WIND TURBINE NOISE

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The Wind Turbine Industry in the USA

At the present time (2013), Vestas, Siemens, General Electric, and Gamesa are involved in supplying the machines for the production of electricity from the wind. In the United States, there has been a production tax credit for sustainable energy. This credit has encouraged investment in wind farms in the United States. According the the American Wind Energy Association's Annual Report for 2012[1], cumulative wind generating capacity in the United States was 60 GW (gigawatts). Some 13,131 MW (megawatts) were installed in 2012. The top states by installed capacity were Texas, California, Iowa, Illinois, and Oregon. That installed capacity represents about 3.5%[2] of the electrical generation in the United States.

Massachusetts — Falmouth

In the Commonwealth of Massachusetts, where the author lives and works, the debate about wind turbine noise has been in the press. Paralleling the national practice, the state government has been encouraging the use of renewable energy, including wind, for at least the past five years. One project which has caused considerable trouble is located in Falmouth, Mass., on Cape Cod.

The story of the wind turbines in Falmouth is taken from a report at the end of April, 2013 in the *Boston Business Journal*[3]. There are, at this time, three wind turbines in Falmouth: Wind 1, Wind 2, and Notus. They are 1.65 megawatt turbines which the Massachusetts Technology Collaborative (MTC) bought in December 2005 for $5.3 million using the state's rate-payer-funded renewable energy trust fund. The goal was to speed up the shipment of the turbines, which were in high demand at the time, to the Town of Orleans. But the Orleans project fell through in 2007. The MTC tried to use them in Fairhaven, but there was a legal challenge, and in Princeton and Gloucester, but Vestas wouldn't approve the locations. By mid-2008, the MTC had put the turbines up for sale. The windmill parts sat unused at facilities in Texas and Canada. In 2009, the Town of Falmouth voted to purchase Wind 1 to save on electric costs at its power-hungry sewage treatment plant. At the town meeting, there was near-unanimous support to purchase the turbine. The town subsequently bought Wind 2, a similar turbine, from Vestas. A Falmouth landowner bought Notus from MTC, and installed in it a nearby industrial park. When Wind 1 started spinning in March 2010, complaints from the neighbors soon started. The nature of the complaints included unexpected amount of noise leading to sleeplessness, headaches, and other problems. The Town believes it would have been better served by a smaller turbine, and/or a quieter blade technology.

> *"Acknowledge the problem and work to eliminate it."*

In 2011, a private study was commissioned to determine why there were so many strong complaints about the loss of well-being and hardships experienced by people living near large industrial wind turbines operating in Falmouth, Mass[4]. The work has also been presented at Inter-Noise in New York City in August 2012. The study focused on whether or not there was infrasonic and low frequency noise from Wind 1, a municipally-owned Vestas V82. By March of 2011, the Falmouth town selectmen voluntarily decided to curtail Wind 1 operations when hub wind speed exceeded 10 m/s. Since the study was performed after that, the work focused on the nearby Notus. The work was performed in the Spring of 2011 and reported in December 2011. Of note in the study was:

> The investigators were surprised to experience the same adverse health symptoms described by neighbors living at this house and near other large industrial wind turbine sites. The onset of adverse health effects was swift, within twenty minutes, and persisted for some time after leaving the study area. The dBA and dBC levels and modulations did not correlate to the health effects experienced. However, the strength and modulation of the unweighted and dBG-weighted levels increased indoors consistent with worsened health effects experienced indoors. The dBG-weighted level appeared to be controlled by in-flow turbulence and exceeded physiological thresholds for response to low-frequency and infrasonic acoustic energy as theorized by Salt. The wind turbine tone at 22.9 Hz was not audible yet the modulated amplitudes regularly exceeded vestibular detection thresholds. The 22.9 Hz tone lies in the brain's "high Beta" wave range (associated with alert state, anxiety, and "fight or flight" reactions). The brain's frequency following response (FFR) could be involved in maintaining an alert state during sleeping hours, which could lead to health effects. Sleep was disturbed during the study when the wind turbine operated with hub height wind speeds above 10 m/s. It took about a week to recover from the adverse health effects experienced during the study, with lingering recurring nausea and vertigo for almost seven weeks for one of the investigators…
>
> The research is more than just suggestive. Our experiencing of the adverse health effects reported by others confirms that industrial wind turbines can produce real discomfort and adverse health impacts. Further research could confirm that these ill effects are caused by pressure pulsations exceeding vestibular thresholds, unrelated to the audible

