Summary of the Ashfield Wind Advisory committee report

The committee agreed that he following items are of known concern:

- **Noise – including measurement, methodology, modeling etc.**
- **Shadow flicker**
- **Ice throw**
- **Tower fall**
- **Fire**
- **Decommissioning**
- **Bonding / Insurance**
- **Historic**
- **Habitat**
- **Viewshed**
- **Construction issues**

There was general agreement that the right to operate a wind turbine might involve having a right of way or easement over properties abutting the lot that the turbine actually stands on. This is referred to as 'participating properties'.

Mostly the committee talked about the very complicated issue of noise. We reviewed a great deal of literature about wind farms and noise pollution published by public interest groups and governmental agencies. We read very little literature from wind energy developers or designers of wind turbines

While the majority of wind farms do not experience significant noise complaints, many if not most of those in proximity to homes do have significant problems. There is evidence that this can be a significant public health problem and therefore needs to be addressed by the board of health as well as by any permit process that allows wind turbines above a certain size.

It is not clear at this time why some installations experience more complaints than others. We do not yet have a full understanding of the correlation between problem sites and turbine height, turbine management, turbine design, topography, the nature of the local wind etc.

In short any large turbine installation in Ashfield would be a proto type with a great deal of uncertainty about what effect it might have on peoples peace of mind or health. Therefore until these issues are understood better by the "experts" Ashfield should require that: turbine noise not be allowed to exceed ambient levels by no more than 5 dBA.[i] Total project sound shall not exceed 32.5 dBA at any non-participating property line, nor shall low frequency LeqC-L90dBA difference be greater than 20 dB at non-participating properties.

We also voted to create a setback of 3400' to non-participating properties. This recommendation is based on current experience, if and when there are; quieter turbines, tried and tested methods for predicting sound, and/or measurement methods for amplitude modulation then this setback recommendation might be subject to change.

The sound measurement protocol approved by the committee should be reviewed by acoustic experts and edited for readability and legal defensibility; generally we will need something like that in order to allow any large turbines in Ashfield.

The committee recommends that shadow flicker shall not be allowed to occur on non-participating properties. Flicker can cause health problems, but unlike sound is perfectly predictable and has been successfully managed by most wind farms

The Committee finds that turbine noise is more complex than other noise and needs to be regulated differently

The committee recommends a setback for safety of at least 1.5 times the height plus the rotor diameter from any residence or public way. This is based on Ice throw data.

The committee has started to research view sheds but has drawn no conclusions at this point.

The committee has not done any significant work on Fire, Decommissioning, Bonding / Insurance, Historic, Habitat, View shed, or Construction issues.

Generally this is a new industry that has great potential to do harm as well as good; Ashfield should step forward very carefully.

Wind Turbine Siting By-law Advisory Committee Report to the Selectboard, - June 22, 2011

Introduction

This report of the Wind Siting Bylaw Advisory Committee (Committee) is submitted in partial fulfillment of its charge from the Ashfield Selectboard to "collect all pertinent information on wind turbine facilities and propose a by-law that will fairly and comprehensively answer to the concerns of the town as to the health, safety, and tranquility of its citizens but without prejudice against technology that will benefit the environment and help ensure sustainable energy supplies." The Committee concluded that the best way to satisfy this charge without compromising citizen amenity and health was to adopt a meaningful set of standards while allowing for the possibility of waivers from abutters to proposed projects.

Beginning in November 2010 the Committee met every two weeks to examine the issues surrounding wind turbine siting. Instead of working from a draft model bylaw subject to revisions, the Committee chose to focus on a few topics in depth, namely sound, shadow flicker, and setbacks, and attempted to gain greater technical mastery of each topic before drafting recommended bylaw language. On May 18 the Committee held a joint meeting with the Planning Board sharing its findings. The recommended draft language that the Committee believes should be part of any town bylaw is included as Attachment A.

Turbine sound/noise was a committee focus

The majority of Committee meetings and most of the several dozen papers and documents reviewed were devoted to the subject of understanding and regulating turbine sound. It is widely acknowledged that the sound from wind turbines is an important siting criterion. The successful siting of a wind generating facility in a community depends upon the creation and enforcement of noise standards that ensure that the new sound levels introduced into the local environment by the turbines will be acceptable to the community. As turbines have grown in size and are increasingly being proposed and sited closer to homes in the more densely populated Northeast, concerns about turbine noise have grown apace as complaints of adverse health effects by abutters to some installed projects have been publicized. [i] In Massachusetts a town owned turbine in Falmouth on Cape Cod has been the subject of persistent complaints by abutters since going online in 2009. Of 120 families within a mile of the turbine, 45 have expressed problems with noise. Although the town has taken steps to curtail turbine operations in high wind conditions, problems persist.[ii]

The committee's recommendations were developed after analyzing governmental regulations, best practice guidelines, and actual wind installations not only in Massachusetts, but in other states and international jurisdictions as well. The committee also reviewed industry standards worldwide and reports and recommendations by non-governmental agencies. A thorough review of peer reviewed academic research was conducted as well, especially as it relates to wind turbine noise and psychoacoustics-- the perceived loudness of turbine sounds. The committee began its investigative process, and was guided throughout by relying on reports from the Acoustic Ecology Institute (AEI), the work of Jim Cummings, who is well regarded as an impartial source of reliable analyses of community responses to turbine sound. AEI has produced a series of reports on turbine sound impacts designed for a layman's understanding, and its website includes helpful links to the original research informing its reports. [iii] The committee's final recommendation on regulating turbine sound have been influenced by careful attention to the work of acousticians –especially Richard James, Robert Thorne and Robert Rand- cited by AEI for their ongoing research and extensive fieldwork at installed wind installations examining turbine sound impacts. By examining the work of these acousticians and that of epidemiologists, noise annoyance studies by academic researchers, sleep experts, and other specialists, the Committee was able to gain a clearer picture of wind turbine sound and craft standards appropriate to the acoustic environment in Ashfield that can reasonably be expected to safeguard all but the most noise sensitive individual's amenity from nuisance levels of noise, in particular sleep disturbance from nighttime turbine noise.

Any attempt to regulate turbine sound must take into account the unique nature of turbine sound, individual differences in noise sensitivity [iv]and place identity [v](i.e. noise expectations of one's living environment), the ambient sound level of the community, and the inherent uncertainty in noise prediction modeling (an important factor and crucial distinction between turbine projects and other zoning decisions because of the lack of effective mitigation strategies for wind projects when pre-project modeling under predicts actual impacts).

Wind turbine sound is a singly unique and tonally complex sound, distinguished from other normal sounds by its modulating character and frequency component, particularly weighted in audible low frequencies and infrasonic frequencies (noise that is below the normal hearing range of all but the most noise sensitive persons [below 20 Hz].) The pulsing quality of the noise (often described as swishing, rumbling, or thumping, "boots in a drier", "plane that never lands"), a function of turbulent inflow of air into the blades, either from the atmosphere or the wake of neighboring turbines, creates noise pulses at about once per second, a time signature very near to the rhythm of human speech. This cyclic quality to the noise is especially attention grabbing and is one explanation why turbine noise is often audible as the dominant noise even when its amplitude is low and near background sound. Low frequency noise, unlike sounds in higher frequencies, travels further, is not easily attenuated by building materials, and is generally perceived as more threatening. It also disturbs sleep more easily.

The results of dose-response noise annoyance studies first conducted by researchers from Scandinavia and the Netherlands and a growing body of experience worldwide confirm that wind turbine noise is more annoying than comparable levels of transportation and other industrial noises as measured using the dBa sound scale.[vi] According to AEI "moderate wind farm noise seems to trigger more than twice the annoyance cased by other typical noise sources." [vii] For this reason facile comparisons between turbine sound and other noise sources are misleading as long as the character and frequency content of the noise sources differs. Research shows that annoyance from turbine noise begins at relatively low amplitude and is markedly higher in rural areas than more built-up areas. This finding is explained in part by the lower background sounds of rural areas, and a place identity marked by greater expectations of peace and quiet among residents, making it more likely that the introduction of a new industrial noise source (especially one that emits noise at nighttime) is not easily masked by other sounds and stands out more intrusively in an acoustic environment heretofore dominated by natural sounds. The intermittency of turbine noise (not knowing when it is going to start up) is also a contributing factor of annoyance. <u>These noise annoyance studies and the community impact assessments of many acousticians based on field studies show that noise complaints begin to rise</u>

with increasing rates of annoyance as noise levels go above 32 dBA in rural areas (research shows that some noise sensitive individuals could experience annoyance from turbine sound levels lower than 32.5 dBA, the absolute limit recommended by the Committee, and the Select board should be aware of this possibility).

In addition to crafting standards informed by an understanding of the character of turbine sound and basing limits on the most recent research into predicted community reactions[viii], the Committee also focused on creating a noise measurement protocol designed to most accurately measure the existing ambient environment in Ashfield and create guidelines for accurate forecasting of the sound levels produced by proposed turbine projects. Too often, acoustic studies for proposed projects have suffered from inadequate data collection and analysis by developer-chosen consultants, yielding overestimations of the background sound and underestimations of turbine sound, leading to poorly sited projects and greater than anticipated sound impacts. A complicated set of interacting factors influence turbine sound levels produced and heard at residences, including but not limited to meteorological conditions, wind turbine spacing, wake and turbulence effects, wind shear, turbine synchronicity, tower height, blade length and design, turbine sound power values, and topographical features.[ix] As a result, there is a great deal of uncertainty involved in the prediction of sound levels, a factor further magnified by the difficulty in accounting for individual differences in noise sensitivity.

State sound regulations inadequate

The need for Ashfield to adopt meaningful sound standards and effective noise measurement protocol is underscored by the paucity and inadequacy of current regulations statewide. [x]Virtually the only state sound standard governing wind projects is MA DEP 310 CMR 7.10, which limits new noise sources to no more than 10 decibels above existing ambient, as measured by the L90 metric. [xi] The more intrusive nature of turbine sound calls into question the use of standards developed for other noise sources. In fact, many international sound standards designed specifically for turbine sound, recommend a limit no more than 5 dB above existing ambient.

