

AEI Special Report: Wind Energy Noise Impacts



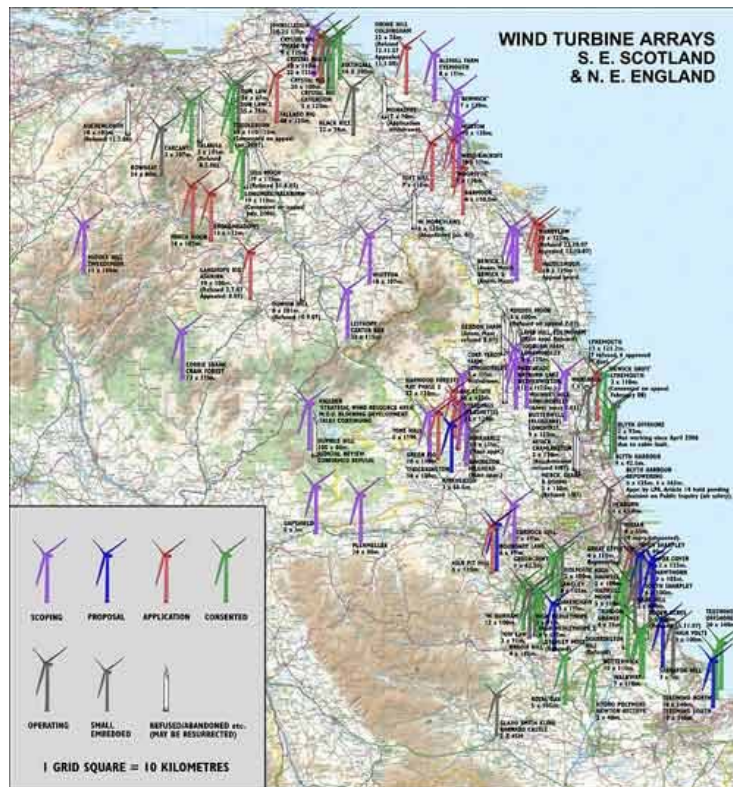
Contents

1	Introduction
6	How Noisy are Wind Turbines?
8	Regulating Wind Turbine Noise Variable individual responses / Low Frequency Noise / Health Effects / Local Regulatory Challenges
13	What Neighbors Are Saying
20	Possible Factors in Noise Complaints Unrealistically optimized / Topographical effects / Atmospheric effects / Coherence Amplitude Modulation / Icing / Possible solutions
24	Detailed Documents/Studies of Note
27	Emerging Technologies
31	Wind Energy Advocates, Pro and Con

Introduction

Wind energy has long been a favorite of many environmental advocates. No carbon emissions, utilizing a free resource without depleting it in the least, even the potential for distributed generation rather than distant centralized power plants: for many of us, wind was the cleanest of green power sources in our dreams of the energy future.

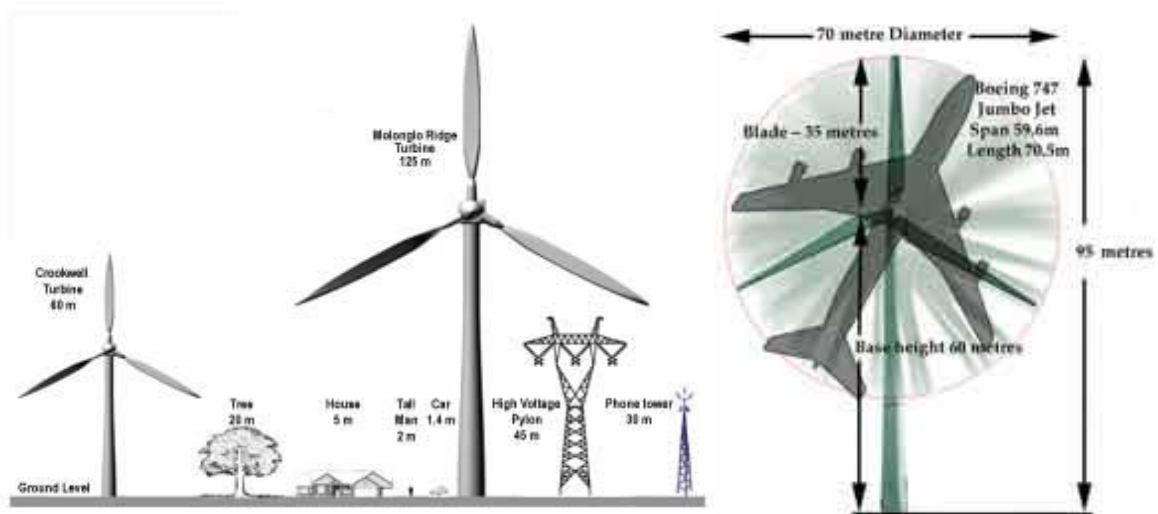
In recent years, as wind turbines have grown from the small backyard kits that the truly committed built in the 70's, the reality has made those dreams become less certain. Modern wind turbines are massive structures, hundreds of feet tall, and often constructed in large wind farms that in effect industrialize rural landscapes, from the rolling grassy hills of California, to the vast rangeland of Texas, to ancient ridgelines in the Appalachians, to the commons in rural England. While the trade-offs may be worth it in some areas, the downsides have become more apparent. Resistance to wind farms is often belittled as NIMBY-ism (Not In My Backyard); but at the same time, proponents often slip into oversimplifed WARYDU rhetoric (We Are Right; You Don't Understand). **If we are to forge a reliable energy future that is respectful of both the environment and the rights of neighbors, we'll need to move past knee-jerk reactions on both sides, and develop best practices that can ensure that the landscape and local residents don't become long-term casualties of today's "Klondike Wind Rush."**



