct? How does one know who to believe? Indeed, does anyone know the whole truth?

When faced with a new situation it is often worthwhile to see if one can learn from the experiences of the 'early adopters.' In the U.K., for example, there are currently about 133 operating WTi developments. Many of these have been operational for over 10 years. The Acoustic Ecology Institute (AEI) cites one study conducted for the British government in its AEI Special Report titled: "Wind Energy Noise Impacts[2]" that found only about 20% of wind farms tend to generate noise complaints. Another study done for the British government by the consulting firm Hayes, McKensie[3] reported that only five (5) of 126 wind farms in the U.K. reported problems with the phenomenon known as Aerodynamic Modulation (AM). Thus, experience in the U. K. shows that not all WTi projects lead to community complaints. The question posed by AEI to these findings in its report is: "**What are the factors in *those* wind farms that may be problematic, and how can we avoid replicating these situations elsewhere?"**

One might expect that the wind industry itself, given the European and U.K. experiences, would have conducted extensive research using independent research institutions to answer this question. The wind industry was aware of, or should have been aware of, the complaints of noise and/or vibration from people living near the "20%" of the projects that are recognized as having problems. Particularly considering there are more stringent noise limits in those countries than are being promoted in the U.S. As discussed later, the wind industry is aware of and follows criteria limiting the WTi to L_{90}+5 dBA limits in some countries or the fixed limits of not-to-exceed 30-40 dBA at night in rural and residential areas of Germany.

A serious question is asked and it deserves a serious answer. Answers based on independent and peer reviewed studies are sought by the committee charged with fact finding. But, the industry response is spurious and misleading. The answer does not address the question. It states that the turbines will be located so as to produce sound levels of 45 dBA. The tone and context imply that 45 dBA is fully compatible with the quiet rural community where they plan to host the WTi. No acknowledgement is made of the dramatic change that will occur for near-by families when a WTi is producing 45 dBA outside their home with the potential for it being 24 hours a day, 7 days a week, and 365 days a year.

No mention is made of how the sounds from the WTi will raise evening and night time background sound levels from existing background levels from the traditional range of 20 dBA to 30 dBA up to 45 dBA once the wind project is operating on a regular basis. There is no disclosure of the considerable low frequency content to the WTi sound; in fact, there are often

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2 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

3 Study review available at: http://www.berr.gov.uk/files/file35592.pdf

claims to the contrary. Yet, modern home construction techniques used for most wood frame homes result in walls and roofs that cannot block WTi low frequencies from penetrating into the interior.

But, from what information the industry has been willing to make public, it appears that none of this prior experience has been applied to the projects in the U.S. Instead, what has been observed of their actions in the U.S. shows WTi project developers and their supporters making claims that wind turbines will not be a noise 'problem' to near-by residents. That the turbines will be "as 'quiet' as a person talking outside the window" of the near-by homes or "no noisier than a refrigerator..."are claims often heard. This ignores the question of just how many people want someone talking outside their bedroom window all night long or wish to sleep with a refrigerator alongside their bed?

A typical WTi developer's response to a question raised by a community committee about noise and health is the following:

> **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.
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> **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

There is no mention of the nighttime sound level recommendations set by the World Health Organization (WHO) in their documents on Community Noise or their "Report on the third meeting on night noise guidelines." In those 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 autonomous nervous system is 10 to 15 dB more sensitive to noise than adults. Even for adults, health effects are first noted in some studies when the sound levels exceed 32 dBA L_{max}. These levels 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 sound levels are 45 dBA outside a home, the interior sound levels must be less than 30 dBA in the sleeping areas to avoid sleep disturbance. This is because the low frequency content of the WTi can penetrate the home's walls and roof with very little low frequency noise reduction. An example demonstrating how WTi sound is affected by walls and windows is provided later in this document.

The wind turbine developers also fail to 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			
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

Even more egregious, the wind industry makes claims like "*These sound levels are well below levels causing physical harm. Medical books on sound indicate sound levels above 80-90dBA cause physical (health) effects.*" First of all, 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 causative factors associated with prolonged exposure to low levels of noise. This type of response is a non-answer. It is a conscious attempt to mislead while giving the appearance of providing a legitimate response.

Further, 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 mis-leading. It ignores the work of researchers like Drs. Eja Pedersen, Amanda Harry, Robin Phipps, and the numerous medical research studies summarized in the work of Frey and Hadden to name just a few. These studies, in addition to the work here in the U.S. by Dr. Pierpont, belie the claims of the wind industry. This 'oversight' of published studies is so blatant as to make some interpret their claim of 'no medical research' as a conscious decision to not look for it. If they looked they would find there are numerous studies by qualified medical researchers that contradict their claim.

Compounding these unfounded and misleading claims to the questions raised by the community's committee members, wind industry advocates who have little or no medical qualifications make statements outside of their area of competence. They 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. These responses cannot be considered as based in fact. They ignore the work of many researchers, including health organizations like WHO on the effect of sounds during nighttime hours that result in sleep disturbance and other disorders that cause physical, not just psychological pathologies. [4] [5] Many people find it difficult to articulate what has changed. They know that something is different and they may express it as feeling uncomfortable, uneasy, and sleepless or some other symptom. Yet, they often cannot explain why this is happening.

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

[5] According to Online Etymology Dictionary, Psychosomatic means: "pertaining to the relation between mind and body," … Applied from 1938 to physical disorders with psychological causes."