The Committee recommends that turbine noise be allowed to exceed ambient levels by no more than 5 dBA.[xii] Total project sound is not allowed to exceed 32.5 dBA at any non-participating property line. [xiii] Another important clause, based on the low frequency content of turbine sound is a requirement that LeqC-L90dBA not be greater than 20 dB outside any occupied structure and a maximum level of 52.5 dBC at non-participating properties. [xiv] Turbine measurement protocol (see Appendix Section#1 of Attachment A) contains a list of conditions for 1.) The predicted estimate of turbine sound levels, and 2.) Ensuring that existing sound levels in the community are accurately measured.

Under 1.), special emphasis is placed on the importance of predicting sound levels under conditions of atmospheric stability [xv](Section B1), considering topographical effects (Section B2b), predictions for line, as opposed to single point noise sources [xvi](Section B2c.), and factoring in margin of error predictions in both the noise prediction model and the manufacturer warranted sound power values [xvii](Section B2d.)

Under 2.), we note especially the importance of requiring the use of the C weighted sound measurement system, which more accurately captures the low frequency component of wind turbine sound.[xviii] (section C1). Another important standard is the requirement that sound measurements be made when ground level wind speeds are 2m/s or less (Section C4). Additional requirements on the season and duration of measurements are designed to ensure an accurate portrayal of the existing acoustic environment (Sections 6-8).

Setbacks

The Committee approved two setbacks, a non-waivable safety setback of one and one-half times the rotor diameter and hub height of the proposed turbine. [xix] The second setback, under the sound section, requires a setback distance of 3400 feet from turbine to non-participating property lines, a requirement that may be waived by property owners. [xx]

Conclusion

In conclusion, although many turbine projects in places with large unpopulated spaces like Texas and Plains states are sited far enough away from homes that sound complaints are non-existent, there are few if any places in Ashfield where sound will not be an important consideration for any proposal to install an industrial wind turbine(s). Recent years have seen a growing chorus of complaints worldwide by abutters of adverse health effects. There is at present a lack of epidemiological studies to properly explain the physiological pathways. It is clear that the main health effect is sleep disturbance and stress related illness. As of now, the only effective solution for safeguarding against sleep disturbance is to place turbines far enough away from homes that the noise will not be an issue. Several of the wind projects in the Northeast where there have been persistent abutter complaints of adverse health effects have also been described by supporters as successful projects, most notably Vinalhaven, on the basis that only a minority of individuals are negatively affected. This raises an important policy question that Ashfield residents will need to address; namely, how many people is it acceptable to impact if the goal is to site an industrial wind turbine locally, and where does one draw the line on the level of discomfort to negatively impacted individuals. Is it ok to cause sleep disturbance to some in pursuit of perceived larger public benefits?

The most recent comments by AEI founder Jim Cummings illustrates the current state of knowledge on turbine siting considerations:

Based on what's been found in other areas where there's a mix of farms and non-residents, if turbines were kept a mile from non-participating homeowners (noise at 30-35 dB), there would likely be virtually no noise issues; if the limit were a half mile (noise of around 40dB) it's likely that some of the neighbors just beyond that range will be quite disturbed and a few may want to move away. Knowing this each community needs to find its own balance between protecting neighbors and embracing wind development.

A reasonable solution would be to set higher distance limits to protect neighbors from unwanted noise impacts, while making it easy for landowners who don't mind some new noise to allow turbines to be built closer to their homes. These "noise easements" are one way to acknowledge that some people are more tolerant of noise than others, and to promote wind development without imposing a dramatic change in quality of life on those who especially value the current peace and quiet.

Shadow Flicker

Shadow flicker describes the phenomenon when rotating turbine blades are positioned between a receiving environment and a setting or rising sun. Computer modeling is used to predict the times of the year when flicker is likely to fall upon nearby homes. The Committee concluded that no amount of shadow flicker at a residence without their consent is desirable. The technology exists to program turbines to shut down during times when flicker is expected and the Committee concluded that the general setback required will likely limit the amount of times that turbine controls will need to be activated, and that individual amenity was guaranteed by adopting this measure. Industry standards and mitigation techniques are not appropriately protective.

Monitoring and Maintenance

See Appendix 1

Abandonment and Decommissioning

See Appendix 1. The Committee recommends that the town submit this section to a thorough legal review so as to ensure that the town is not held liable or responsible for the potentially costly removal of turbines at the end of their useful life.

Other Considerations

There are several other important topics for consideration as part of a wind energy bylaw that the Committee discussed informally without making formal recommendations. Of these, judging the appropriateness of siting turbines on ridgelines and determining the impact to wildlife and water sources are important subjects for further study. Limitations on blasting and changes allowed to topographical features of the landscape is another important concern that should be addressed in a bylaw. The inevitable visual impacts and the documentation thereof are under discussion.

Guidance from Selectboard Requested

The Committee requires further guidance on how to proceed, especially as the Planning Board is in the process of creating its own wind bylaw. Although opinions among committee members differ as to the meaning and intent of parts of the recently refilled state legislation to enact wind siting legislation, there is general agreement that this bill will change the way wind projects are reviewed at the local level. A bylaw approved by residents of the town will provide the best guidance to local officials on the standards for reviewing project proposals. The Selectboard may want to carefully consider the implications and potential value for passage of a bylaw before state legislative initiatives are voted upon sometime in the next several months.

Endnotes

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In addition to the well-publicized problems at the Falmouth MA turbines, there have been similar noise problems at several Maine sites: Mars Hill, Vinalhaven, and Freedom. At each site a combination of low background noise and homes within a mile have led to vigorous noise complaints. Michael Nissenbaum, a physician, has conducted a study awaiting publication in which 22 out of about 33 adults who live within 3500 feet of a ridgeline arrangement of 28 1.5 megawatt wind turbines were evaluated, compared to 28 people of similar age and occupation living about three miles away. Some of the preliminary results are: 82% of study subjects reported new or worsened chronic sleep disturbance, versus 3% in the control group. 36% reported new chronic headaches vs. 3% in the control group. 55% reported 'stress' versus none in the control group, and 82% persistent anger versus none in the control group. 95% of the study subjects perceived reduced quality of life versus 0% in the control group.

From AEI Wind farm Noise: 2009 in Review: *First and foremost is sleep disruption. There is little question that noise levels of more than 5 or 10dB over the still late-night ambient levels of 20-30 dB can wake people. Some wind farm neighbors report many nights of getting only four or five hours sleep. Less appreciated is that low levels of noise also triggers non-waking arousal during sleep which disrupts normal sleep stages, leaving the sleeper less well-rested upon waking in the morning. Many wind farm neighbors complain of headaches, irritability, trouble concentrating, and similar symptoms that are often rooted in lack of solid nighttime rest.*

The name given to the constellation of symptoms identified by abutters is 'wind turbine syndrome' a term coined by Dr. Nina Pierpont, who conducted and self-published a case study of selected subjects in 2009. According to Pierpont, symptoms caused by turbine exposure include sleep disturbance, headaches, pressure and pain in the ear and eyes, dizziness, vertigo, unsteadiness, and nausea, essentially seasickness on land, sensations of internal pulsation or movement, in the chest or abdomen, associated with panic-like episodes, and problems with memory and concentration.

It should be stressed that further epidemiological studies need to be conducted testing Pierpont's hypothesis. As a result of complaints, several governmental bodies, including the Australian Senate, State of Oregon, and the government of Japan are currently examining the issue of adverse health effects in connection with turbine noise.

[ii] It should be noted that the town of Falmouth regulations restrict turbine noise to 40dB. The town has maintained that recent post-construction acoustic studies addressing the problem has demonstrated that the turbine is in compliance with this standard. If true this suggests the inadequacy of a 40dB limit for a built-up suburban area with a busy highway running very near to the turbine and affected homes. Residents have lodged complaints of sleep disturbance as far away as 3400 feet from the turbine.

[iii] The Committee began its work by reviewing AEI report *Wind Farm Noise: 2009 in Review.* http://www.acousticecology.org/spotlight_windfarmnoise2009.html Jim Cummings, the head of AEI, further elaborated AEI's evolving understanding of turbine sound impacts in a presentation on community noise for a webinar at the request of the New England branch of the Wind Powering America program, a wind advocacy project of the US Department of Energy (http://aeinews.org/archives/972). More recently, an article by Cummings in Renewable Energy World detailed the current state of understanding on the world of research into turbine sound impacts (http://aeinews.org/archives/1236).

From AEI's mission statement: "On public policy questions, we tend toward the precautionary principle (erring on the side of caution while awaiting definitive research). Our overarching goal is to help find pragmatic ways to bridge the gaps between extreme positions voiced by advocacy-oriented organizations, and so to contribute toward the development of ethical public policies regarding sound."

Using the work of AEI as an impartial guidepost for accurate research was highlighted by the fact that one of the two developers exploring a turbine installation in Ashfield personally recommended the work of AEI to the Committee chair.