Wind farms built and proposed in the UK
Image Source: Windbyte.co.uk

This AEI Spotlight Report will focus specifically on the noise impacts of wind turbines and wind farms. However, it is worth mentioning some of the other concerns that rural residents have raised about the sudden appearance of industrial wind farms in their communities. Besides the visual impact, which many residents are, in the end, willing to accept as a

tradeoff for producing clean energy, the most common argument against wind energy is that wind farms are notoriously inefficient, rarely achieving even half their rated capacity, due to fluctuating winds. Some claim that this means back-up power sources would need to be built, but wind proponents point out that future "back up" energy sources can be the traditional power sources already in place, and industry reports suggest the grid could accommodate up to 20-25% of total power coming from wind, using current installed traditional capacity as needed during low wind conditions. A more important long-term issue, still flying mostly under the radar, is that lease agreements between land owners and power companies can be full of holes, raising the very real specter of ridge lines and rangelands becoming, over time, abandoned junkyards of massive metal hulks, rusting and disintegrating for decades.



How big are modern wind turbines? The ones on the left are 60m and 125m; the one on the right is 95m, with blades sweeping an area the size of a 747.

See full-size images at www.aweo.org/windsize.html and www.mlg.org.au/visual.htm

It is entirely possible that ongoing technical innovation, combined with closer legal scrutiny, can overcome these issues. Similarly, **noise impacts are not necessarily deal-killers for wind energy, as long as developers are honest about what is likely to be heard and continue to work diligently to investigate the aspects of wind turbine noise that are still not fully understood.** Continually improving turbine design will likely mean that tomorrow's turbines are not as noisy as today's. **Local residents should be sure that their fears are not based on others' experiences with older turbines, and wind energy advocates must be diligent in not glossing over potential noise impacts.** With continual incorporation of best technology and best practices in siting, wind energy need not be stymied by noise issues. However, with noise impacts gaining more public credence, it is clear that **the current boom in wind farm development could well backfire, for both the industry and a clean energy future, if the current generation turbines are sited too close to residences.** The Altamont Wind Farm in California, shortsightedly built on a major raptor flyway in the early years of industrial wind development, has rippled through the years as a poster child for the bird-killing power of wind turbines, despite widespread understanding that it was an exceedingly bad siting decision. Similarly, many noise complaints today seem to be coming from people whose homes are on the near edge of fairly lax siting guidelines (within 500 meters in many cases, and often much less).

As you'll read below, it appears that **noise can be a significant issue in at least some**

situations when turbines are within about a half mile of homes (roughly 800m), with some impacts apparent up to a mile away. Some acousticians and health professionals are encouraging setbacks of as much as 1.5 miles (a bit over 2km). In the US, it is quite common to have setbacks defined as a multiple of turbine height; for example, 5 times the turbine height from a home (which would equate to 500m for a 100m turbine). It appears to AEI that a half-mile (2600ft/800m) setback is appropriate if the goal is to minimize impacts on residents, with a one-mile (1.5km) setback offering near assurance of avoiding noise issues.

If the thousands of wind farms likely to be built in the coming decade are placed too close to homes, the industry will be faced with an echoing chorus of complaints and resistance for years to come, even if it manages to invent much quieter machines. Better to be conservative, accepting the fact that even occasional atmospheric effects should be factored in to siting decisions today, so as to build a reservoir of good will, rather than a rising tide of complaints.