The attempt to make light of the well established physical effects of nighttime sounds from WTi located too close to homes by labeling them as 'psychosomatic' is the only response the wind industry offers to a question about real health risks. To many, the constant denial by the wind industry and its promoters about health risks is a 'red flag' that something is amiss.

Industry representatives on State level governmental committees have worked to establish sound limits and setbacks that are even more lenient. In Michigan, for example, the Governor's State Task Force 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.

Who are on these Task Forces? When Wisconsin's Town of Union wind turbine committee made an open records request to find out what scientific basis there was for the sound levels and setbacks in the state's draft model ordinance it was revealed that no scientific or medical data was used at all. Review of the meeting minutes provided under that request showed that the limits had been set by Task Force members representing the wind industry. [6]

Why have State level committees and/or task forces drafted ordinances with upper limits of 50 dBA or higher instead of the much lower limits applied to similar projects in other countries? Where do they find the support for claims that locating 400 foot tall WTi as close as 1000 feet (or less) to non-participating properties will not create noise disturbances or other risks? How can they make the claims in the face of a legacy of complaints from people living near existing wind turbine developments? Why so close? [7] Whose interest is being served? [7]

It is disappointing that the studies that are needed have not been done by the wind industry or any of the other people eager to satisfy our federal and state government's unbridled enthusiasm for wind energy. This type of work has been delegated by the wind industry and its supporters to private individuals and researchers who are working to understand what differences in siting, weather, and operational modes result in the 'failures.' When people in a community complain about an existing wind project doesn't this create a serious public relations problem for the wind industry? Why is there a sense of denial in its response to these situations?

The burden of the small percentage of failures is placed on the people who are being forced to live with conditions they find annoying at best and intolerable at its worst. Many of these people feel that they have had no part to the decisions that created these conditions. Often, they were members of a citizen's group that tried to forewarn their local government about the

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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**
>
> <u>Do not stay within a radius of 400m (1300ft) from the turbine unless it is necessary</u>. 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. ….

possibility that the wind project would not be compatible with their community. On top of this individualized burden they are asked, like the rest of us, to bear the increased costs for electricity, subsidies, and taxes that result from the government incentives to entice investments in WTi developments.

This is why the two studies in this document are so important. They are not the product of a well funded research project by a major research group, but are instead the personal work of private individuals with expertise in their respective fields, but limited in both funds and access to the internal data of the wind industry.

Both studies are based on solid foundations and their authors are experienced in their respective fields. But, these studies are of necessity limited by the barriers that prevent access to internal data and the time and funds to conduct the research while trying to conduct their normal business activities. Those who may not like the results of the studies will work hard to find flaws to use in an attempt to discredit them, but those are the same people and organizations that have not been pro-active by funding the appropriate independent research or providing access to data that is now claimed as 'trade-secrets' by the industry. Whether the attempts to discredit are to claim that the research is too limited or that the information upon which the conclusions are drawn are limited or some other argument the truth is that the wind industry should have done this work in an open, public manner using research groups that are both qualified and totally independent. That is the real problem.

There is much that can be done even in the face of limited resources. For example, there may be questions about whether wind turbines produce low frequency or infra-sound emissions or not. But, one does not have to know that there are high levels of low frequency or infrasound to develop criteria that will protect against excessive levels just in case they are part of the WTi sound emissions. One does not have to know what the mechanism is for pathology, if one knows that moving away from wind turbines allows the pathologies to stabilize or reverse then it is best to move away. Knowing what we wish to avoid is often enough to justify establishing rules and guidelines that protect a community just in case those problems do exist.

These are early studies that should lead to more thorough studies, with proper funding. If this work had been done by the wind industry prior to generating the government enthusiasm for their product with claims of compatibility with land-use in rural communities then people like Dr. Pierpont and the authors of this article would not be doing it on their behalf. We sincerely hope that our work will lead to a higher level of interest in seeking the answer to the question of why some WTi projects do not result in acceptance by people living near them in the host communities.

No new industrial process should be imposed on an unsuspecting public without having been thoroughly, publicly, and independently studied beforehand. Only after such studies show that industrial WTi projects do not introduce risks to the health or safety of the target communities should they be permitted to proceed. If the studies show there are risks, then the next step is to determine what is needed to prevent them.

Until such work is done and accepted by independent reviewers, no WTi projects should be permitted using taxpayer funds without stringent rules for noise and other risk factors. In the absence of such work, it is both prudent and necessary to error on the side of caution regarding public health and safety including stringent standards limiting noise and other risk factors until more and better information becomes available.

Options for Siting Criteria

We started our research into guidelines for proper siting by reviewing the various guidelines used in other countries to limit WTi sound emissions. A recent compendium of many of these standards was presented in the report: "Wind Turbine Facilities Noise Issues"[8]. We found some common ground in many of them. Some like Germany set explicit not-to-exceed sound level limits like 40 dBA nighttime in residential areas and 35 dBA nighttime in rural and other noise sensitive areas. Other countries used 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 we 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. We also focused 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.

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. But, wind turbine sounds are not comparable to the more common noise sources of vehicles, aircraft, rail and industry. Several studies[9] have shown that annoyance to wind turbine sounds begins at levels as low as 30 dBA. This is especially true in quiet rural communities that have not had previous experience with industrial noise sources. This increased sensitivity may be a result of the periodic 'whoosh'

> 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."