[iv] According to AEI, noise sensitivity among the general population is divided generally into three groups: 20% of the population is noise sensitive, 50% noise tolerant, and 30% moderately noise sensitive (a group which notices most sounds but reactions are sound and situation dependent)

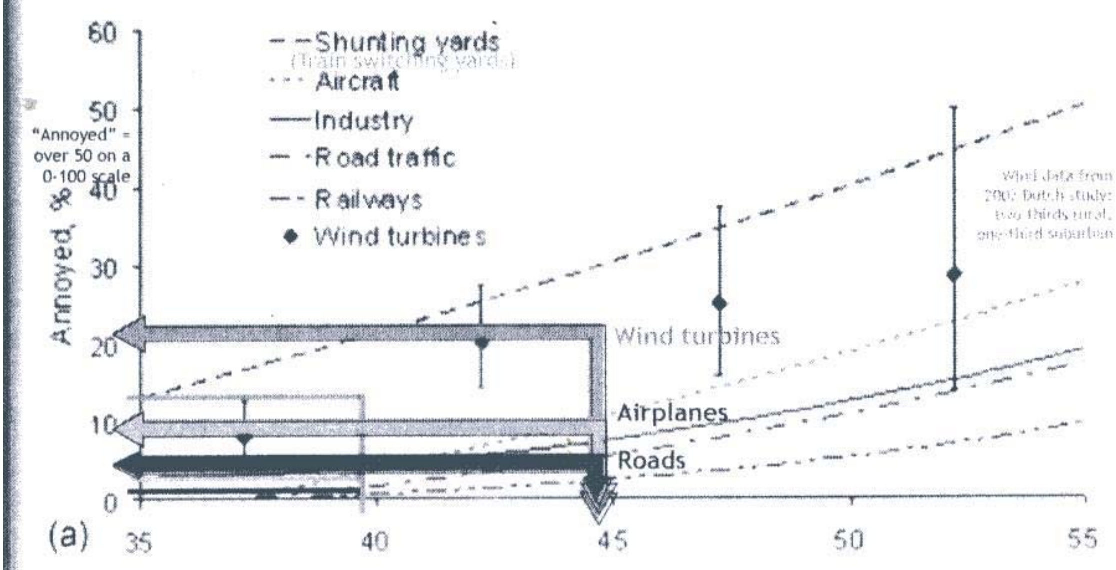
From *Public Health Impacts of Wind Turbines* by the Minnesota Department of Public Health, p. 15: *Human sensitivity to sound, especially to low frequency sound, is variable. Individuals have different ranges of frequency sensitivity to audible sound; different thresholds for each frequency of audible sound; different vestibular sensitivities and reactions to vestibular activation; and different sensitivity to vibration. Further, sounds, such as repetitive but low intensity noise, can evoke different responses from individuals. People will exhibit variable levels of annoyance and tolerance for different frequencies. Some people can dismiss the signal while for others, the signal will grow and become more apparent and unpleasant over time…These reactions may have little relationship to will or intent, and more to do with previous exposure history and personality.*

Daniel Sheperd, an expert in psychoacoustics, whose work was reviewed by the Committee, has written extensively on the subject: *Finally, as with other noise sources there is individual variation in regards to the effects of wind turbine noise. However, it is a fallacy to argue* *that because only some suffer symptoms while others do not then those who claim to be suffering the symptoms must be making them up. In the field of epidemiology the differential susceptibility of individuals are known as risk factors, and assuming that individuals of a population can be represented by the average characteristics of the population is known as the ecological inference fallacy.*

[v] There is an increasing focus of attention on the fact that community setting and individual expectations within that setting is an important predictor of annoyance rates. AEI has observed that turbine noise annoyance is higher in rural areas than suburban or urban areas, in part because turbine noise level are more intrusive in a landscape with low background sound and little experience with industrial sound. But there are differences in reaction between rural areas as well, and AEI has speculated that one's expectations of the landscape play a role. If the country side is seen as a place for economic activity and technical development /experimentation, a farm landscape in Iowa for example, turbine noise is more likely to be accepted than in a rural place which is seen by residents as a place for peace and restoration. AEI has commented that this distinction may be one reason turbine noise is less easily tolerated in some rural areas with more non-farming residents. Also, according to AEI "'work the land' folks can't understand the extreme reactions of 'restorative' identity neighbors, while 'restorative' have a hard time imagining how anyone could not be bothered by noise intrusions."

[vi] The strikingly different rates of annoyance when turbine noise is compared to other transportation and industrial noise sources suggests that there is something about the character of turbine sound influencing the listener that is more important than the amplitude, or loudness of the noise.

Below are several graphs showing the different rates of annoyance from dose response survey research where annoyance is charted as a function of noise level. The first and second graphs are from an AEI webinar quantifying this research, showing the different rates of annoyance between turbine noise and others noise sources and breaking down study results as a function of whether the respondent lived in a suburban or rural area. The third graph is from the work of Eja Pederson and Kristen Perrson Waye.



Moderate wind farm noise seems to trigger more than twice the annoyance caused by other typical noise sources

Even when it meets statutory noise limits for wind farms:
State/local US limits: 50dB 45dB 40dB 36dB

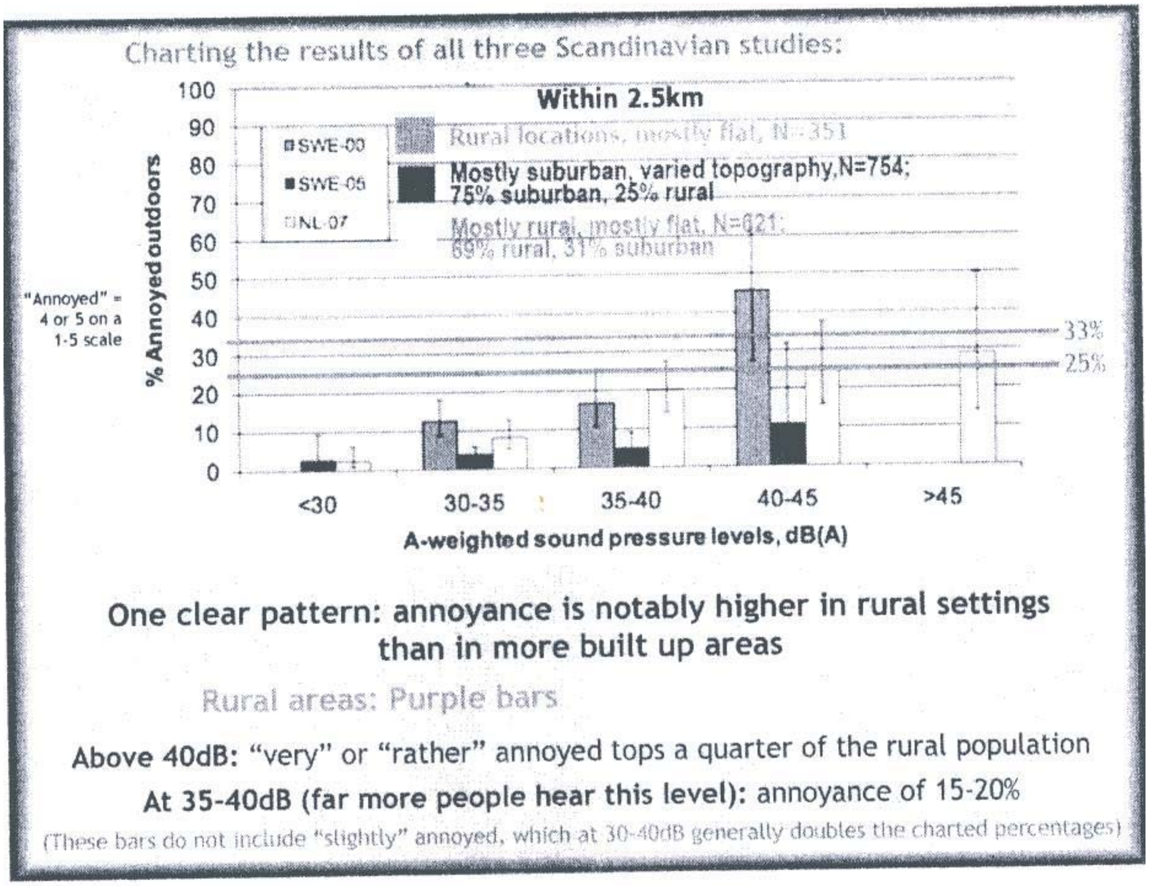
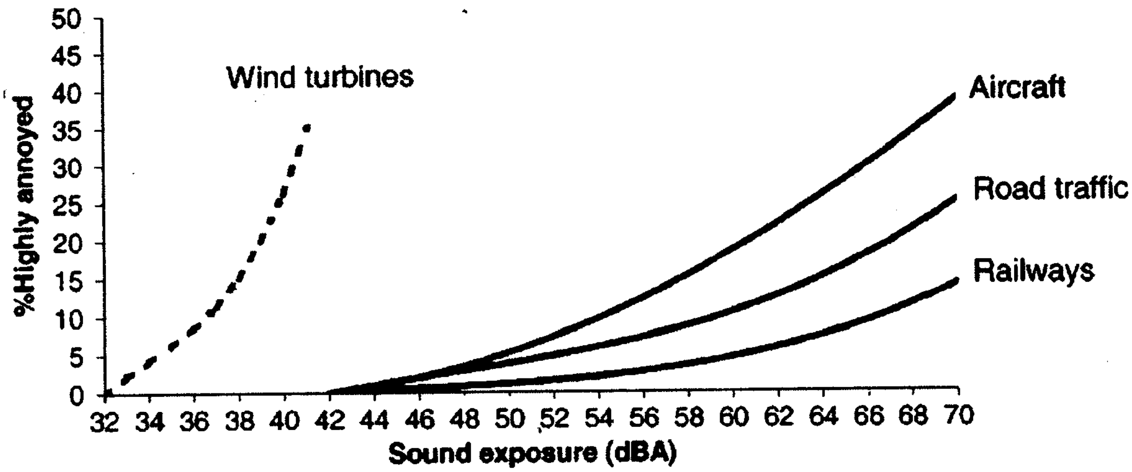


Figure 6: Annoyance associated with exposure to different environmental noises



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

Noise studies performed on behalf of other projects in Massachusetts have acknowledged these findings. *The Sound Level Impact Assessment Report* for the Minuteman Savoy Wind Project states:

Although wind turbine noise is not separately regulated by Massachusetts DEP, a study of wind turbine noise indicates that, in general, it may be more annoying at a specific noise level than noise from other community noise sources. This is due to the time-varying sound level of the noise as the blades rotate, which makes it more noticeable, and to the nearly continuous (more than several hours at a time) duration of wind turbine noise. This study indicates that some people surveyed found wind turbine noise to be annoying at a level of 35 dBA, and about half of the people surveyed found wind turbine noise to be more annoying at a level of about 40 dBA. Therefore, these levels will also be computed and displayed, as guidelines in determining locations where noise annoyance could occur.