A 200 ft (65m), 1.5MW wind turbine at the Trent Mesa Wind farm in Texas

Image source: <http://www.trentmesa.com/ptour.htm>

A key point is made in a study completed in 2007 by the National Research Council, the research arm of the National Academy of Sciences, which found conflicts are widespread because of a fundamental reality of wind power. The environmental costs—visual impacts, noise, landscape and wildlife disturbances—are primarily felt by those near the wind farm. The benefits, however (reduced global warming emissions and other air pollution, less dependence on foreign oil and less mining and drilling) are felt more on the regional or national scale. "Benefits and (costs) don't necessarily affect the same people," said David Policansky, who directed the study. "If you talk to a national representative of an environmental organization, it's quite likely that person will be in favor. Whereas, when you talk to a local representative, it is more likely that person will be opposed to some local project."

Likewise, local reactions vary widely. In most cases, locals predominantly favor wind development, because they support green energy or appreciate the additional revenue that turbine leases provide, and a 2005 report from the UK found that local attitudes are more favorable in areas with existing wind farms than in areas with proposed wind farms, with those within 5km actually more favorable than those at greater distances (though the study did not break out those living very close, e.g., under 1.5km). Dueling reactions among nearby neighbors are also common, with some driven to distraction by noise, and others saying it's no problem; however, reports of such disparate reactions virtually never note whether the parties live upwind or downwind of turbines; living closely upwind of a turbine

is likely to be much more tolerable than living more distantly downwind, as illustrated by the "wind roses," below.

This AEI Special Report is designed to provide a layman's introduction to the types of noise produced by wind turbines. It is not our intention to over-emphasize noise complaints, but rather to provide information that can foster informed conversation about any specific wind farm proposal. **A recent UK government survey suggests that about 20% of wind farms tend to generate noise complaints, with half of these considered clearly noise-generated (the other half are considered to be primarily visual issues with noise as a secondary concern); the question is, what are the factors in those wind farms that may be problematic, and how can we avoid replicating these situations elsewhere?**

NOTE: This AEI Special Report will be continually updated, incorporating new research, more recent reports, and suggestions/comments from readers. Several topics will be added over time, including: effects of noise on wildlife and habitat, offshore wind energy, and the health effects of chronic noise exposure. The online version will generally be more up to date than the downloadable versions. See <http://www.AcousticEcologyorg/srwind.html>

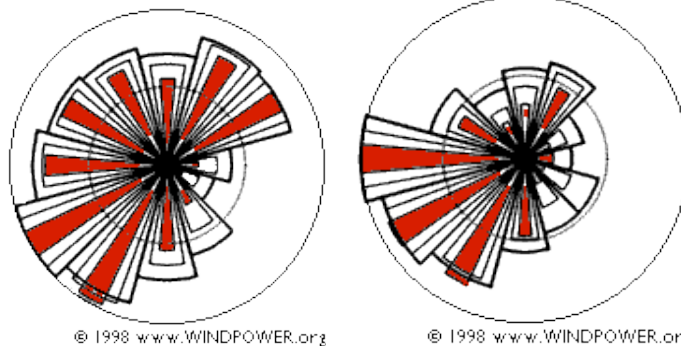
How Noisy Are Wind Turbines?

The US National Wind Coordinating Collaborative, a multi-stakeholder group that aims to build consensus on best practices to facilitate wind development, summarizes the situation in fairly straightforward terms:

By and large, those affected by the noise generated by wind turbines live within a few miles of a large wind power plant or within several hundred feet of a small plant or individual turbine. Although the noise at these distances is not great -- a 300-kilowatt (kW) turbine typically produces less noise at 400 feet than does light traffic 100 feet away -- it nevertheless is sufficient to be heard indoors and may be especially disturbing in the middle of the night when traffic and household sounds are diminished.

In a similar vein, the American Wind Energy Association's fact sheet on noise notes that "Today, an operating wind farm at a distance of 750 to 1,000 feet is no noisier than a kitchen refrigerator." Which raises a question: how many of us sleep in the kitchen?

The bottom line is that most modern industrial wind turbines are designed to keep noise levels at or below 45dB at 350 meters, which should drop to 35-40dB at 1000m (commercial turbines are quite often built this close to homes). Some are rated at lower sound levels. However, as is noted below, atmospheric conditions can wreak havoc with nice clean sound propagation models, especially at night. And, as turbines get bigger, their noise can be deceptively hard to predict; certainly, they can be quieter at their bases than some distance away, and temperature inversions, wind layers, and other atmospheric effects can lead to surprisingly distant sound impacts.