frequency spectrum but are instead related to the response of the vestibular system to the low frequency noise emissions. The vestibular system appears to be stimulated by responding to these pressure pulsations rather than by motion or disease, especially at low ambient sound levels. Dysfunctions in the vestibular system can cause disequilibrium, nausea, vertigo, anxiety, and panic attacks, which have been reported near a number of industrial wind turbine facilities. The study emphasizes the need for epidemiological and laboratory research conducted by medical health professionals and acousticians working together who are concerned with public health and well-being. It is especially important to include a margin of safety sufficient to prevent inaudible low-frequency wind turbine noise from being detected by the human vestibular system.

What is noteworthy is that the researchers themselves experienced the adverse health effects from the wind turbines.

About the same time as the private study was going on, the Commonwealth of Massachusetts Department of Environmental Protection and the Massachusetts Department of Public Health commissioned a wind turbine health impact study, using an independent expert panel. Their report is dated January, 2012[5]. Their members were from Harvard Medical School, Massachusetts General Hospital, Boston University, Boston University School of Public Health, University of Massachusetts at Amherst, University of New England, and Harvard School of Public Health. The panel focused on public health based on scientific findings. It also limited its analyses to land-based installations. The panel sought human epidemiological studies in the scientific literature. Most of the conclusions in the study were that there was limited or insufficient evidence. Some comments on health effects of wind turbines from the executive summary of the report:

2. There is limited evidence from epidemiologic studies suggesting an association between noise from wind turbines and sleep disruption. In other words, it is possible that noise from some wind turbines can cause sleep disruption.
3. A very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest of sleepers at that same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study would provide these levels.
4. Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence of wind turbines, there is evidence that sleep disruption can adversely affect

Fig. 1. The photo is by the author of a wind turbine in Hull, Mass.

mood, cognitive functioning, and overall sense of health and well-being.

5. There is insufficient evidence that the noise from wind turbines is *directly (i.e., independent from an effect on annoyance of sleep)* causing health problems or disease.
6. Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system.
   a. The measured levels of infrasound produced by modern upwind wind turbines at distances as close as 68 m are well below that required for non-auditory perception (feeling of vibration in parts of the body, pressure in the chest, etc.).
   b. If infrasound couples into structures, then people inside the structure could feel a vibration. Such structural vibrations have been shown in other applications to lead to feelings of uneasiness and general annoyance. The measurements have shown no evidence of such coupling from modern upwind turbines.
   c. Seismic (ground-carried) measurements recorded near wind turbines and wind turbine farms are unlikely to couple into structures.
   d. A possible coupling mechanism between infrasound and the vestibular system (via the Outer Hair Cells (OHC) in the inner ear) has been proposed but is not yet fully understood or sufficiently explained. Levels of infrasound near wind turbines have been shown to be high enough to be sensed by the OHC. However, evidence does not exist to demonstrate the influence of wind turbine-generated infrasound on vestibular-mediated effects in the brain.
   e. Limited evidence from rodent (rat) laboratory studies identifies short-lived biochemical alterations in cardiac and brain cells in response to short exposures to emissions at 16 Hz and 130 dB. These levels exceed measured infrasound levels from modern turbines by over 35 dB.
7. There is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a "Wind Turbine Syndrome."
8. The strongest epidemiological study suggests that there is not an association between noise from wind turbines and measures of psychological distress or mental health problems. There were two smaller, weaker, studies: one did note an association, one did not. Therefore, we conclude the weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.
9. None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

The study also recommended A-weighted sound levels based on World Health Organization data at night. It also recommended a comprehensive assessment of wind turbine noise in the Commonwealth based on IEC 61400-11. It is understandable that the reviewers took a "safe approach," looking for incontrovertible evidence. The United States is in its relatively early stages with respect to identifying and understanding the causes of the individual problems experienced by the near neighbors of these installations.