[vii] According to Heather Goldstone, a toxicologist by training who recently devoted a weeklong series on the noise problems being experienced by abutters to the Town of Falmouth's wind turbine (see climatide.wgbh.org), the word annoyance in this context is often misinterpreted as a "subjective emotional response" and thus the secondary health effects of annoyance are dismissed. In medical usage annoyance is a technical term as expressed in a formal definition by acoustician Alice Suter; *Annoyance has been the term used to describe the community's collective feelings about noise ever since the early noise surveys in the 1950s and 1960s, although some have suggested this term tends to minimize the impact. While "aversion" or "distress", might be more appropriate descriptors, their use would make comparisons to previous research difficult. It should be clear, however, that annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life.*

[viii] Robert Rand, a Maine acoustician who has taken extensive field measurement at wind installations and is an expert in community impact assessments, created the graphs below. Rand has written that research data show that "there can be an adverse community reaction, with associated activity interference, for wind turbine noise levels above 32 dBA in rural areas."

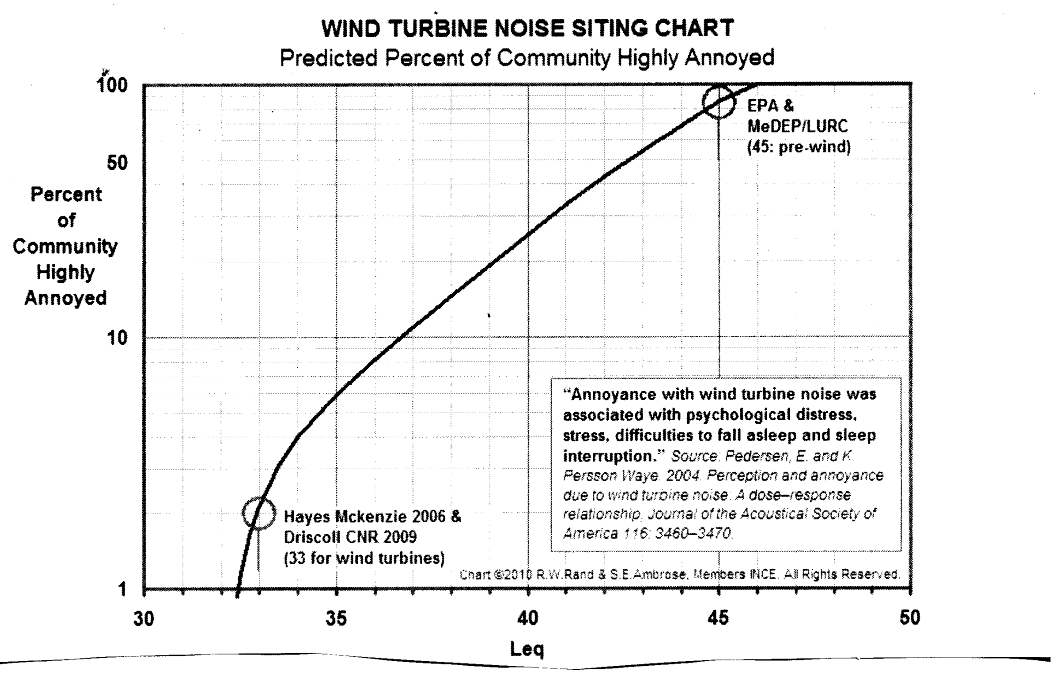
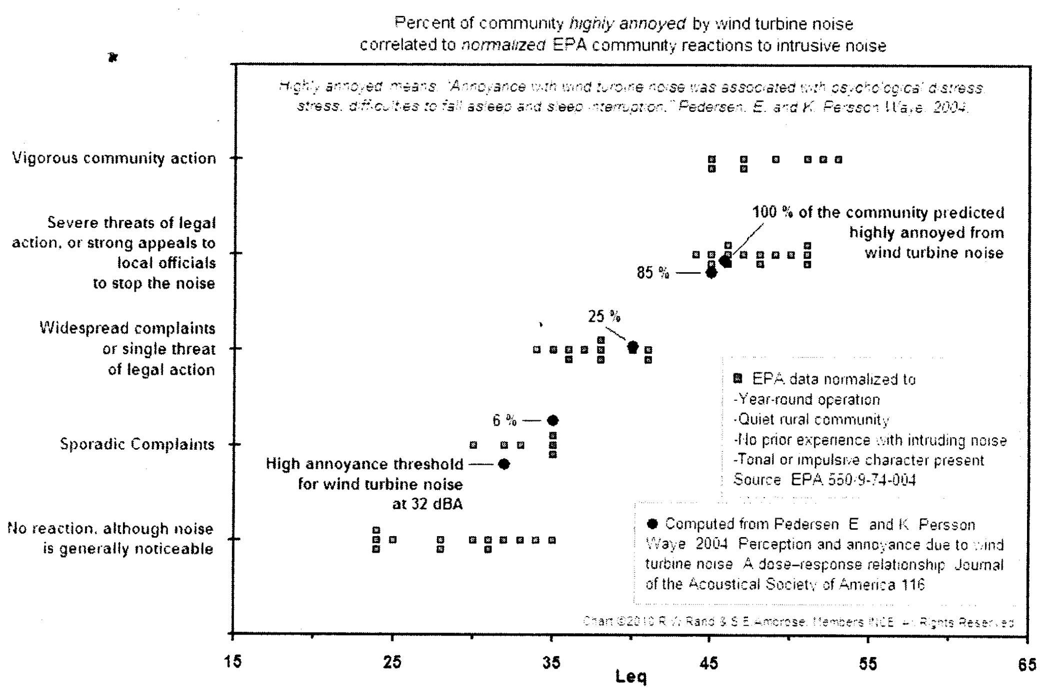

WIND TURBINE NOISE SITING CHART
Predicted Percent of Community Highly Annoyed
Percent of Community Highly Annoyed
100
50
10
1
30
35
40
45
50
Leq
EPA & MeDEP/LURC (45: pre-wind)
Hayes Mckenzie 2006 & Driscoll CNR 2009 (33 for wind turbines)
"Annoyance with wind turbine noise was associated with psychological distress, stress, difficulties to fall asleep and sleep interruption." Source: Pedersen, E. and K. Persson Waye. 2004. Perception and annoyance due to wind turbine noise. A dose–response relationship. Journal of the Acoustical Society of America 116: 3460–3470.
Chart ©2010 R.W.Rand & S.E.Ambrose, Members INCE. All Rights Reserved.

Figure 1 – Percent of Community Highly Annoyed.



1. Information On Levels Of Environmental Noise Requisite To Protect Public Health And Welfare With An Adequate Marg Of Safety, 550/9-74-004, March 1974.
2. Pedersen, E. and K. Persson Waye, Perception and annoyance due to wind turbine noise: A dose–response relationshi Journal of the Acoustical Society of America 116, 2004.

ix The difficulty inherent in accurately forecasting noise impacts is highlighted in a recent article describing a new research project at the University of Adelaide devoted to studying the causes of turbine noise with the goal of making them quieter. According to research leader Dr. Con Doolan, "wind turbine noise is very directional. Someone living at the base might not have a problem but two kilometers away, it might be keeping them awake at night." http://www.news.com.au/university-of-adelaide-to-investigate-reducing-wind-turbine-noise/story-e6frea83-1226067109947

x In 2007 the National Research Council (NRC), the principal operating agency of the National Academy of the Sciences, released a study examining local, state and national guidelines governing the development of wind energy in the United States. The 267-page congressionally mandated report, *Environmental Impacts of Wind Energy Projects*, concluded that clearer guidelines for effectively evaluating the environmental benefits and drawbacks of wind energy were needed. In contrast to this country's lack of clear guidelines, and their uneven application, the report commended best practice guidelines of other countries with longer experience in wind energy. Although the state of Massachusetts has developed ambitious goals for siting large numbers of turbines in the state, to date there has been little effort devoted to developing siting standards based on scientific understanding of turbine impacts.

Excerpts from *Environmental Impacts of Wind Energy Projects*

- *The United States is in the early stages of learning how to plan for and regulate wind energy. The experience of other countries, where debates over wind energy have been going on for much longer, can be instructive for bringing U.S. frameworks to maturity.*
- *Europe and Canada have generally done a more thorough job in providing definitive best practice guidelines. The integration of local, regional, and national planning and review efforts in those countries contributes to the success of their review processes….Here, standards for best practices are evolving as communities and states recognize the need for a more systematic approach to evaluating visual impacts. There is considerable variability in the review of proposed projects.*
- *Once regulatory authorities receive information on environmental effects, costs, and technical specifications for proposed wind-energy developments, they are charged to decide whether to allow the development to go forward, and with what, if any, conditions to ameliorate negative effects. Directions for this complex weighing of pluses and minuses of using wind energy are scant and generally limited to general statements about "balancing" interests and acting "in the public good," resulting in a holistic balancing of positive and negative impacts of the proposed development, rather than a decision based on clearly stated decision criteria.*
- *Because wind energy is new to many state and local governments, the quality of decisions to permit wind-energy developments is uneven in many respects.*
- *Wind energy projects can have positive as well as negative impacts on human health and well-being… to the extent that wind-energy projects create negative impacts on human health and well being, the impacts are mainly experienced by people living near wind turbines who are affected by noise and shadow flicker.*
- *Regulation of wind-energy development is new for most jurisdictions, so both the regulations themselves and the procedures for implementing them are evolving and precedents are being gradually set through experience.*
- *In evaluating current regulatory-review processes, the committee was struck by the minimal guidance offered about the kind of information that should be provided for review; the degree of adverse or beneficial effects of proposed developments that should be considered critical for approving or disapproving a proposed project; and how competing costs and benefits of a proposed project should be weighed…This lack of guidance leaves a lot to the discretion of regulatory authorities and the other agencies that review elements of the proposed project, making both developers and the public vulnerable to inconsistent requirements among proposed projects and among potential locations. It also has limited our knowledge of the impacts of wind energy development on human and natural resources.*

[xi] The current state noise policy regulated by the Department of Environmental Protection, 310 CMR 7.10, allows up 10 dBA above the ambient. The fact sheet from the DEP states:
This policy was originally adopted by the MA Department of Public Health in the early 1970's. It was reaffirmed by DEP's Division of Air Quality Control on February 1,1990, and has remained in effect.