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

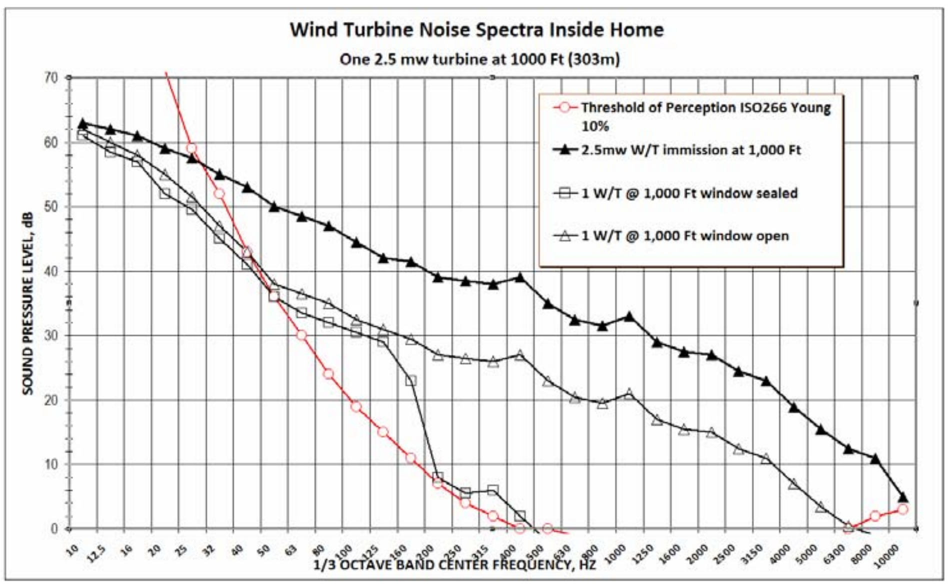
[9] Eja Pedersen, "Human response to wind turbine noise – Perception, annoyance and moderating factors, Occupational and Environmental Medicine," The Sahlgrenska Academy, Gotenborg 2007 and the more recent work "Wind Farm Perception".

from the blades against the quiet rural soundscape or it may be more complex. But, it is a legitimate response to wind turbine sound based on solid peer reviewed research.

In the adjacent text box are a series of observations and recommendations of the World Health organization (WHO) supporting the need for stricter limits when there is substantial low frequency content in the outdoor sound. Our review of other studies plus our own studies has demonstrated that wind turbine sound includes considerable low frequency content. We elected to 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 any dBA criteria.

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

To demonstrate the effects of outdoor low frequency content from wind turbines we prepared the figures below showing the effect of a single turbine (propagation model based on sound power level test data) at 1000 feet and ten (10) turbines at one (1) mile. The graphs each show the outdoor sound pressure levels predicted for the distance of 1000 feet or one mile as the upper graph line. There is also a curve that shows the threshold of human perception for sounds at each 1/3 octave band center. When the graphs representing wind turbine sound have data points above this curve the sounds will be perceptible to at least 10% of the population. 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[10]. One graph represents the condition of no open windows and the other represents one open window. Note how the two graph lines for the inside conditions are significantly higher in amplitude than the curve representing the threshold of perception. Even with the windows closed the sound pressure levels in the 63 Hz to 200 Hz octave bands still exceed the perception curve, in many cases by more than 10 dB. 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

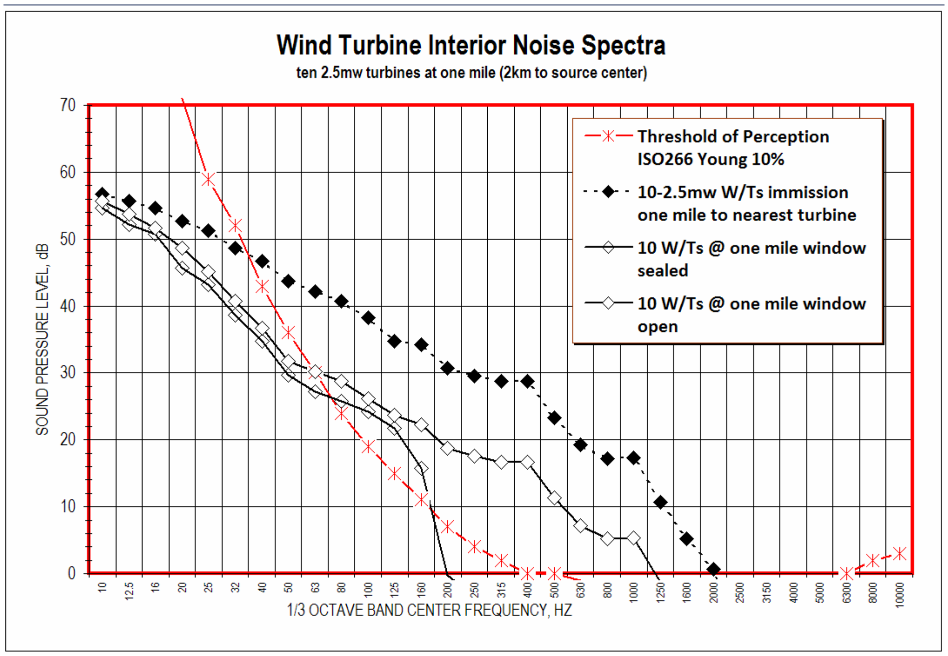


10 The typical wood stud exterior used in modern home construction is vinyl siding over 1/2 inch OSB or rigid fiberglass board applied to 2 X 4 studs with the stud space filled with thermal and 1/2 inch gypsum board applied on the exposed interior side. This has a mass of about 3-4 lbs/sq ft and low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

5 dBC[11,12,13]. If we looked only at dBA it would appear that the home's walls and roof provide a reduction of 15 dBA or more. But, that is misleading. It incorrectly ignores the effects of low frequency sound. Relying on dBA alone will not work for community noise criteria. It is the low frequency phenomena associated with WTi emissions that makes the dBC tests an important part of the proposed criteria.