Two examples of a "Wind Rose" These diagrams chart the wind patterns at a given turbine location, based on prevailing wind speed from various directions. Most turbines will have an "upwind" side where little sound propagates.

It is important to recognize that night-time ambient noise levels in rural areas are often 30dB or lower; so, it is not that hard for wind farms to become a new and dominant acoustic presence. All too often, wind developers tell local planning boards that the turbines will be inaudible, which is rarely the case. Similarly, some investigations of noise complaints come to the conclusion that anomalously high noise levels occur so infrequently that they are insignificant (a recent UK investigation of Amplitude Modulation found that it was only an issue 5-15% of the time). But if temperature inversions or other atmospheric stability effects that cause excessive noise occur just 10% of the nights, that means that nearby residents may find their sleep disturbed 35 nights a year. Is this insignificant? Such questions need to be considered directly, not shunted aside.

Interestingly, smaller backyard turbines are often noisier than large industrial turbines. This is due to faster blade rotational speeds, and the fact that industry and government money is being devoted to making industrial turbines quieter. And of course, backyard turbines tend to be much closer to residences than industrial machines, making their noise more constant. On the positive side, many new nearly-silent designs are becoming available for small turbines; see the pictures and links at the bottom of the page.

It is sometimes noted that large wind turbines are getting quieter. This is clearly true for the mechanical noise emitted by motors and gears, which have seen noise-reduction design changes including soundproofing of turbine boxes, gears that flex, and sound-dampening to limit vibrations being passed to the tower and ground. While overall noise levels per unit of energy output are dropping, today's turbines are far larger than older ones, so total noise output is not necessarily decreasing, and is now mostly generated by the sound of the turbine arms swinging through huge arcs in the air. **Design of turbine blades is of course continually being improved; after all, the noise is a sign of inefficiency (rotational energy sacrificed by aerodynamic turbulence), so newer blades are likely to be quieter.**

While in many situations, the sound from turbines is drowned out by nearby wind noise, or is perceived as a gentle whooshing noise that is quite easy to accommodate, in some wind or atmospheric conditions, a pulsing noise can arise, which is much harder to ignore or acclimate to, making it a major source of complaints. Perceptually, the problem is that any pulsed or irregular sound (this rhythmic thumping can wax and wane over the course of a night) will tend to cause more disturbance. **It also seems that these sounds travel farther in calm night air; one widely-respected study (van den Berg, see below) found that sound levels were 5-15dB louder than predicted in some night-time atmospheric conditions, and noted that residents as far as 1.9km away were disturbed by noise.**

In some cases, the pulses are caused as the blades pass the tower, with maximum noise pulses audible in different areas around the turbine, depending on the wind direction. This has been termed Amplitude Modulation of Aerodynamic Sound, or Aerodynamic Modulation. The physics of this phenomenon are not fully understood. There has been some speculation that modern turbine designs, with the rotors on the upwind side of the tower, should reduce or eliminate the problem, though ongoing reports of such pulsing sounds suggest otherwise.

UPDATE: New research indicates possible directional noise vectors are key to Amplitude Modulation - A new line of research questions the old "blades passing the tower" theory behind amplitude modulation, and instead suggests that there are two extremely directional noise vectors that come off the back of each blade as it turns. This research finds that the trailing edge of the blade sends sound out in two directions, 90 degrees apart from each other. Dick Bowdler, Amplitude Modulation of Wind Turbine Noise: A Review of the Evidence.

DOWNLOAD THIS PAPER: <http://www.windaction.org/?module=uploads&func=download&fileId=1639>

Current Approach to Regulating Wind Farm Noise

While the United States does not have national noise standards, many European countries do. These countries, and many state or county regulations in the US, typically set an absolute sound level that any industrial facility must meet. Commonly, 45dB is used as the night-time limit, and 55dB as the day time limit; higher thresholds are sometimes allowed, but rarely does the night time limit drop below 40dB. The problem comes in rural areas, where night-time ambient noise (wind, distant traffic, etc.) is often 35dB, and sometimes as low as 25dB. Given that 10dB is perceived as twice as loud, the problem is obvious.