This policy makes no distinction between commercial or residential areas, and unlike other countries with greater experience in wind energy, doesn't require absolute lower sound limits based on zoning or acoustical classification. Most other new noise sources do not potentially make noise 24 hours a day, as wind turbines do when the wind is blowing. More importantly, the policy was created before wind turbines were in Massachusetts (other than in an experimental way) and presumes that wind turbine noise is similar to other noises. Recent research has demonstrated the opposite.

[xii] Audible Sound Limit
Draft language …***No wind turbine shall be located so as to cause an exceedance of the preconstruction background sound levels by more than 5 dBA….***

- *An increase of 10 dB(A) deserves consideration of avoidance and mitigation measures in most cases….In non-industrial settings the SPL should probably not exceed ambient noise by more than 6 dBA at the receptor*. ~New York State Department of Environmental Conservation Program Policy. Assessing and Mitigating Noise Impacts. Department ID: DEP 00-01, Rev: 2 Feb 2001
- Sound standards in various international jurisdictions: France +5 day/+3 night, UK L90 +5dBA, New Zealand and Australia L90 + 5
- *A change in sound level of 5dB will typically result in a noticeable community response.. A 10 dB increase is subjectively heard as an approximate doubling in loudness, and almost always causes an adverse community response.* ~Rogers,AL, Manwell,J.F Wind Turbine Noise Issues RERL, University of Massachusetts at Amherst June 2002, as amended March 2004.
-

[xiii] 3. General Clause
draft language- ***sound not to exceed 32.5 at any non-participating property line***

- *…. Researchers appear to be coalescing around recommended wind farm noise standards of 30-35 dB, which do in fact come closer to the familiar goal of keeping new noise intrusions to within 5-10 of existing ambient conditions (rural night ambient is often around 25 dB, even when winds aloft trigger turbines into action).* ~Jim Cummings, Acoustic Ecology Institute *Looking for Wind Industry Leadership in reducing Noise Impacts*, **Renewable Energy World** , February 23, 2011
- *It is concluded that, based on professional opinion, serious harm to health occurs when a susceptible individual is so beset by the noise in question that he or she suffers recurring*

sleep disturbance, anxiety, and stress. The markers for this are a) a sound level of LAeq 32 dB outside the residence and b) above the individual's threshold of hearing inside the home. ~Dr. Robert Thorne Wind farm Noise Guideline 2011, page 7.

- *For the primary prevention of subclinical adverse health effects in the population related to night noise, it is recommended that the population should not be exposed to noise levels greater than 30 dB of Lnight outside during the night when most people are in bed. Therefore L night outside 30 dB is the ultimate target of Night Noise Guidelines to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of noise.* ~ World Health Organization (2009) Night Noise Guidelines for Europe. Copenhagen
- *We are proposing an immission limit of 35 dBA or L90 + 5 dBA whichever is lower…*~Rick James and George Kamperman, Simple Guidelines for Siting Wind Turbines to Prevent Health Risks. Noise Con 2008.
- 30 dB ~ recommendation Dr. Daniel Sheperd, PhD. In psychoacoustics, faculty of Health, Aukland University of Technology.
- Graph created by Robert Rand, a Maine acoustician for predicting high annoyance, based on EPA methodology and survey research of Eja Pederson, "clearly shows that there is a predictable adverse community response for wind turbine noise levels above 32 dBA." ~Stephen Ambrose and Robert Rand, members of the Institute for Noise Control Engineering, randacoustics.com
- *There are some locations that are particularly quiet at times and so the recommended limit at 40 would be considered to be unreasonable…[under these conditions] the sound from the wind farm during the evening and night time should not exceed the background sound level by more than 5 dB or a level of 35 dB LA90 (10 min) whichever is the greater.* ~ The New Zealand Wind Farm Standard 2010
- 35 dB at property line ~testimony of Leslie Blomberg, executive director of the Noise Pollution Clearinghouse on wind project proposed in Lowell VT.
- Selected International Noise Standards: Germany-35dB rural nighttime limit, New South Wales and Western Australia- 35 dB (or L90 + 5dB)
- *While many jurisdictions have set a standard based upon a 40 dBA limit there are some emerging concerns that the 40 dBA measured at the exterior of a receptor is not sufficient to avoid unacceptable effects. The Australian guideline of 35dBA or 5dBA above the background noise is an example of a more conservative basis to establish a decibel based limit regarding impacts to human health and quality of life….(p 25) While there are no universally accepted dBA standards, the range proposed most often by other municipalities in recent standards, or by credible researchers, is 35dBA (more conservative) or 40 dBA (less conservative but more common) or 5 dBA above background levels at the exterior of the nearest habitable dwelling.*(p 71) ~ Final Report Model Wind Turbine Bylaw and Best practices for Nova Scotia Municipalities, 2008.
- *Complaints appear to rise with increasing outside noise levels above 35 dBA.* ~ Minnesota Department of Public Health, Public health Impacts of Wind Turbines, 2009.
- Recommendation that noise levels be no greater than 35 dBA at the nearest residence ~ report by the Ohio Department of Public Health, 2008.

- *No turbine should produce more than 30 decibels of noise, measured from a half mile away* ~ draft bylaw of the Falmouth MA Planning Board, as reported in The Enterprise, November 23, 2010.
-

[xiv] 2. Low Frequency Sound Limit

draft language- ***The Leq and L90C sound levels …shall not exceed the lower of either: LeqC-L90 greater than 20 dB outside any occupied structure***

- *The World Health Organization (WHO) recommends that if dB(C) is greater than 10 dB more than dB (A), the low frequency components of the noise may be important and should be evaluated separately. In addition, WHO says "[it] should be noted that a large proportion of low frequency components in noise may increase considerably the adverse effects on health.* ~ Minnesota Department of Public Health, Public Health Impacts of Wind Turbines, 2009.
- *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….. For noise with a large proportion of low frequency sounds a still lower guideline (than 30 dBA) is recommended.* ~ World Health Organization
-

xv **Atmospheric Stability and Wind Turbine Noise**

The current practice of using a standard atmospherically neutral profile for predicting noise impact does not adequately reflect the actual sound power output of larger turbines under relatively common meteorological conditions. As a result, noise modeling is underestimating noise impacts.

The inadequacy of current standards for measuring turbine noise are noted in The National Research Council report:

- *Recent research studies regarding noise from wind-energy projects suggest that the industry standards (such as the IEC 61400-11 guidelines) for assessing and documenting noise levels emitted may not be adequate for nighttime conditions and projects in mountainous terrain. This work on understanding the effect of atmospheric stability conditions and on-site specific terrain conditions and their effects on noise needs to be accounted for in noise standards. In addition, studies on human sensitivity to low frequencies are recommended.*
- *A recent study by van den Berg (2004,2006) suggests that, especially at night during stable atmospheric conditions, low frequency modulation (at around 4 Hz) of higher frequency swishing sounds is possible*

The original research of G.P. van den Berg, noted above, has contributed to the understanding of why complaints of wind turbine noise are growing worldwide, especially complaints of nighttime noise. Van den Berg's work has demonstrated that current noise prediction models based on a neutral atmospheric profile do not accurately model noise under conditions of atmospheric stability, most often experienced at nighttime. He showed that the noise is also higher than expected, and that due to changes in the wind gradient under those conditions wind turbines produce sound with an impulsive character that is highly annoying to nearby residents. This thumping sound can be heard at distances far greater than wind industry calculations predict is even possible. This sound is also not detectable at the base of a wind turbine. The common suggestion that standing underneath a wind turbine is a good indicator of the type of noise residents could expect to hear is belied by van den Berg's research. Van den Berg shows that the impulsive thumping sound that many residents living near turbine installations find so annoying, which is a result of a certain wind profile and the interaction of sound from different turbines, is not heard underneath a turbine, but **is** heard at considerable distances from turbines. And the impulsive beating sound gets louder and travels farther especially under stable atmospheric conditions at nighttime.

Van den Berg's findings grew out of his investigation into the noise complaints by Dutch neighbors of a German wind project with tall wind turbines. Residents as far as 1900 meters (6,234 feet) away from turbines expressed annoyance with turbine sound. Van den Berg's research showed that noise prediction models based on a standard neutral profile significantly underestimated the actual noise experience by residents.

In *"Effects of the wind profile at night on wind turbine sound"* <u>Journal of Sound and Vibration</u> G.P. van den Berg states:

> *It is usual in wind turbine noise assessment to calculate immission sound levels assuming wind speeds based on wind speeds v10 at reference height (10m) and a logarithmic wind profile. This study shows that the sound immission level may, at the same wind speed v10 at 10m height, be significantly higher (up to 18dB) during nighttime than in the daytime. Another, 'stable' wind profile predicts a wind speed at hub height 1.8 times higher than expected and agrees excellently with the average measured night-time sound immission levels. Wind speed at hub height may still be higher; at low wind speeds v10 up to 4m/s, the wind speed vh is at night up to 2.6 times higher than expected.*
>
> *Thus, the logarithmic wind profile, depending only on surface roughness and not on atmospheric stability, is not a good predictor for wind profiles at night. Especially for tall wind turbines, estimates of the wind regime at hub height based on the wind speed distribution at 10m, will lead to an underestimate of the immission sound level at night: at low wind speed (v10< or = 4m/s) the actual sound level will be higher than expected for a significant proportion of time. This is not only the case for a stable atmosphere, but also, to a lesser degree, for a neutral atmosphere.*
>
> *The change in wind profile at night also results in lower ambient background levels than expected: at night the wind speed near the ground may be lower than expected from the speed at 10m and a logarithmic wind profile, resulting in low levels of wind induced sound from vegetation. The contrast between wind turbine and ambient sound levels is therefore more pronounced at night.*

Further explanation on the role of atmospheric stability and its effect on daytime and nighttime turbine sound is offered by van den Berg in *"The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise"*:

- *There is a distinct audible difference between the night and daytime wind turbine sound at some distance from the turbines. On a summer's day in a moderate or even strong wind the turbines may only be heard within a few hundred meters and one might wonder why residents should complain of the sound produced by the wind farm. However, in quiet nights the wind farm can be heard at distances of up to several kilometers when the turbines rotate at high speed. In these nights, certainly at distances from 500 to 1000m from the wind farm, one can hear a low pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broad band 'noisy' sound. A resident living at 1 km from the nearest turbine says it is the rhythmic character of the sound that attracts attention: beats are clearly audible for some time, then fade away to come back again a little later. A resident living at 2.3 km from the wind farm describes the sound as 'an endless train'. In daytime these pulses are usually not audible and the sound from the wind farm is less intrusive or even inaudible (especially in strong winds because of the then high ambient sound level).*
- *A high wind shear at night is very common and must be regarded a standard feature of the nighttime atmosphere in the temperate zone and over land. In fact the atmosphere is neutral for only a small part (approximately 10%) of the time. For the rest it is either stable (sun down) or unstable (sun up).*
- *To assess wind turbine electrical and sound power production the use of a neutral wind profile should be abandoned as it yields data that are not consistent with reality.*
- *1) [B]ecause wind turbines become taller, there is growing discrepancy between prediction and practice; 2) measurements are usually done in daytime when the wind profile resembles more closely the commonly used standard profile; 3) based on the sound that occurs in daytime, it is hard to imagine the sound can be so different at night.*
- *It is often assumed that there is a fixed relation between the wind velocity at hub height and at a reference height of 10 meter. This is the relation valid in a neutral or 'standard' atmosphere. No other relations are given in legislation or international guidelines for wind turbine sound that are valid in other conditions of the atmosphere, viz. The stable and unstable conditions.*

  The atmosphere is unstable when in daytime the air near the ground is relatively warm from contact with the surface heated by solar insulation. In that case vertical air movements originate and the wind profile is not equal to the profile in a neutral atmosphere, though is does not differ strongly. A stable atmosphere however has a markedly different wind profile. The atmosphere is stable when the air close to the ground is relatively cold due to contact with the ground surface when this cools down at night by radiating heat. A stable atmosphere occurs especially in nights with a partial or no cloud cover and the wind is not too strong (close to the ground). In a stable atmosphere the turbulence has decreased substantially and as a result layers of air are less strongly coupled. The lower layer of air is thus less taken along with the wind that at higher altitudes keeps on blowing, giving rise to greater differences between with velocities at different heights.
- *At the same wind velocity at a reference height of 10 meters, wind turbines in a stable atmosphere generate more sound than in a neutral atmosphere, while at the same time the wind velocity near the ground is so low that the natural ambient sound due to rustling*

vegetation is weaker. As a result the contrast between wind turbine sound and natural ambient sound is more pronounced in stable conditions than it is in neutral conditions.

Not only did van den Berg show that after sunset turbine sound often becomes louder, but he also demonstrated that the sound exhibits stronger fluctuations. The National Research Council report identified noise fluctuation strength as being correlated with unpleasantness. Van den berg describes a phenomenon in which the turbine blades acquire a more distinct periodic sound, described as blade swish, and is experienced by those nearby as a pronounced audible beating sound. The effect is described by van den Berg in *The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines* from Journal of Low Frequency Noise, Vibration and Active Control 24 (1), March 2005:

- *Our experience at distances of approximately 700 to 1500 m [2,296 to 4,921feet] from the Rhede Wind Farm, with the turbines rotating at high speed in a clear night and pronounced beating audible, is that the sound resembles distant pile driving. …Several residents near single wind turbines remark that the sound often changes to clapping, thumping, or beating when night falls: 'like a washing machine.' It is common in all descriptions that there is a noise ('like a nearby motorway', 'a B747 constantly taking off') with a periodic increase superimposed.*
- *Part of the relatively high annoyance and the characterization of wind turbine sound as lapping, swishing, clapping or beating may be explained by the increased fluctuations of the sound [2,21] Our results show that in a stable atmosphere measured fluctuation levels are 4 to 6 dB for single turbines, and in long term measurements (over many 5 minute periods) near the Rhede Wind Farm fluctuation levels of approximately 5 dB are common but may reach values up to 9 dB.*
- *It can be concluded that, in a stable atmosphere, the fluctuations in a modern wind turbine sound can be readily perceived.*
- *Those who visit a wind turbine in daytime will usually not hear this and probably not realize that the sound can be rather different in conditions that do not occur in daytime.*
- *Atmospheric stability has a significant effect on wind turbine sound, especially for modern tall turbines*
- *First, it is related to a change in wind profile causing strong, higher altitude winds, while at the same time wind close to the ground may become relatively weak. High sound immission levels may thus occur at low ambient sound levels, a fact that has not been recognized in noise assessments where a neutral or unstable atmosphere is usually implied. As a result, wind turbine sound that is masked by ambient wind-related sound in daytime, may not be masked at nighttime.*
- *Secondly, the change in wind profile causes a change in angle of attack on the turbine blades. This increases the thickness (infra) sound level as well as the level of trailing edge (TE) sound…..The calculated rise in sound level during swish then increases from 1-2 dB to 4-6 dB. This value is confirmed by measurements at single turbines in the Rhede Wind Farm where maximum sound levels rise 4 to 6 dB above minimum sound levels within short periods of time.*
- *Thirdly, atmospheric stability involves a decrease in large-scale turbulence… As a result turbines in the farm are exposed to a more constant wind and rotate at a more similar speed*

with fewer fluctuations. Because of the near synchronicity, blade swishes may arrive simultaneously for a period of time and increase swish level.

- *Sound level differences (LA max-LA min) (corresponding to swish pulse heights) within 5 minute periods over long measurement periods near the Rhede Wind Farm show that level changes of approximately 5 dB occur for an appreciable amount of the time and may less often be as high as 8 to 9 dB. This level difference did not decrease with distance, but even increased 1 dB when distance to the wind farm rose from 400m to 1,500 m [1312 to 4921 feet] The added 3-5 dB, relative to a single turbine, is in agreement with simultaneously arriving pulses from two or three approximately equally loud turbines.*

Van den Berg concludes with a recommendation:

> *It is obvious that in wind turbine sound measurements atmospheric stability must be taken into account. When the impulsive character of the sound is assessed, this should be carried out in relation to a stable atmosphere, as that is the relevant condition for impulsiveness. Also sound immission should be assessed for stable conditions in all cases where nighttime is the critical noise period. Wind speed at low heights is not a sufficient indicator for wind turbine performance. Specifically, when ambient sound level is considered as a masker for wind turbine sound, neither sound should be related to wind speed at reference heights via a (possibly implicit) neutral wind profile.*

The fluctuation sounds described by van den Berg are supported by other research involving surveys of residents living near actual wind farms. In a paper for the Swedish Environmental Protection Agency, titled *Noise Annoyance from Wind Turbines-a review*, Eja Pedersen describes a similar phenomenon to that described by van den Berg:

> *When listening to a wind turbine, one may distinguish broadband noise and a beating noise. Broadband noise is characterized by a continuous distribution of sound pressure. The beating noise is amplitude modulated, i.e. the sound pressure level rises and falls with time. This noise is of interest for this review, as it seems to be more annoying than a non-modulated noise at the same sound pressure level.*

To date the effects described by van den Berg appear to have been completely ignored by state agencies and consultants working to promote wind projects in MA.

A report commissioned in 2006 by the UK Department of Trade and Industry -- *The Measurement of Low Frequency Noise at Three UK Wind Farms* by Hayes Mckenzie Partnership Ltd concluded that the major reason for complaints associated with wind turbine noise was the audible modulation of the aerodynamic noise, especially at night.

- *The analysis indicates that it may be appropriate to re-visit the issue of aerodynamic modulation and the means by which it should be assessed. In the presence of high levels of aerodynamic modulation a correction for the presence of the acoustic feature should be considered.*
- *The risk of high levels of aerodynamic modulation is believed to be greatest for sites where stable atmospheric conditions occur and tall wind turbines are proposed/operating or where high levels of wind shear exist at a site. In general, stable atmospheric conditions are more likely to occur at level sites which are to be found in the UK…*

Interestingly, as part of its investigation the authors interviewed turbine manufacturers about the problem of AM. The comments of one turbine manufacturer are illuminating:

> *A Danish wind turbine manufacturer indicated that extreme wind shear may lead to local stall phenomena when the blade is in the top azimuth position. This might lead temporarily to increased levels of aerodynamic noise at the top of the rotor arc which would give modulated noise output consistent with AM. It was also indicated that assuming a neutral atmospheric condition may underestimate the source noise level of a wind turbine in actual conditions. In these circumstances, wind turbine noise immission levels would be higher than predicted and might lead to a greater audibility of wind turbine noise than might normally be expected. This relates to the findings and description of the overall sound pressure level measurements undertaken by van den Berg (2006)*

The research annotated above suggests the need for conservative noise modeling, especially at sites with greater potential for wind turbine noise issues. Any modeling should be based, as much as possible on actual field data from the proposed site (not assumptions about projected wind speeds or noise levels based on limited data) including consideration of wind shear, meteorological conditions, number of turbines proposed, and community expectations of acceptable noise levels.

[xvi] From the *Public Health Impacts of Wind Turbines* by the Minnesota Department of Public Health, p.23*: In general, sound tends to propagate as if by spherical dispersion. This creates amplitude decay at a rate of about -6dB per doubling of distance. However, low frequency noise from a wind turbine has been shown to follow more of a cylindrical decay at long distances, about -3dB per doubling of distance in the downwind direction (Sheperd and Hubbard, 1991) This is thought to be the result of the lack of attenuation of low frequency sound waves by air and the atmospheric refraction of the low frequency sound waves over medium to long distances. (Hawkins).*

[xvii] The committee requires sound modeling to incorporate margin of error values into the sound estimates for the particular noise modeling program being used and for the turbine manufacturer warranted sound power values.