On October 23, 2011, in conjunction with this issue, Richard H. Campbell, FASA, FAES, NCAC of East Falmouth wrote to the *Falmouth Enterprise*[6]:

> I have been immersed in acoustics all of my professional life. My experience includes noise control, performance halls, houses of worship and speech communication in noise. A disability has slowed me up in recent years but I have read nearly all of the reports and letters regarding Wind 1. Some of my colleagues have acted as consultants on this project and on occasion we have discussed the findings.
>
> Fifty years ago there was not much known about quantifying hearing damage due to noise. A very large data collection process with intelligent analysis led Karl D. Kryter to author the seminal book synthesizing the subject, *The Effects of Noise on Man*. The first noise regulation in the US was in 1975 in Portland, Oregon. From then on noise became an environmental issue rather than just a "nuisance."
>
> Now we have a potentially serious noise problem with Wind 1. An even larger problem we have as acoustic engineers is that there is no metric for evaluating disturbance due to infrasonic modulated noise – at least not yet. In fact there is not even an instrument that can accurately measure the radiated acoustic and vibration field from slow-moving turbine blades. Falmouth is not alone as there is a lot of attention being paid to the problem in the UK, Canada and the EU.
>
> The worst thing we can do is to ignore the affected people. They are a point on a curve yet to be drawn. Looking back at the history of hearing damage I can see many points shaping the curves we use to evaluate and predict industrial noise exposure. I personally delivered a hearing protector to a machinist who complained about the noise in an unforgettable way – his family life was coming apart. He agreed to wear them faithfully every time he ran the machine and a week later, after interviewing him again, I was astonished and pleased. Another point on the curve.
>
> Noise regulations in effect now do not encompass turbine noise as a physiological or psychological disturbance. I see a statement that " … it does not violate the state regulation for environmental noise …". Okay, agreed. What instrument was used?

A standard calibrated Type 1 Sound Level Meter, of course, exactly to state or local requirements. My reaction is, "Why don't you come back when there is a new regulation and an instrument capable of evaluating what these unfortunate neighbors are feeling and reporting?"

There is a new institute formed at the University of Waterloo in Ontario on exactly this subject and Dr. Nina Pierpont of Johns Hopkins Medical School has written in Counter Punch Magazine:

> "… *The vestibular organs – the semicircular canals, saccule, and utricle – function as Mother Nature's gyroscope, controlling our sense of motion, position, and balance, including our spatial thinking. (Remember when you got carsick as a kid? Or seasick?)*
>
> *Humans share these enigmatic organs with a host of other backboned species, including fish and amphibians. Some scientists indeed see them as a kind of pan-species master key for an extraordinarily broad range of brain function – amounting to a sixth sense.*
>
> *One of those functions, it now appears, is to register and respond to the sounds and vibrations (infrasound) we don't consciously hear, but feel – as from wind turbines. For many people, the response is swift and disastrous.*"

The last line says it all – what you can't hear can hurt you – stop talking around the subject, mitigate as required to the comfort of the neighbors, and wait for more points to get the curve right.

It should also be noted that, as Dick Campbell no doubt knew, the regulations are made necessarily after you have a way to measure it. The privately-funded study by Ambrose and Rand used dBG-weighting to isolate the low-frequency components and infrasound. Note: Dick Campbell died on October 11, 2012.

The Massachusetts Department of Environmental Protection (DEP) performed acoustical tests on neighboring properties in Falmouth in March 2012[7]. The study compared the "maximum levels" (L_{max}) at night, assumed to be from the turbine, with measured background (L_{90}s) at night. The readings were A-weighted slow response, and were attended. The difference measured at one location from Wind 1 was more than 10 dB above the background, the DEP's definition of noise impact. The use of "maximum level" drew some criticism from the wind developer community. It is unfortunate that the DEP used this term, because the data were time-stamped 1-second A-weighted equivalent levels (L_{eqs}), not maximum levels. The DEP report was obtained from their website. In fact, most of the "maximum levels" were disqualified by the observer as belonging to other noise sources. A better term might have been "observed level."