It should be noted that the majority of wind farms do not trigger noise complaints. These are likely sited far enough away to work well for nearby residents. A 2007 report from the UK found that roughly 20% of wind farms (27 of 133) had received complaints about noise (researchers report that about half of these were primarily visual complaints, with noise a secondary issue). While noise modeling (predicting the noise levels around wind turbines) tends to indicate that noise impacts should be insignificant beyond several hundred meters, **the French National Academy of Medicine has called for a halt of all large-scale wind development within 1.5 kilometers (roughly 1 mile) of any residence, and the U.K. Noise Association recommends a 1km separation distance.** In the US, there is no overall recommendation; siting decisions are made locally, and often are based on a 45dB night-time noise limit, so that turbines are sited no closer than 350m (roughly 1100 feet); **350-700m is often considered a reasonable setback in the US, based on simple sound propagation modeling.** Though it is also common for larger setbacks to be used, 1000m (1km) or 1500m setbacks are rarely required.

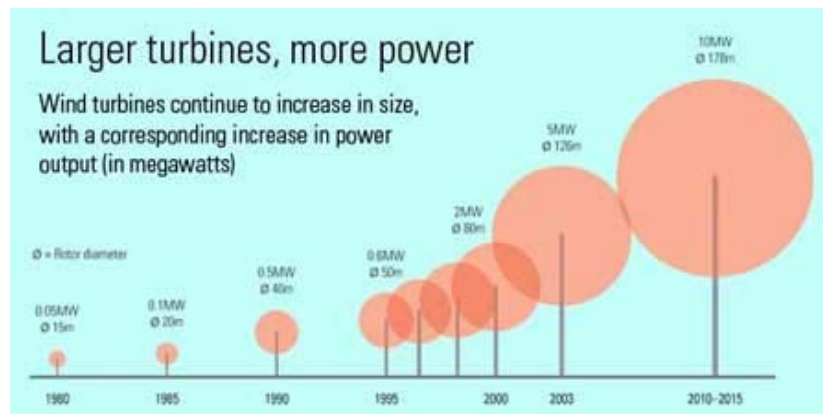


Image source: BP.com <http://tinyurl.com/9ezww7>

The International Standards Organization sets recommendations for all manner of human impacts, including noise. **The IMO recommendations are markedly lower than those used in most places, especially in the dead of night** (note: ISO 1996-1971 has been replaced by a newer standard, ISO 1996-2:2007; I have yet to find a chart of the new standard. If a reader can clue me in, I'll update this chart)

ISO 1996-1971 Recommendations for Community Noise Limits

District Type	Daytime Limit	Evening Limit 7-11pm	Night Limit 11pm-7am
Rural	35dB	30dB	25dB
Suburban	40dB	35dB	30dB
Urban residential	45dB	40dB	35dB
Urban mixed	50dB	45dB	40dB

Variations in Individual Responses to Wind Farm Noise

A particularly vexing aspect of trying to regulate wind farm siting to assure that neighbors will not be subject to undue noise impacts is the well-known wide variation in individual perception and response to any given noise level or noise source. Not only are there a wide variation in simple acoustic perception (i.e., how well people hear), but some people are more apt to be annoyed by sounds than others. **Industry spokespeople too often claim that anyone complaining about noise is actually using sound as a ready excuse for their general opposition to a local wind farm; in fact, there is a substantial body of research that explores the individual variation in response to similar sounds, and this variation is reflected in surveys of people living near wind farms.**

Of course, a key factor in whether a sound is annoying is one's attitude toward that sound; your own loud music is far less apt to bother you than your neighbor's quieter stereo wafting in on the breeze. But again, this is not the whole story: there is an inherent variation in sensitivity to and annoyance in response to noise. Those who are bothered by noise are likely to experience a wide variety of responses, including sleep disturbance, annoyance, and stress.

Surveys around wind farms provide some insight into this factor. While results vary somewhat, an overall trend seems clear: **while about half the people who can hear wind turbines seem not to be particularly bothered by the noise, a substantial minority (around 25%) are more sensitive to the noise, often reporting serious sleep disturbance.** As noise levels rise above 40dB (common at a quarter to half mile), annoyance rises substantially; at sound levels of 30-35dB (likely to be heard at a half mile to a mile), far fewer people report severe annoyance or regular sleep disruption. **For more detailed consideration of some of these studies, see two posts at AEInews.org: WISCONSIN SURVEY: <http://aeinews.org/archives/465> SUMMARY OF THREE EUROPEAN SURVEYS: <http://aeinews.org/archives/456>**

Many of those being bothered by noise were not opposed to their local wind farm when it was proposed or built; they simply were not prepared for the degree of disruption that the turbines' noise would cause. Some say that it is primarily turbines within a half mile that are intolerable, and that they could easily live with the noise of those farther away; others say that there are turbines between a half mile and mile could still cause them problems. But in either case, the issue is not looking at turbines—in large wind farms, turbines are easily seen, and seem surprisingly close (visually) at distances out to several miles.