Noise Modeling Uncertainty

Because noise is site specific, and is affected by the interaction of a variety of factors, including topography, meteorological influences, wind speed and direction, it is difficult to make accurate noise predictions with confidence. The inadequacy of noise modeling programs to account for certain atmospheric conditions, and the margin of error of these programs and of manufacturer warranted sound power values, upon which sound power output predictions are made, all argue for the need for a minimum setback expressed in distance instead of relying only on a noise standard and theoretical modeling as a basis for determining setbacks. This need is reinforced by the fact that if the turbines are installed and noise is louder than theoretical projections, there is little effective mitigation available, other than ceasing operation, an unlikely possibility for projects as capital intensive as turbine projects are.

ISO-9613

Although the calculation methodology of ISO9613 is widely used in noise modeling for turbine projects, its predictive shortcomings are widely acknowledged.

The ISO-9613-2 model has an acknowledged margin of error of 3%. The implications of this fact for confidence levels of prediction were explored in *Modeling Uncertainty Creep due to Variability in Model Constituents*, a paper presented at Inter-Noise 2006 by Parzych and Putnam. In this paper the authors question, "the accuracy of the acoustical prediction methods, such as those based on the ISO 9613-2 standard. As with all prediction methods, the ISO 9613-2 based models use many approximations to model source to receiver sound propagation." Their analysis "indicated that a 3 dB(A) design margin [the stated margin of error] will result in a confidence level of approximately 70% while a design margin of approximately 10 dB(A) is necessary for a 98% confidence level."

Turbine Manufacturer Warranted Sound Power Values

The projected sound of a turbine at a residence is based in part on manufacturer warranted sound power values. There is evidence by noise experts though, that actual sound levels of turbines in operation may be louder than stated sound values. For example, *Summary of IEA Topical Expert Meeting on noise Immission*, an account of a meeting of experts in 2000, experts noted:

The discussion came to concentrate on how to certify the manufacturers specifications. When measuring noise emission from prototypes the conditions are often perfect and the prototypes optimized. The noise level will therefore most probably be as low as it can be for that type of turbine. An emission level of about 2-3 dB compared to more realistic conditions is quite common. Some authorities also always assume that the turbines will emit 2-3 dB more than stated while others warn developers who are too close to the regulation limit that measurements will be done after the installation. There is also an ageing effect that needs to be considered; a wind turbine will often emit more noise some time after the installation. Today the manufacturers often only measure on one turbine. If they measured the emission from 2-3 turbines the result could be a bit more accurate but the measurements would still be done at unrealistic conditions

[xviii] Many researchers reject the sole use of the A-weighting curve as a valid measure for assessing wind turbine noise due to the large contribution of low frequency components in turbine sound. According to Alec Salt, an NICD funded researcher on the effects of infrasound, "the A-weighting curve corrects measurements according to the sensitivity of human hearing, de-emphasizing low frequency components for which the ear is insensitive. It is valid to use this correction if hearing the sound is the prime concern, but is not appropriate to use this approach when processes unrelated to hearing (such as whether a low frequency sound affects your ear) are being considered. ….A-weighting completely deemphasizes the low frequency components as if they didn't exist.

Low frequency sound—20-200hz—is "corrected" on the A-weighting scale by artificially reducing sound in the 125 hz band by 16.1 dB, reducing sound in the 63 Hz band by 26.2 and essentially cancelling sounds below 63 Hz. Since many of the complaints about wind turbine noise relate to the presence of low frequency components, the sole use of the A-weighted scale

underestimates noise annoyance of turbines, especially larger turbines.
http://oto2.wustl.edu/cochlea/wt4.html

[xix] The safety setback is based on creating a zone of protection from potential for ice throw and turbines falling. The safety setback agreed to is based on typical safety setbacks advocated by academic research, industry standards, and best practice guidelines based on experience with actual wind installations worldwide.

Ice throw- Typical formula for determining safe distance is 1.5 times (hub height and rotor diameter). Support for this formula is found in the following academic, industry and government publications:

i. *Ice and Snow- and the Winds do Blow*, by Ian Baring-Gould of the National Renewable Energy Laboratory, as presented at the NWCC Technical Considerations in Siting Wind Developments Conference, December 1-2, 2005
ii. *Risk Analysis of Ice Throw from Wind Turbines*, by Henry Seifert
iii. *Wind Energy Production in Cold Climates*, research supported by the EU
iv. GE Company document *Ice Shedding and Ice Throw-Risk and Mitigation*

[xx] While the safety setback was based primarily on concerns over immediate physical safety, the sound setback in Section 5 of Sound Limits [See Attachment A] agreed to by a majority of committee members was intended in part, to limit the effects of noise on residents. The committee gave consideration to a number of factors, including, but not limited to:

a. Uncertainty of noise modeling as a reliable predictor of noise at residences/ need for minimum setback based on distance as safeguard for potential inaccuracies in measurement/predictions
b. Sleep disturbance criterion-
c. Noise annoyance studies
d. Record of operating wind installations/ consideration of impact on residents as a function of proximity to turbines
e. Reliable way for non-participating property owners, or buyers to have a known reliable setback from turbine to property.

From AEI's Wind Farm Noise: 2009 in review: *(Note: Half-mile limits are sometimes proposed as a precautionary response to noise concerns, but there are definitely many people between a half and three-quarters of a mile who are affected, as well, including some of the more severe noise issues. While adoption of half-mile setbacks would alleviate many of the worst problems, it is not enough to eliminate routine noise issues.*

Most recently on the AEI website: *when wind turbines are built closer than a kilometer or so from homes in rural areas, a high proportion of those nearby neighbors experience significant quality of life impacts due to audible turbine noise.*
http://aeinews.org/archives/1383 - comments

Town of Ashfield, Massachusetts

Industrial-Grade Wind Turbine Siting Standards

Revised May, 27th, 2011

Table of Contents

Preface

The siting standards contained herein are meant to relate to industrial-grade wind turbine facilities. Said classification is meant to relate to a single wind turbine with a nameplate capacity less than 100 kW, and a turbine height less than 150 feet. Seperate, less restrictive bylaws will be developed for residential use.

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 15 dBA above L_{90A} for the same time period.

b. A 5 dB penalty shall be applied for tones as defined in IEC 61400-11.

2. Low Frequency Sound Limit

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

a. LeqC-L90A greater than 20 dB outside any occupied structure, or

b. A maximum not-to-exceed sound level of 52.5 dBC (L90C) from the wind turbines without other ambient sounds on all non-participating properties.

3. General Clause

Project sound not to exceed 32.5 dBA at any non-participating property line.

4. Noise Measurement Standards and Procedures

a. In order to demonstrate that a proposed project would comply with the sound standards outlined above, a sound report prepared by a Qualified Acoustic Consultant shall be submitted to the SPGA with any application for a wind energy facility. The sound report shall be conducted as specified in Section #1 of the Appendix to this bylaw.

b. Complaints about operating facilities shall be governed by the procedures outlined in Section #1 of the Appendix.

5. Noise Setback

a. Wind turbines shall be set back a minimum distance of 3400 from all non-participating property lines. The SPGA may impose a greater setback if it deems it necessary to protect the public health, safety, and welfare of the community. Non-participating property owners may waive this setback with a written Mitigation Waiver.

b. Mitigation Waiver - Non-participating property owners may waive certain specified protections in this bylaw using a written, legally enforceable Mitigation waiver negotiated between the wind turbine Applicant and the Non-participating land owner. Copies of executed Mitigation Waivers must be included with submission of the wind turbine application. The Mitigation waiver must be recorded in the Franklin County Register of Deeds, describe the benefited and burdened properties and run with the land. The deed must advise all subsequent owners of the burdened property.

Shadow Flicker

Wind facilities shall be sited such that shadow flicker will not fall on any non-participating property. The applicant has the burden of proving that this effect will not impact non-participating properties through either siting or mitigation. For purposes of this section, mitigation shall be defined solely as the act of programming a turbine to shut down when continued operation would otherwise create flicker effects at non-participating properties.

1. If a wind turbine is proposed closer than a separation of 1.5 miles from turbine to the project boundary lines, a shadow flicker analysis shall be conducted modeling the flicker impact in the area. The study shall be prepared by a registered professional regularly engaged in this type of work who is approved by the SPGA. The Applicant shall be responsible for paying the registered professional's fees and all cost associated with conducting the study. The Applicant shall provide financial surety to the Town of Ashfield for the cost of the study. No wind turbine project shall be approved unless either:

   a. Documentation based on accepted software for the purpose is presented demonstrating that nearby residential properties would not be affected by seasonal shadow flicker or:

   b. Applicant submits a legally binding agreement requiring the shutting down of turbines casting the shadow flicker during the identified time periods of the identified days, for each year of operation, when shadow flicker would fall on residential property.

   c. Any waiver of the shadow flicker requirements shall run with the land and be recorded as part of the chain of title in the deed of the subject property.

2. In the event that project modeling is incorrectly performed and flicker effects fall upon any non-participating properties, through no malice or forethought of the project operator, the operator shall not be held liable and shall be given one week to correct the error through reprogramming of the turbine shutdown option.

Safety Setback to Residences & Non Participating Properties

Relating to All Residences – Safety setback distances from proposed wind turbines to existing residences (non-waivable) may not be of a distance less than the following;

$$d = (D + H) * 1.5$$

Where:
d: represents the maximum throw distance
D: represents the rotor diameter
H: represents the hub height

Relating to Land - In addition, safety setback distances from proposed wind turbines to other non participating properties may not be of a distance less than the formulae distance unless expressly waived by the record owner. Any waiver of the safety setback requirements shall run with the land and be recorded as part of the chain of title in the deed of the subject property.

Monitoring and Maintenance

Facility Conditions The applicant shall maintain the wind facility in good condition. Maintenance shall include, but not be limited to, painting, structural repairs, and integrity of security measures. Site access shall be maintained to a level acceptable to the local Fire Chief and Emergency Medical Services. The project owner shall be responsible for the cost of maintaining the wind facility and any access road, unless accepted as a public way, and the cost of repairing any damage occurring as a result of operation and construction.

Modifications
All material modifications to a wind facility made after issuance of the special permit shall require approval by the special permit granting authority as provided in this section.