Eventually, both wind turbines were shut down at night. At the end of April 2013, the Town of Falmouth was considering tearing down the two city-owned turbines for $8 million. The vote failed, but $100,000 was approved to further study the issue.

Other Recent Wind Turbine Noise Studies

In the Wind Turbine Noise session at the International Congress on Acoustics in Montreal, Canada, in June 2013, there were some interesting observations made by some of the authors. George Hessler and Paul Schomer[8] independently arrived at a design goal of 40 dBA or less at the nearest residence from wind turbines. Paul Schomer later presented data from a wind farm in Shirley, Wisconsin. In his section on adverse physiological effects, he writes:

> Recently, measurements were made at a small wind farm in Shirley, Wisconsin. These measurements were made in the homes of three families who had abandoned their homes because they could not tolerate physiological results caused by the acoustic emissions of wind turbines. This same story is being played out in a seemingly random fashion around the world. Between Hessler Associates and Schomer Associates, five wind farms are known to have reported problems similar to those at Shirley. Perhaps 1% of wind farms have reported problems like those at Shirley; the remaining 99% have not documented such problems, and the reasons that a small percentage have these problems are not known. And within those wind farms that have these problems, only a small segment of the populations is actually affected to the degree exhibited at Shirley, again on the order of perhaps 1% to 3% of households.
>
> From the residents of Shirley we learned: (1) most residents did not hear the turbines; residents said they could sense when the turbine was on, (2) the effects did not vary with changes in the orientation of the turbines with respect to the homes, (3) the general symptoms of those affected adversely by the wind turbine emissions were virtually the same as symptoms for motion sickness, and (4) afflicted residents were prone to motion sickness.
>
> This told us that (1) the resident had no noise annoyance because they did not hear any wind turbine noise, (2) the wavelength of the "sound" must be large — on the order of 100 m, and (3) there must be a mechanism by which this very low frequency infrasound can cause symptoms of motion sickness in people. To this end, we found a study developed by the Navy showing that linear accelerations at 0.7 Hz were moving well into the nauseogenic region, and that the frequency that induces motion sickness at the lowest acceleration is approximately 0.2 Hz.
>
> The turbine model used in Shirley, the Nordex N-100, is among the largest ever installed in residential areas, and has a blade passage frequency of 0.7 Hz, and corresponding rotor frequency of 0.23 Hz. The 0.7 Hz was evident in the measurements during times when the turbines were at full power, but not when the turbines were throttled back. The 0.23 Hz was only evident part of the time.
>
> At this point we must note that after over 4000

years of study, no one knows exactly what causes motion sickness or why some people are more affected than others. In the following, we show that it appears to be possible that an acoustic wave at 0.5 to 0.7 Hz can generate a similar signal in the brain as the signal generated by an acceleration at 0.5 Hz. We do not expect any time soon to be able to predict who will and who will not be affected by low-frequency wind turbine emissions or the mechanism by which they occur any more than we can predict who is affected by motion sickness and who is not, and the mechanism by which people are affected by motion sickness. What we can show is that it appears quite possible for the acoustic emissions from wind turbines to produce this effect in some people. The following discussion analyzes the linear motion sensing function of the ear, and explains how the ear could respond to wind turbine emissions.