There is far more gray than black and white in the surveys made around wind farms. Still, they provide a concrete picture of annoyance and sleep deprivation increasing as turbine noise increases, along with a better sense of the proportion of affected neighbors who will experience these impacts at various distances and received sound levels. **Clearly, 35-45dB is a range at which impacts on neighbors become far more widespread. The social question that will need to be addressed is what proportion of nearby neighbors we will accept causing sleep deprivation or annoyance in: 10%? 20%? Where will we draw the line, beyond which we consider turbine placement too close?**

Low-Frequency Noise

In some cases, low-frequency noise can become an issue with wind turbines. These sounds may be inaudible to the human ear, yet still be perceptible as a vibration, especially inside houses. Such low-frequency noise could be transmitted through the ground from towers, or be a component of a broadband noise field generated by spinning turbine blades. Low-

frequency noise travels greater distances with less loss of intensity than higher-frequency sound.

It is important to measure the noise from turbines using a dB(C) scale, which is weighted to accentuate low-frequency components of a broadband sound field. Most noise standards are weighted to the dB(A) scale, which accentuates frequencies heard best by the human ear. It is becoming a **standard procedure in dealing with industrial and machine noise to compare dB(C) and dB(A) readings; when dB(C) is 20dB more than dB(A), or when dB(C) is 60dB or higher, it is considered an indicator that low-frequency noise is at problematic levels**, and the need for special low-frequency mitigation is then generally called for.

An area of increased controversy in the past year has been the question of whether low-frequency (infrasonic) noise from wind farms can cause physiological responses in nearby neighbors. Some wind farm neighbors report uncomfortable pressure or pulsing in their heads or ears, dizziness, and similar feelings, and **a 2009 publication, Wind Turbine Syndrome, has triggered intense reactions on all sides of the issue**. The book reports on what is likely the worst-case scenarios of health impacts among wind turbine neighbors, compiled to make the case for further study of the issue, and postulates that the issue is low-frequency noise triggering a reaction in the vestibular (inner ear/balance) system. **Acousticians who have studied physiological responses to low-frequency noise claim it takes much higher exposure levels (e.g. as experienced in factories or inside spacecraft) to trigger any health problems, while a steady trickle of reports from around the world from people near wind farms continue to fuel concerns**.

It is important for all concerned to not get overly caught up in the controversy over low-frequency noise; all too often, far more straightforward audible noise concerns are discounted with a sweep of the hand in response to low-frequency reports that are far harder to substantiate. Likewise, **fears about low-frequency noise impacts are often at the center of pre-construction local resistance efforts, despite the fact that these problems appear to be much more rare and unpredictable than audible noise issues**. As mentioned above, individual variation in sensitivity and audibility of noise is a key factor; these variations are even more pronounced with low-frequency noise, with a very wide range of individual responses. It is likely that those who report vibrations and strange feelings are the most sensitive people; it is also very possible that many of the symptoms reported are primarily caused by loss of sleep, rather than direct impact of low-frequency sound waves.

Health Effects

Many people in recent months have expressed concern about the health effects of wind farm noise, but **it is quite likely that most of the symptoms reported (irritability, increased blood pressure, headaches, poor concentration, etc.) are, in most cases, largely secondary effects of sleep disruption**, rather than being directly caused by noise exposure or sound waves. A recent paper by sleep disturbance expert Dr. Christopher Hanning (not an academic paper, but an informal paper written in support of a community group) offers a good lay summary of what is known about sleep disruption by moderate noise levels. Hanning's primary point is that **external noise need not wake a sleeper to cause problems, and that repeated "arousals" can break the most restful periods of sleep**. He notes that "The sleep, because it is broken, is unrefreshing, resulting in sleepiness, fatigue, headaches and poor memory and concentration." These are precisely the symptoms often reported by people living near wind farms. He stresses that arousals are also associated with "physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. **Arousals occur**

naturally during sleep and increase with age (Boselli 1998) which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dBA and awakenings with events of 42dBA (Muzet and Miedema 2005), well within the measured noise levels of current wind farms" and the levels permitted by most jurisdictions.