We applied the façade sound isolation data from the Canada Research Council to the 2.5 MW wind turbine example used in our Noise-Con 2008 paper (next section). With just one turbine at 1,000 feet there is a significant amount of low frequency noise above hearing threshold inside a home near an exterior wall without windows or very well sealed windows. 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 in the homes whenever the turbines are operating.

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 in the figure below. For air absorption we assumed 20°C and 50% RH. Ground reflection had



already been accounted for in the earlier 2.5 Mw 1,000′ calculations of SPL from the sound power data (L_w).. We used only simple inverse-square propagation. 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.

This may explain why some residents as far as two (2) miles from a wind farm find the wind turbines sounds highly annoying.

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

[12] "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

[13] 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 K

The next section of this article presents the Noise-Con 2008 paper with some recent revisions. It is therefore more current than the version published in the proceedings.

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Simple guidelines for siting wind turbines to prevent health risks[14]

By:

George W. Kamperman, INCE Bd. Cert. Emeritus
Kamperman Associates, Inc.
george@kamperman.com

Richard R. James, INCE
E-Coustic Solutions
rickjames@e-coustic.com

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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 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?[15] No! State and Local governments are in the process of establishing wind farm noise limits and/or wind turbine

[15] 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.

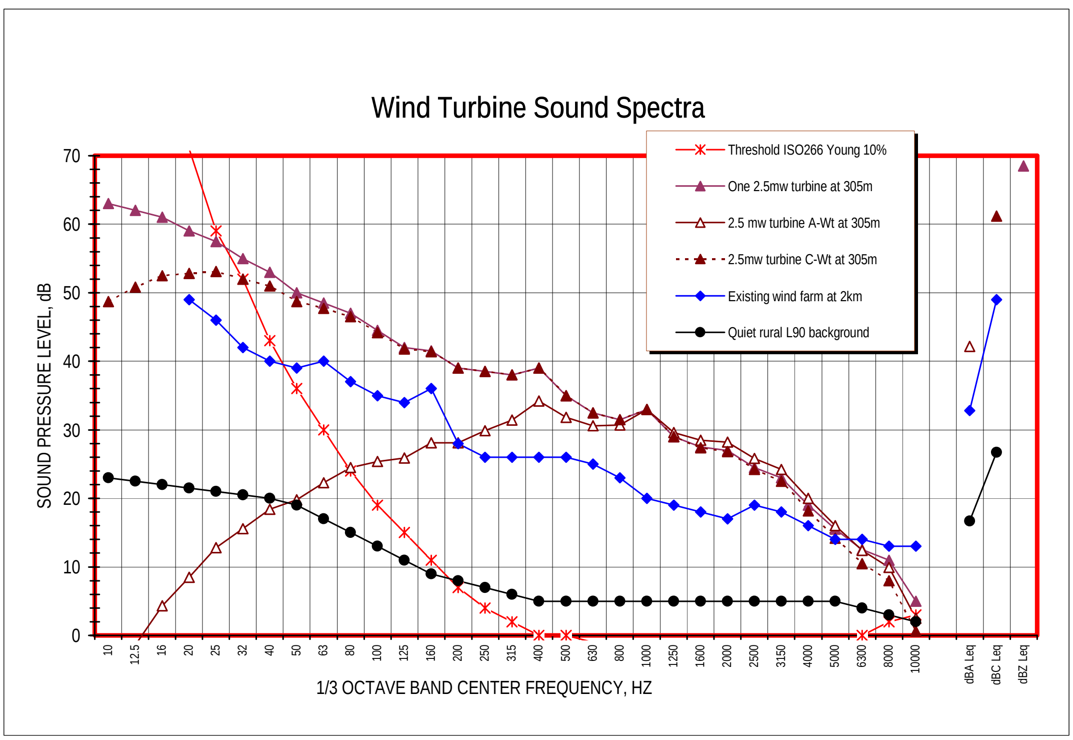


Figure 1-Generalized Sound Spectra vs. perception and rural community L_{90A} background 1/3 octave SPL

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 blades'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 highest 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-Octave frequency band limits: About 50 dBA (day) and about 46 dBA (night), Wisconsin-50 dBA and Michigan-55 dBA.

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 are lower and also 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 and 55 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 correct, but 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 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 fault with this argument is shown during the frequent nighttime conditions with a stable atmosphere when the wind turbines generate the maximum electricity and noise 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, this methodology is usually faulty, as much of the wind noise measured by unattended sound monitors is the wind noise generated at the microphone windscreen resulting in totally erroneous results. (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 to be programmed to include measurement of L_{eqA} , L_{10A}, L_{eq90A} and L_{eqC}, L_{10C}, L_{eq90C} plus start time & date for each 10 minute sample. These results will be utilized to help validate the L_{90} data. For example, on a quiet night one might expect L_{10} and L_{90} or L_{eq} to show similar results within 5 to 10 dBA and 10 to 15 dBC. On a windy night or day the difference between L_{10} and L_{90} may be more than 20 dBA and 30 dBC. There is also a need to obtain a ten minute time averaged one-third octave band analysis over the frequency range from 6.3 Hz to 10k Hz. The frequency analysis is very helpful for identifying and correcting for extraneous sounds such as interfering insect noise. A standard averaging sound level meter has the capability to perform all of the above acoustic measurements simultaneously and store the results internally. 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 maximum 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 measurements 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_{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. 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. 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.