Thus, it appears that the observation that the symptoms of "wind turbine syndrome" are like those of seasickness appear to have some basis in fact. Another paper, by William Palmer[9] of Ontario, Canada, presented a study of observations by citizens after four years of operation of a wind power development. The citizens' observations were from the Ministry of the Environment:

- The sound of the turbines comes through the pillow. Sleep is disrupted 50% of the time. It is a roaring freight train going through our home. Electrical issues have been noted in the home.
- The noise level is very high and sleeping is a problem. The home vibrates. One member has developed headaches, dizziness and light-headedness. The quiet country property is now completely changed by indoor and outdoor noise; sleep deprivation, flicker, and disturbing health symptoms that did not exist before.
- Jim (not real name) often sits up all night and cannot sleep. He has taken dizzy spells and is prone to falling. He has become forgetful and disorganized. When away, he sleeps like before, but on returning home the problems recur. The complaint protocol has been of no help in resolving the issue.
- Since the turbines started, she is tired all the time, and never feels rested and relaxed. Her husband has headaches frequently now, but never had them before. Teenaged children are constantly tired and have headaches that go away when away from the home.
- She finds her body began to vibrate with the onset of the turbines, has developed ringing in the ears, loss of concentration and heart palpitations. Up two or three times a night due to sleep disruption. Son gets sharp spiking headaches.
- Noted sound increase inside and outside home. Headaches, taken to spending time in the basement for respite. Headaches leave when away from home, but developed nausea and lowered appetite. Up half the night tossing and turning, and walking around due to the noise.
- Need to have television volume up higher to mask the whoosh, whoosh, whoosh. Developed ringing in ears and chest tension. Work difficulties resulted in loss of regular employment. Fears going to a doctor as he might take away driving license – tired and fall asleep at the wheel. Would lose my job and then our home.
- Sleep deprivation, headaches, and sensation in ears, pressure in head, restlessness, nausea, and motion sensitivity. All developed over time. Can no longer work. Nausea, lost weight, migraines.
- Pain in ears, toss and turn at night, sleep disturbed. Senses vibration in body when at home. Removed ability to enjoy their property.
- Flicker, noise, vibration in their bodies. Migraines, blood pressure problems. Stress. Tinnitus.
- Sleep disturbance, headaches, tinnitus, and stomach upset.
- Child tired, irritable, complains head hurts and tummy hurts. Home is a nightmare. Symptoms did not exist before turbines include headaches, dizziness, pressure in ears, sleep disruption, tingling in head and face. Increased confusion, irritability. Mental instability. Visitor taken to hospital with vertigo. Family member with stroke like symptoms.
- Flicker, electrical interference that did not exist before. Complaint protocol ineffective.
- No longer live in home – walked away. Migraines sleep disruption, vibration. Tried to sell property — no offers. Bank foreclosed — lost home.
- Vertigo, unless away from home.

In four of the homes on the list, a family member died from a sudden cardiac arrest, unexpectedly, and traumatically. These families grieve, and we can only speak for them. One person in her 30s, one in his 50s, who reported not a week before his death that his health was not impacted, and two in their sixties who died unexpectedly. No, there is not "direct" proof to link these deaths to wind turbines, but the frequency exceed provincial average, and begs a detailed evaluation of all deaths surrounding turbines.

The homes investigated in Kincardine had nearest turbines between 453 and 1848 meters. The closest had up to 18 turbines within 2000 meters. The calculated levels were within the 40 dBA required by the applicable Canadian standard. In Ontario, the wind turbine capacity has gone from 15 MW in 2003 to about 1700 MW at the end of 2012. Projects in Ontario are expected to grow to 5810 MW by 2015.

Health Study — Canada

There is a study going on in Canada to assess the health impacts of wind turbine noise. Its design[10] was reported at Inter-Noise 2012 in New York City. Excerpting from that paper:

The study will be conducted on a sample of 2000 dwellings randomly selected from those located near 8 to 12 WT installations in Canada.

Sampling will be conducted on volunteers that are at least 18 years of age. Each participant will be asked to complete a 25-minute computer-assisted personal interview. The questionnaire will be read to the subject and it includes modules that assess demographics and validated scales that provide information on well-being, sleep quality and noise annoyance. The prevalence of chronic illness and symptoms collectively referred to as "WTN syndrome" are also included in the questionnaire.