Refining previous Community Noise Guidelines issued in 1999, and incorporating more recent research, the **World Health Organization in 2009 released a comprehensive report on the health effects of night time noise**, along with new (non-mandatory) guidelines for use in Europe. Rather than a maximum of 30dB inside at night (which equals 45-50dB max inside), the **WHO now recommends a maximum year-round outside nighttime noise average of 40db to avoid sleep disturbance and its related health effects**. The report notes that only below 30dB (outside annual average) are "no significant biological effects observed," and that between 30 and 40dB, several effects are observed, with the chronically ill and children being more susceptible; however, "even in the worst cases the effects seem modest." Elsewhere, the report states more definitively, "There is no sufficient evidence that the biological effects observed at the level below 40 dB (night,outside) are harmful to health." **At levels over 40dB, "Adverse health effects are observed," and "many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected."**

The 184-page WHO nighttime noise report offers a comprehensive overview of research into the various effects of noise on sleep quality and health (including the health effects of non-waking sleep arousal), and is recommended reading for anyone working with noise issues. The use of an outdoor noise standard is in part designed to acknowledge that people do like to leave windows open when sleeping, though the year-long average may be difficult to obtain (it would require longer-term sound monitoring than is usually budgeted for by either industry or neighborhood groups). **While recommending the use of the average level, the report notes that some instantaneous effects occur in relation to specific maximum noise levels, but that the health effects of these "cannot be easily established."**

In late 2009, New York physician Nina Pierpont will release a book that summarizes her preliminary research into the health effects of wind farms, centering on a "case series" study of people with similar physical responses in different locations. She proposes a new term, **Wind Turbine Syndrome**, to describe what she **suspects is a vestibular system (inner ear/balance) disturbance**. *(It should be clearly noted that only a small proportion of people living near turbines are strongly affected; Pierpont's work focuses on those few and is a first step at moving past a simplistic "it's all in their heads" response to these cases.)* While industry sources object to this focus on the few with special sensitivity, Pierpont is undertaking the first step in standard medical research: case series studies describe a new health issue, and provide a basis for design of more detailed field and clinical studies. **Her work is generating a surprising amount of enthusiastic praise from fellow doctors, and marks an important new threshold in our consideration of the impacts of wind farms on people living within a mile or so.** Of the ten families included in her case series, all living between a half mile and mile from turbines, eight have (so far) moved out of their homes; Pierpont recommends setbacks of 2km (1.25 miles) in flat terrain, and 3.2km (2 miles) in hilly terrain.

READ EXCERPTS AND TESTIMONIALS: windturbinesyndrome.com
(Please see AEI's comments on this work in the Low Frequency Noise section, just above)

Local Regulatory Challenges

Small town governing bodies are generally ill-equipped to address the questions before them when wind energy companies apply for local permits. In many cases, the proposed wind farm is the first outside industrial facility to be proposed in the town; it is almost always the first 24/7 noise source to appear in the local rural landscape and soundscape.

Energy company experts attend town council or selectmen meetings, often submitting comprehensive documentation that is rarely fully comprehensible to the lay members of the town's governing body. **While these documents don't generally promise anything quieter than 45dB, the outside experts too often assure local officials that the wind farms will be inaudible--relying on flawed assumptions that high winds will always create enough increase in ambient noise to drown out the turbines.** The use of comparisons, such as "a kitchen refrigerator" or "traffic 100 yards away" is likewise a common way of reassuring locals--one such expert went so far as to assure a council that the 45dB drone of turbine noise was "comparable to" bird song on a summer afternoon!

"There are no rules and regulations on windmills," Paul Cheverie, chairman of the Eastern Kings Community Council (Prince Edward Island, Canada) said. "The more we get into it, the more we realize we jumped the gun."

Wisconsin towns and counties have been especially proactive in implementing wind farm ordinances. In addition to Calumet County (above), another county adopted a one-mile setback requirement. The state legislature is likely to consider new measures to adopt statewide regulatory standards and preempt these local initiatives.

READ SOME WISCONSIN NOISE ORDINANCES: <http://tinyurl.com/aygdsc>

Resources/Advice for landowners signing lease and easement agreements with energy companies

- *Iowa State University Center for Agricultural Law and Taxation:* Legal Issues and Related Concerns for Landowners <http://tinyurl.com/7jwnyu>
- WindAction.org leasing info links <http://www.windaction.org/columns/17312> (scroll to bottom)
- *Ontario Federation of Agriculture:* 30 Suggestions on Wind Power Leases for Farmers <http://tinyurl.com/8lrell>