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 the 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 known 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. But, 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 increased significantly. 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. 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 which are setbacks commonly seen in U.S. based wind turbine standards set by many states and used for wind turbine developments.

Proposed Wind Turbine Siting Sound Limits

1. Audible Sound Limit

a. No Wind Turbine or group of turbines shall be located so as to cause an exceedance of the pre-construction/operation background sound levels by more than 5 dBA. The background sound levels shall be the L_{90A} sound descriptor measured during a pre-construction noise study during the quietest time of evening or night. All data recording shall be a series of contiguous ten (10) minute measurements. L_{90A} results are valid when L_{10A} results are no more than 10 dBA above L_{90A} for the same time period. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in L_{eqA} and L_{eqC}) which are to be provided by the developer.

b. Test sites are to be located along the property line(s) of the receiving non-participating property(s).

c. A 5 dB penalty is applied for tones as defined in IEC 61400-11.

2. Low Frequency Sound Limit

a. The L_{eqC} and L_{90C} sound levels from the wind turbine at the receiving property shall not exceed the lower of either:

1) L_{eqC}-L_{90A} greater than 20 dB outside any occupied structure, or

2) A maximum not-to-exceed sound level of 50 dBC (L_{90C}) from the wind turbines without other ambient sounds for properties located at one mile or more from State Highways or other major roads or 55 dBC (L_{90C}) for properties closer than one mile.

These limits shall be assessed using the same nighttime and wind/weather conditions required in 1.a. Turbine operating sound immissions (L_{eqA} and L_{eqC}) shall represent worst case sound immissions for stable nighttime conditions with low winds at ground level and winds sufficient for full operating capacity at the hub.

3. General Clause

a. Not to exceed 35 dBA within 30 m. (approx. 100 feet) of any occupied structure.

4. Requirements

a. All instruments must meet ANSI or IEC Precision integrating sound level meter performance specifications.

b. Procedures must meet ANSI S12.9 and other applicable ANSI standards.

c. Measurements must be made when ground level winds are 2m/s (4.5 mph) or less. Wind shear in the evening and night often results in low ground level wind speed and nominal operating wind speeds at wind turbine hub heights.

d. IEC 61400-11 procedures are not suitable for enforcement of these requirements except for the presence of tones.

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

This next section presents 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 this article 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.

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 noise 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 all part of the ambient sound environment but are <u>not to be considered part of the background sound.</u> If present, a different time or location should be selected for determining the L_{90} background sound levels.

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

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

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

"**Background Sound (L_{90})** refers to the sounds that would normally be 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 near-by birds and animals or people must be excluded from the background sound test data.

Background sound level (dBA and dBC (as L_{90})) is the sound level present for at least 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. Longer term tests, such as 24 hours or multiple days are not appropriate since the purpose is to define the quiet time background sound level. It is defined by the L_{90A} and L_{90C} descriptors. It may be considered to be the quietest one (1) minute during a ten (10) minute test. L_{90A} results are valid only when L_{10A} results are no more than 10 dBA above L_{90A} for the same time period. L_{10C} less L_{90C} should not exceed 15 dBC to be valid.

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

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

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

"**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.

"**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.

"**Impulsive Sound**" refers to short-term acoustical impulses typically lasting less than one second each. It may be the only sound emitted from a noise source or it may be a component of a more complex sound. For evaluation of wind turbines, impulsive sound includes swishing or thumping sounds.

"**Infra-Sound**" sound with energy in the frequency range of 20 Hz and below is considered to be infrasound is normally considered to not be audible unless in relatively high amplitude. The most significant exterior noise induced dwelling vibration occurs in the frequency range between 5 Hz and 50 Hz. Moreover, even 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, its presence will be accounted for in the comparison of dBA and dBC sound levels for the complaint test provided later in this document. See low-frequency sound (LFN) for more information.

"**Low Frequency Sound (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 pressure level and an A-weighted sound pressure level is greater than 20 decibels at any measurement point outside or inside a noise sensitive receptor site, residence, or other occupied structure. E.G. C-A>20 dB.

"**Measurement Point (MP)"** means location where sound and/or vibration measurements are taken such that no significant obstruction blocks sound and vibration 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 Wind Speed**" For measurements conducted to establish the background sound pressure levels (dBA, dBC, $L_{90\ 10\ min}$, and etc.) the wind speed at the microphone's Measurement Point shall average 2 m/s (4.5 mph) or less for valid background measurements. For valid measurements conducted to establish the post-construction sound level the wind speed at the microphone's Measurement Point shall not exceed 4m/s (9 mph) average and the wind speed at the WES blade height shall be at or above the nominal rated wind speed. 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 wind speeds at the microphone to 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 dBA and dBC sound levels in the community adjacent the nearest WES. For the purpose of constructing the model the wind direction shall consider the dominant wind direction for the seasons from the late Spring to early Fall. If other wind directions may cause levels to exceed those of the predominant wind direction at nearby sensitive receptors, these levels and conditions 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.