To ensure that the validity of the study is not compromised in any way, the questionnaire and sampling locations will only be revealed when the study is completed. Self-selection bias is something that needs to be carefully addressed in this study because it is unreasonable to assume that subjects will not be aware of the purpose of this study. This can be partially accounted for with a participation rate of between 70 and 75% and with a characterization of non-respondents that includes demographics and dwelling location relative to the turbines.

In addition to the questionnaire, subjects' blood pressure will be taken following a standardized protocol. A small hair sample will be collected for the purpose of quantifying average cortisol levels over the 3 months preceding the collection period. A wrist-worn actimeter will be used to provide an objective measure of total sleep time and sleep efficiency for a period of 7 consecutive days. A small pilot study utilizing 15 volunteers will be conducted to evaluate different actimeter models, and to assess anticipated issues associated with non-compliance. The value of adding a complementary sleep diary will also be part of this pilot study.

The study is, presumably, underway in Canada. It is hoped that the measurements are appropriate to determine that the symptoms experienced by the subjects are real. It is certain than people do not just make these things up. Many of the stories told about wind turbine syndrome are of people who were *solidly for the technology*. So far, most governments have been in denial mode about the adverse health effects of living too close to wind turbines. It is hoped that the data from the various studies will confirm the existence of a problem.

Wind Turbine Noise Study — Massachusetts

Another study is underway in Massachusetts, under the aegis of the Massachusetts Clean Energy Center. The work was solicited in September 2012[11]. Massachusetts has over 40 operating wind turbines in the size range of 100 kW to 2.0 MW. The work was expected to commence in October 2012 and last for 18 months. The study is being done in cooperation with the Massachusetts Department of Environmental Policy and a Technical Advisory Group. The project is in two phases: Project Monitoring and Data Analysis. Quoting from the RFP:

The **Phase 1: Project Monitoring** will be performed at all participating projects by qualified acoustical consultants. Consultants will seek to complete monitoring at up to 12 operating projects. The monitoring period will last approximately two weeks and will consist of both short-term attended monitoring and long-term unattended monitoring. The short-term attended monitoring would be used to collect data to complete both the Basic and Detailed Analysis of Phase 2. The concurrent long-term monitoring would only be used to complete the Detailed Analysis.

Phase 1 will also require concurrent collection of meteorological data at or near the site. The possible data sources for each project will have to be evaluated on a case-by-case basis, but might include existing nearby met towers, a temporary SODAR installation, or a temporary met tower installation.

Terrain data will also be collected in Phase 1, specifically related to ground cover, topography and any other relevant factors that could influence project acoustics. This phase might further collect data related to any indoor monitoring, such as building type, construction, and room size, if such analyses are undertaken.

The **Phase 2: Data Analysis** will utilize the data collected in Phase 1 to analyze the acoustics of individual projects and to assess the influence of different factors on the acoustics of all projects. Phase 2 will be broken down into two tasks, as described below:

The *Task 1: Basic Analysis* will utilize the short-term attended monitoring data to provide a basic analysis of wind project sound levels compared to existing ambient by quantifying both

- the ambient acoustic levels without the turbine operating
- the basic acoustic impact with the turbine operating.

The Task 2: Detailed Analysis will utilize both the short-term attended and the long-term unattended monitoring data to

- Understand qualities of sound impact from different turbines under different conditions
  - > How do the acoustic emissions vary with respect to wind turbine technology (power capacity, power regulation, tower type, blade design, etc.)?
  - > How do impacts vary with respect to distance, direction, and ambient environment (rural or suburban)?
  - > Are there characteristics of wind turbine noise that are significantly different than those in the existing environment (frequency spectrum, amplitude modulation, etc..)?
  - > Are there characteristics of the Massachusetts environment that particularly influence wind turbine acoustics (wind shear, atmospheric conditions, land cover, topography, etc.)?
- Understand the correlation between predictive acoustic modeling and actual acoustic impact

- Inform design guidelines for wind siting
  - > How do different measurement technologies quantify wind turbine noise differently?
  - > Is there a more appropriate methodology to quantify noise impacts of wind turbines?