Abandonment or Decommissioning

Removal Requirements - Any wind facility which has reached the end of its useful life or has been abandoned shall be removed. When the wind facility is scheduled to be decommissioned, the applicant shall notify the town by certified mail of the proposed date of discontinued operations and plans for removal. The owner/operator shall physically remove the wind facility no more than 150 days after the date of discontinued operations. At the time of removal, the wind facility site shall be restored to the state it was in before the facility was constructed or any other legally authorized use. More specifically, decommissioning shall consist of:

> **(a)** Physical removal of all wind turbines, structures, equipment, security barriers and transmission lines from the site.
>
> **(b)** Disposal of all solid and hazardous waste in accordance with local and state waste disposal regulations.
>
> **(c)** Stabilization or re-vegetation of the site as necessary to minimize erosion. The special permit granting authority may allow the owner to leave landscaping or designated below-grade foundations in order to minimize erosion and disruption to vegetation.

Abandonment - Absent notice of a proposed date of decommissioning, the facility shall be considered abandoned when the facility fails to operate for more than one year without the written consent of the special permit granting authority. The special permit granting authority shall determine in its decision what proportion of the facility is inoperable for the facility to be considered abandoned. If the applicant fails to remove the wind facility in accordance with the requirements of this section within 150 days of abandonment or the proposed date of decommissioning, the town shall have the authority to enter the property and physically remove the facility.

Financial Surety - The special permit granting authority may require the applicant for utility scale wind facilities to provide a form of surety, either through escrow account, bond or otherwise, to cover the cost of removal in the event the town must remove the facility, of an amount and form determined to be reasonable by the special permit granting authority, but in no event to exceed more than 125 percent of the cost of removal and compliance with the additional requirements set forth herein, as determined by the applicant. Such surety will not be required for municipally or state-owned facilities. The applicant shall submit a fully inclusive estimate of the costs associated with removal, prepared by a qualified engineer. The amount shall include a mechanism for Cost of Living Adjustment.

APPENDIX

Section #1

Noise Measurement Protocols

A. **Measurement Protocol for Sound Assessment of Proposed and Existing Wind Energy Facilities**

All applications for a wind energy facility must submit to the SPGA a comprehensive sound study. The purpose is to establish a consistent and scientifically sound procedure for estimating existing (ambient) background sound levels in a project area, and second to determine the likely impact that operation of a new wind energy system will have on the existing sound environment.

B. Sound Level Estimate for Proposed Wind Energy Facility

A Qualified Independent Acoustical Consultant shall conduct all noise studies. The Acoustical Consultant shall be selected and retained by the Town and the applicant shall be responsible for paying the Acoustical Consultant's fees and all costs associated with conducting the study and meeting with town officials. A suitable propagation model must be selected to most accurately predict the worst-case noise level at all relevant and sensitive receivers and be in accordance with internationally recognized standards. The report should include:

1. A contour map of the expected sound level from the new wind turbine(s) must be provided, using 5dBA increments extending out to the lesser of of two (2) miles or background sound. For projects with multiple wind turbines, the combined sound level impact for all wind turbines operating at full load must be estimated. Turbine operating sound immissions (LeqA and LeqC) shall represent worst-case sound immissions for stable nighttime conditions with low winds at ground level and winds sufficient for full operation capacity at the hub.

2. When conducting pre-construction noise prediction analysis, the Applicant shall make specific reference to assumptions used as input, including but not limited to:

   a. noise levels at the relevant receivers should be predicted allowing for the propagating effect of wind in the direction from the wind turbine to the receiver, the range of atmospheric conditions likely to occur in the area of the project site, and should be modeled assuming a flat, hard ground with no buildings or other intervening structures.

   b. the unique aspect of the mountainous contours and terrain of the area and its effect on noise predictability

   c. line source noise predictions (emanating from a line of Wind Turbines) in addition to the traditional single point source predictions and;

d. margin of error of noise prediction model and of manufacturer warranted sound power levels used to create worst case scenario for highest sound power value and noise prediction.

3. Any noise level falling between two (2) whole decibels shall be deemed the higher of the two.

4. A comparison of calculated sound pressure levels from the wind turbine project with ambient background sound levels at measurement locations in order to determine compliance with town and state noise regulations.

5. In the event that there are several pending Permit Applications, or preexisting Wind Turbine(s), the estimated post-construction values shall be the combined predicted output of all proposed or existing Wind Turbines. All of these Wind Turbine(s) will be treated using the same methodology to arrive at combined value for the predicted post-construction sound level. Each additional Wind Turbine adds to the sound-burden of a community. If the contribution to sound levels of proposed wind turbine together with the sound generated by pre-existing Wind Turbine(s) would raise the sound levels beyond the limits of this Ordinance, then the proposed Wind Turbine(s) will not be approved.

   For sites being measured with existing Wind Turbine(s) two sets of measurements are required:

   a. One set with the Wind Turbine(s) off and;
   b. One set with the Wind Turbine(s) running.

C. Measurement of the Existing Sound and Vibration Environment

1. Prior to permit application approval, a pre-construction baseline existing background noise level study shall be conducted at the following locations:

   a. the nearest non-participating property line in every cardinal direction from each proposed wind turbine site, and
   b. other potentially sensitive non-participating parcels within 2 miles of any proposed wind turbine, as determined by the SPGA.

   All measuring points shall be located in consultation with the property owners (who shall be pre-notified by registered post) and such that no significant obstruction blocks noise and vibration to the site. Noise sensitive sites are to be selected based on wind development's predicted worst-case sound emissions (in L_{eqA} and L_{eqC}) that are to be provided by the Qualified Acoustic Consultant in consultation with the town. Particular emphasis should be placed on selecting measurement locations at residences within the measurement area, especially those at downwind locations, and at locations of residences with unique topographical profiles, such as residences in sheltered hollows, where the acoustical profile may be unique to that location.

2. Procedures must meet all current and applicable ANSI standards.

3. Outdoor noise level measurements must be taken at least 30 feet from any sound reflective surfaces, natural or constructed.

4. Measurements must be made when ground level winds are 2m/s (4.5 mph) or less and with appropriate wind screening for the recording device. Measurements should be obtained during representative weather conditions when the Wind Turbine noise is most noticeable, including periods of temperature inversion most commonly occurring at night.

5. Measurements should exclude or adjust collected data that would distort the establishment of a baseline level representative of the L90 rural environment. These include, but are not limited to periodic noise events such as periods of insect or other seasonal noise, seasonal farming activities, unusual weather conditions (i.e. heavy precipitation) and should also exclude periods or moments of observed heightened sound levels not considered typical ambient noises (i.e. passing airplane or train)

6. Tests shall be reflective of seasonal changes to vegetation and atmospheric conditions. At a minimum one set of test should be performed during each of the four (4) calendar seasons of the year. The SPGA may request additional testing if it determines that weather events interfered with representative recordings.

7. Measurements shall be taken at each of the following three time periods:
   a. Day (10am-2pm)
   b. Evening (7pm-11pm)
   c. Night (12 midnight- 4am)

8. Measurements shall be replicated during the same time periods over five different days within the same season for a total of fifteen measurements per location per season (i.e. five daytime measurements in the winter, five evening measurements in the winter, five night time measurements in the winter). The lowest of the three measurements per time period, per season, will be used to determine the pre-construction ambient noise for that time period and season.

9. For each measurement the following minimum criteria will be recorded:
   a. Lmax, Leq, L10 and L90 in dBA
   b. Lmax, Leq, L10 and L90 in dBC
   c. One-third (1/3) octave band sound pressure levels, averaged over each ten (10) minute sample selection.
   d. A narrative description of any intermittent noises registered during each measurement
   e. Wind speed and direction, humidity and temperature at time of measurement
   f. Description of local weather conditions at time of measurement
   g. Description of topography and contours relative to proposed or actual Wind Turbines.

D. Post-construction Compliance and Monitoring

1. Within six months after the date when the project is fully operational, the Licensee shall repeat the existing sound environment measurements taken before the project approval. Post-construction sound level measurements shall be taken with all Wind Turbines running and also with all wind Turbines off. A Qualified Independent Acoustical Consultant selected by the Town shall conduct the noise studies. The applicant shall be responsible for paying the Acoustical Consultant's fees and all costs associated with conducting the study and reporting to the Town. The Licensee shall provide all technical information and wind system data required by the Qualified Independent Acoustical Consultant.

2. For nuisance complaints after the Wind Turbine(s) are operational, the measurement points, season, time and duration of measurements shall be selected in consultation with the affected property owner. If requested by the property owner, continuous measurements may be taken for longer periods of time to capture intermittent nuisance noise patterns. Testing will be paid for by the Licensee

3. A serious noise violation is defined as three (3) verified noise complaints attributed to the operation of a Wind Turbine within a period of one month or less with a measurable noise level greater than 5 dBA above pre-construction ambient noise levels or 50 dBC inside or at a non-participating residence,

    a. For serious violations the Licensee will respond within five (5) days of the complaint. The Licensee is responsible for mitigating the problem within ten (10) days from a final determination of any cause attributed to the operation of the Wind Turbine. Failure to mitigate the problem will result in the Wind Turbine being declared unsafe and emergency shutdown procedures will be implemented.

    b. Noise violations not determined to be a serious violation or an emergency require the Licensee to mitigate the problem within thirty (30) days from a final determination of any cause attributed to the operation of the Wind Turbine. Mitigation involving significant construction or physical modification may have up to ninety (90) days to be completed.

Definitions

Qualified Independent Acoustic Consultant- Qualifications for persons conducting baseline and other measurements and reviews related to the application for a wind turbine project or for enforcement actions against an operating WECS 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 bylaw. The Independent Qualified Acoustical Consultant can have no direct or indirect financial or other relationship to an Application

Background sound level (dBA and dBC (as L90)) 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 L90A and L90C descriptors. It may be considered to be the quietest one (1) minute during a ten (10) minute test. L90A results are valid only when L10A results are no more than 10 dBA above L90A for the same time period. L10C less L90C should not exceed 15 dBC to be valid.

Background Sound (L90) 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.