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

"**Pure Tone**" A sound for which the sound pressure is a simple sinusoidal function of the time, and characterized by its singleness of pitch. Pure tones can be part of a more complex sound wave that has other characteristics.

"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 and Full Membership in the Institute of Noise Control Engineers (INCE). Certifications such as Professional Engineer (P.E.) do not test for competence in acoustical principles and measurement and are thus not, without further qualification, appropriate for work under this document. The Independent Qualified Acoustical Consultant can have no financial or other connection to a WES developer or related company.

"**Sensitive Receptor**" means places or structures intended for human habitation, whether inhabited or not, public parks, state and federal wildlife areas, the manicured areas of recreational establishments designed for public use, including but not limited to golf courses, camp grounds and other nonagricultural state or federal licensed businesses. These areas are more likely to be sensitive to the exposure of the noise, vibration, 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. It cannot be assumed that these values represent the highest sound output for any operating condition. 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 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 0.1 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. This information is used to project the wind farm sound levels at all locations of interest. Confirmation of the projected sound spectrum can be determined with a small portable one-third octave band frequency (spectrum) analyzer. The frequency range of interest for wind turbine noise is approximately 10 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_{AN}, where L_{AN} is the A-weighted sound pressure 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} the noise level exceeded for 90% of the ten (10) minute sample period. The L_{90} noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level. Leq is the frequency-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

“**Tonal sound (sometimes Pure Tone)”** 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 energy on a large, industrial scale for commercial or utility purposes. Small scale wind systems of less than 170 feet in height with a 60-foot rotor diameter and a nameplate capacity of less than 100 kilowatts or less are exempt from this definition and the provisions of this Ordinance.

"Wind Turbine" or "Turbine" (WTi) means a 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.

IV. APPLICATION PROCEDURE FOR WIND ENERGY SYSTEMS

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

B. The application shall be on a form provided by the LGA Clerk.

A. Information to be submitted with Application:

1. Information regarding the: make and model of the turbines, Sound Power Levels (L_w) for each one-third octave band from 6.3 Hz up through 10,000 Hz, and a projection showing the expected dBA and dBC sound levels computed using the one-third octave band sound power levels (L_w) with appropriate corrections for modeling and measurement accuracy tolerances and directional patterns of the WTi for all areas within and to one (1) mile from the project boundary for the wind speed, direction and operating mode that would result in the worst case WTi sound emissions.

The prediction model shall assume that the winds at hub height are sufficient for the highest sound emission operating mode even though the enforcement tests will be with ground level winds of 10 mph or less. This is to accommodate enforcement under weather conditions where there is significant difference in the wind speed between ground and hub heights. This condition often occurs during summer evenings when wind shear is affected by the reduction in solar heating of the earth's surface between sunset and sunrise.

The projection may be by means of computer model but shall include a description of all assumptions made in the model's construction and algorithms. If the model does not consider the effects of wind direction, geography of the terrain, and/or the effects of reinforcement from coherent sounds or tones from the turbines these should be identified and other means used to adjust the model's output to account for these factors. These results may be displayed as a contour map of the predicted levels, but should also include a table showing the predicted levels at noise sensitive receptor sites and residences within the model's boundaries. The predicted values must include dBA and dBC values but shall also include un-weighted octave band sound pressure levels from 8 Hz to 10k Hz in data tables.

2. 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 here-in and in the Appendix showing background dBA and dBC sound levels ($L_{90\ (10min)}$) over one or more valid ten (10) minute continuous measurement periods prior to approval for the final layout and construction as part of an environmental study evaluating what impact the project may have on sensitive receptors in the vicinity of the proposed WES sites.

> a. If any proposed wind farm project locates a WES within one mile of a sensitive receptor these studies are mandatory. The preconstruction baseline studies shall be conducted by an Independent Qualified Acoustical Consultant selected by the LGA.
>
> b. The LGA shall hire an Independent Qualified Acoustical Consultant to conduct the sound study for the LGA as specified in this document. However, 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 dBA or dBC sound levels exceed the criteria specified in this document then the application cannot be approved.

3. 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 against the predicted dBA and dBC sound levels supplied with the application. The reasonably necessary costs associated with the review of the sound study shall be the responsibility of the applicant, in accord with the terms of this ordinance.

V. 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. Sound.

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. 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 WTi.

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_{90A}) can be substituted for the "all WES off' tests if a random sampling of 10% of the pre-construction study sites shows that background $L_{90A \text{ and } C}$ conditions have not changed more than +/- 5 dB (dBA and dBC) measured under the pre-construction nighttime meteorological 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 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 own consultant is free to observe the publicly retained consultant at the convenience of the latter. The WES developer/applicant shall provide all technical information and wind farm data required by the independent qualified acoustical consultant before, during, and/or after any acoustical studies required by this document and for local area acoustical measurements.

3. Sound Limits

1. Audible Sound Limit

a. No WTi or WES shall be located so as to cause an exceedance of the pre-construction/operation background sound levels by more than 5 dBA. The background sound levels shall be the L_{90A} sound descriptor measured during a pre-construction noise study during the quietest time of night (10pm until 4am). All data sampling shall be one or more contiguous ten (10) minute measurements. L_{90A} results are valid when L_{10A} results are no more than 10 dBA above L_{90A} for the same time period and L_{10C} less L_{90C} is no more than 15 dBC. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in L_{eqA} and L_{eqC}) which are to be provided by developer.

b. Test sites are to be located along the property line(s) of the receiving non-participating property(s).

c. A 5 dB penalty is applied for tones as defined in IEC 61400-11.