The Massachusetts methodologies cited in the RFP would imply A-weighted, C-weighted, and octave band levels from 20 to 10,000 Hz. Although lower frequencies were desired, it is not clear that they would be provided, given the budgetary and time restrictions. The winning team (November 2012) was Resource Systems Group (RSG) of Vermont, in cooperation with Epsilon Associates of Massachusetts and Northeast Wind, as subcontractors. The maximum contract value allocated for the work was publicly stated at $400,000.

Some observations about the different measurements used in community noise. For the last 40 years, measurements of facilities have been either A-weighted or in bands: octave or ⅓-octave. These measurements were originally limited by the technology available in the instrumentation. The A-weighted curve approximates the human ear's response at 40 dB over the audible frequency range. Sounds heard are not "masked" unless the sounds fall within the ear's critical bands. Those bands are on the order of the ⅓-octave. Therefore, unless the intruding sounds are in the same critical bands as the background sounds, the facility will be heard.

Planners and governmental officials like to have a "budget" that can be used for approving or denying projects. Unfortunately, the human being does not act as an adding machine for sound, where you can get to "too much." Each person hears the components of the environment and will know where each individual sound is coming from. In the case of internal combustion engines, it is possible to not know whether the engine is a distant car, airplane, or something else. As the sound source gets closer, an identification can often be made. The budget approach has been successfully used for hearing loss in workplaces. In the case of community projects, the equivalent level (L_{eq}) or the day-night A-weighted equivalent level (DNL), used in transportation projects, has a disconnect with the levels observed by the people impacted by the sounds from the project. One concern is the statement about the percentage of highly annoyed residents. There seems to be a tacit assumption that some percentage of residents can be permitted to be highly annoyed by a project. What if this small percentage turns out to be those who are physically disposed to some disease, such as motion sickness? Are they to be "thrown under the bus" because they are highly annoyed about it? The percentage which was used for aircraft in the 1970s was 15% highly annoyed. Has anyone ever talked to these people about why they are highly annoyed? If those people have to move out of their homes because of the noise, will the project or the government compensate them? Probably not. It will be: "Too bad for you," which will just make them more upset.

In the case of wind turbines, their sound is, apparently, very distinctive. In addition, in some cases, the blade passing frequency is in a range where the walls of a home do not attenuate the sound, and where symptoms of seasickness are prevalent.

Other Problems, Including Noise

In a recent *Wall Street Journal* editorial[11], Jay Lehr makes the following observations about some of the lesser-known problems with wind turbines:

> So, you might wonder, do high winds make turbines really hum? No. Turbines must be shut down in high winds because centrifugal force would begin to tear the blades apart. Also, the world has learned from experience in Europe — whose wind sculpture gardens may one day dwarf ours — that a one-millimeter buildup of bugs on the blades reduces their power output by as much as 25%.
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> There are other problems. Thousands of turbine breakdowns and accidents have been reported in recent years. The basic concrete foundations are suffering from strains, as reported by industry sources and on the wind-farm construction website windfardbop.com.
>
> And there are environmental factors. Annoyingly, low-frequency noise produced by wind turbines, particularly large turbines, is driving some people away from their homes, according to numerous press reports. (Low-frequency noise regulations are already in place in Denmark while the phenomenon is the subject of continuing research.) The Audubon Society now estimates bird deaths from turbines exceed a million per year …"

Elsewhere it has been reported that some of those bird deaths are endangered species such as the American bald eagle.

Summary

This article has reviewed information on wind turbine noise which is familiar to the author. The information was from studies in the United States and abroad. The most recent information was all land-based. Despite reassurances by the developers of wind farms and the industry, there is evidence to support the existence of a health problem under some conditions and for some people with wind turbines, which appears to be tied to the infrasound or low frequency portion of the acoustic emissions of the turbine. It is important for scientists and engineers to acknowledge the problem and to work to eliminate it for affected residents who were the industry's supporters. It is unfortunate that many of the affected citizens feel disenfranchised by their governments in response to this issue.

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