2. Low Frequency Sound Limit

a. The L_{eqC} and L_{90C} sound levels from the wind turbine at the receiving property shall not exceed either:

1) L_{eqC}-L_{90A} greater than 20 dB outside any occupied structure, or

2) A maximum not-to-exceed sound level of 50 dBC (L_{90C}) from the wind turbines without contribution from other ambient sounds for properties

located one mile or more away from state highways or other major roads or 55 dBC (L_{90C}) for properties closer than one mile.

These limits shall be assessed using the same nighttime and wind/weather conditions required in 1.a. Turbine operating sound immissions shall represent worst case sound immissions for stable nighttime conditions with low winds at ground level and winds sufficient for full operating capacity at the hub.

3. General Clause

a. Not to exceed 35 $dBA_{Leq\ 10\ min.}$ within 30 m. (approx. 100 feet) of any occupied structure.

4. Operations Exceeding any of the limits in this section will be considered as proof that the WES/WTi is non-compliant and must be shut down immediately.

5. Requirements

a. All instruments must meet ANSI or IEC Type 1 Precision integrating sound level meter performance specifications.

b. Procedures must meet ANSI S12.9 Part 3 including the addendum in the Appendix to this document. Where there are differences between the procedures and definitions of this document and ANSI standards the procedures and definitions of this document will be applied. Where a standard's requirements may conflict with other standards the most stringent requirement shall be followed.

c. Measurements for background sound levels must be made when ground level winds are 2m/s (4.5 mph) or less with wind speeds at the hub at or above nominal operating requirements and for other tests when ground level winds are 4m/s (9 mph). Weather in the night often results in low ground level wind speed and nominal operating wind speeds at wind turbine hub heights.

d. IEC 61400-11 procedures are not suitable for enforcement of these requirements except for the presence of tones.

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 acoustical consultant acceptable to the complainant and the local agency charged with enforcement of this ordinance.

3. Testing shall commence within ten (10) working days of the request. If testing cannot be initiated within ten (10) days, the WES(s) in question shall be shut down until the testing can be started.

4. A copy of the test results shall be sent to the property owner, and the LGA's Planning or Zoning department within thirty (30) days of test completion.

5. If a Complaint is made, the presumption shall be that it is reasonable. The LGA shall undertake an investigation of the alleged operational violation by a qualified individual mutually acceptable to the LGA.

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

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

6. After the investigation, if the LGA reasonably concludes that operational violations are shown to be caused by the WESF, the licensee/operator/owner shall use reasonable efforts to mitigate such problems on a case-by-case basis including such measures as not operating during the night time 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 actual 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.

MEASUREMENT PROCEDURES

APPENDIX 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 - 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 dBA and dBC[16] as part of the required information submitted with the application.

These values shall be presented as overlays to the applicant's iso-level plot plan graphics (dBA and dBC) and 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

[16] Calculated from one-third octave band sound power levels (L_W per IEC 61400-11) provided by the wind turbine manufacturer covering the frequency range from 6.3 Hz to 10,000 HZ or higher.

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 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 addresses requirements for the sound propagation model to be supplied with the application.

Finally, if the project is approved, this Appendix 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 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.

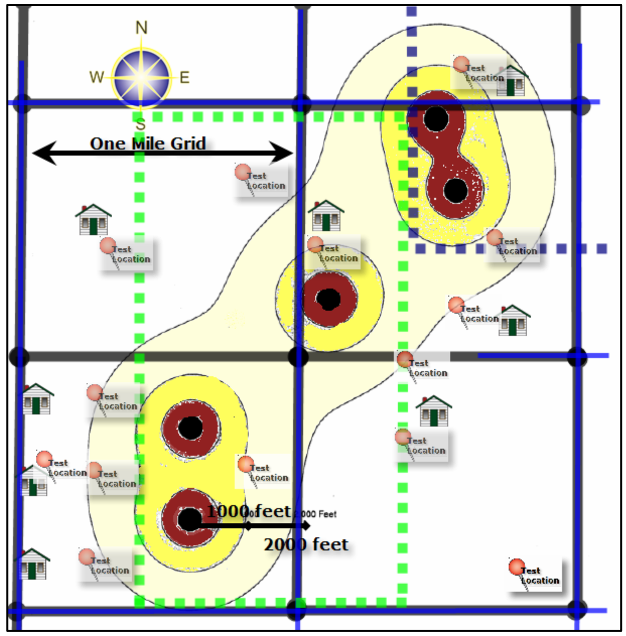
The characteristics of the proposed WES project and the features of the surrounding environment will influence the design of the sound and vibration study. Site layout, types of WES(s) selected and the existence of other significant local audible and low frequency sound sources and sensitive receptors should be taken into consideration when designing a sound and vibration study. The work will be performed by an independent qualified 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 with one-third octave band analyzer with frequency range from 6.3 Hz to 20k Hz and capability to simultaneously measure dBA L_N and dBC L_N. The instrument must also be capable of measuring low level background sounds down to 20 dBA. Measurements shall only be made with the instrument manufacturer's approved wind screen. A compatible acoustic field calibrator is required with certified ± 0.2 dB accuracy. Portable meteorological measurement requirements are outlined in ANSI S12.9 Part 3 and are required to be located within 5m of the sound measuring microphone. The microphone shall be located at a height of 1.2 to 1.5 meters for all tests unless circumstances require a different measurement position. In that case, the reasons shall be documented and include any adjustments needed to make the results correspond to the preferred measurement location.

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

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 Appendix. 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 dBA and dBC sound emissions of the proposed WES project will be overlaid on a map (or separate dBA and dBC maps) of the project area. An example (right) shows an approximately two (2) mile square section with iso-level contour lines prepared by the applicant, sensitive receptors (homes) and locations selected for the baseline dBA and dBC 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 one (1) mile beyond the perimeter of the project boundary. This may be extended to more than one mile 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 WTi in the project. Usually, this will be the closest WTi. If there is more than one WTi 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 be most likely 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 one-third octave band sound pressure levels for the sound measuring consultants file) 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 with 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 continuous minutes for each criterion at each location. The duration must include at least 6 minutes that are not affected by transient sounds from near-by and non-nature sources. Multiple 10 minute samples over longer periods such as 30 minutes or one (1) hour may be used to improve the reliability of the L_{90} values. The ten 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 must be made on a weekday of a non-holiday week. Weekend measurements may be taken at selected sites where there are weekend activities that may be affected by WTi sound.

Measurements must be taken 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.

Reporting

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

   a. L_{Aeq}, L_{10}, and L_{90}, in dBA

   b. L_{Ceq} , L_{10}, and L_{90}, in dBC

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 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 when wind speeds exceed 2m/s (4.5 mph) at the microphone location will not 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 minimum and maximum distance between any Measurement Points.
- 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 collected as part of an earlier baseline study. Wind speeds must be suitable for background testing.

2. One set of measurements with the wind generator(s) running with wind speed at hub height sufficient to meet nominal power output or higher and at 2 m/s or 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 (2m/sec or less) at the ground surface yet, at hub height, sufficient to operate 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 WTi to existing project)

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

The qualifications of the firm should be presented along with details of the procedure that will be used, software applications, and any limitations to the software or prediction methods.

Provide the manufacturer's sound power level (Lw) 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 L_w sound power level information from 6.3 Hz to 10k Hz. Furnish the data with and without A-weighting. 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 dBA levels of 30 dBA and above. The same area shall be used for reporting the predicted dBC levels. Contour lines shall be in increments of 5 dB.

Present tables with the predicted sound levels for the proposed WES(s) in dBA, dBC 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 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 in the background study.

Provide a contour map of the expected sound level from the new WES(s), using 5 dBA and 5 dBC increments created by the proposed WES(s) extending out to a distance of at least 2500 feet from the project boundary or the 35 dBA or 50 dBC boundary whichever is greater.

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}, L_{10} and L_{90}, in dBA
2. Report expected changes to existing sound levels for L_{Ceq}, L_{10} and L_{90}, in dBC
3. Report the predicted sound pressure levels for each of the 1/1 octave bands as un-weighted dB in tabular form from 8 Hz to 10k Hz.
4. Report all assumptions made in arriving at the estimate of impact, any limitations that might cause the sound levels to exceed the values of the estimate, and any conclusions reached regarding the potential effects on people living near the project area. If the effects of coherence, worst case weather, or operating conditions are not reflected in the model a discussion of how these factors could increase the predicted values is required.
5. Include an estimate of the number of hours of operation expected from the proposed WES(s) and under what conditions the WES(s) would be expected to run. Any differences from the information filed with the Application should be addressed.

IV. Post-Construction Measurements

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

1. Within twelve months of the date when the project is fully operational, and within two weeks of the anniversary date of the Pre-construction ambient 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 except as provided the ordinance.

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

3 Project Boundary: A continuous line encompassing all WES(s) and related equipment associated with the WES project.

V. REFERENCES

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.

For the purposes of this ordinance the options that are provided in ANSI S12.9-Part 3 (2008) shall be applied with the additional following requirements:

Wind Turbine Siting Acoustical Measurements
ANSI S12.9 Part 3 Selection of options and other requirements

5.2 background sound: Use definition (1) 'long-term'
5.3 long-term background sound: The L_{90} excludes short term background sounds
5.4 basic measurement period: Ten (10) minutes $L_{90(10\ min)}$
5.6 Sound Measuring Instrument: Type 1 integrating meeting ANSI S1.43
6.5 Windscreen: Required
7.1 Long-term background sound
7.2 Data collection Methods: Second method 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.
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 sound measurement to be valid the wind velocity shall not exceed 2m/s (4.5 mph) measured less than 5m from the microphone. Compliance sound measurements shall not be taken when winds exceed 4m/s.
8.3(c) In addition to the required acoustic calibration checks the sound measuring instrument internal noise floor 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 from the sound level meter or other recording instrument to determine an approximation of the instrument self noise. This calibrator covered microphone must demonstrate that the results of this test are at least 5 dB below the immediately previous ten minute acoustic test results for the acoustic 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 dew point. Minor moisture condensation inside a microphone or sound level meter can increase the instrument self noise and void the data.
8.4 to the end: The remaining sections of ANSI S12.9 Part 3 Standard do not apply.

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

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

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

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

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

This standard provides performance requirements for analog, sampled-data, and digital implementations of bandpass filters that comprise a filter set or spectrum analyzer for acoustical measurements. It super-sedes ANSI S1.11-1986 (R1998) American National Standard Specification for Octave-Band and Frac-tional-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 PROCEDURE