What Some Neighbors Are Hearing

Complaints from wind farm neighbors about noise are often discounted as the griping of a tiny but very vocal minority. Are we simply hearing from the most sensitive or the most crotchety people? A recent research paper suggests not. Christopher Bajdek's paper focused on creating realistic expectations about noise (and in so doing, countered both over-reactions of some websites and overly sanguine projections by industry reps). Presented at NOISECON 2007, a noise control industry conference, it included two key maps that charted dB measurements and the percentage of residents who were "highly annoyed" by the noise: **44-50% of people under a half mile away were "highly annoyed"** (over a third within a half mile had been awakened by turbine noise); **only as sound levels drop below 40dB do annoyance levels drop substantially; as sound drops below 35dB (a bit under a mile from nearest turbines), annoyance drops to 4% and less.** Bajdek noted higher annoyance responses to wind farms than to other similarly loud industrial noises, such as roads and railroads, with the supposition that visual impacts elevate reported annoyance. However, that cannot account for the many people awakened by the noise; the irregularity of turbine noise may be a more important factor in making wind farms more annoying than other industrial sounds.

Elmira, Prince Edward Island: 1km from wind farm with ten 120m turbines

Problems began within weeks after the turbines started operating. Downwind from the turbines, when the air was moving just enough to turn them, (12-15 knots from the northeast), the noise was loud. It was a repetitive modulated drone of sound. Dwayne Bailey and his father Kevin both claimed it sometimes was loud enough to rattle the windows of their homes on the family farmstead. The sound was even worse in the field behind their homes. Distances from 1 to 1.5 kilometers were the areas of the most annoying sounds. This spring the winds created constant misery.

"My idea of noise is a horn blowing or a tractor - it disappears," said Sheila Bailey. "This doesn't disappear. Your ears ring. That goes on continuously."

Dwayne developed headaches, popping and ringing ears, and could not sleep. He tried new glasses, prescription sleep aids and earplugs, to no avail. Dwayne's two year old was sleeping well prior to the wind farm, but began waking up, 5- 6 times a night.

Kevin Bailey stated, **"When you are outside working and absorbed in what you are doing, you are OK. If inside, resting or reading, it's a problem. Forget about sleeping at night. The repetitions would go away, you think that it is gone, and it comes back again."** Kevin tried sound dampening by draping the front walls inside his house, and sleeping in the back, but this did not work. Aspects of their experience (including vibrating appliances) suggest low-frequency noise may have been a key factor here.

Pubnico Point, Nova Scotia: 4000 ft, then 1000 ft, from 400 foot turbines

Life for the d'Entremont family since the Pubnico Point windfarm began operating has been filled with sorrow, illness, heartache and disbelief. How could a company be permitted to enter our community and turn our pristine area into a noise ravaged battleground. Why did it happen to us? Not that we would wish it on anyone else.

The first 2 turbines were operating in May 2004. **One was 4000ft from our home, the second 4700ft. A 120 day trial period was required to monitor their productivity. We could**

hear them well and Carolyn, my wife was experiencing ringing in her ears. Visitors would comment that the one 4000ft away seemed really close. Some neighbors were complaining they were bothered by them at night.

Three months later construction began again. It was easy to tolerate the noise and construction dust because we knew it was only temporary.



d'Entremont family home, now abandoned

Photo courtesy DangerWind.org

(web site by the d'Entremont family, advocating 1-mile setbacks)

February, 2005 the windfarm was fully operational, 17 wind turbines. The windmill 4000ft away seemed far off compared to the one 1000ft from our home. They are loud. They've been compared to jet engines. A plane that will not take off. **There is no gentle swoosh, it is a whoosh noise. They grind, they bang, they creek. The noise is like surround sound, it's omni-directional.** It feels like there's this evil thing hovering above you and it follows you everywhere, it will not leave you alone. This noise will not allow you to have your own thoughts, the body cannot adapt, it's a violation of your body. **It is a noise that the human body cannot adapt to even after more than a year of exposure. As time progresses the noise becomes even more unbearable.**

Our 5 year old son Elias was afraid and unable to sleep in his own bed for more than one year. He would get in our bed or in his brother's bed. We would put him to bed at 8:30 and many nights at 11:00 he would still be awake. Finally **he would fall asleep wrapped up in the blankets in the fetal position with his head covered and with a fan at his head. We had to create more noise to mitigate the windfarm noise. The body can adapt to the fan noise. In the morning he would get up tired and cranky.** In September 2005 he started school and he was not getting enough rest. He began getting more and more aggressive with his friends. He was very defiant. We knew he was suffering terribly. He's had throat infections and often had a fever and not feeling well.

We abandoned our home February 21st, 2006. Since the move Elias has been doing much better. He sleeps in his own bed every night. He sleeps partially covered with his arms and legs spread everywhere. It was only ten days after the move while he was having his back rubbed in bed he said "it's nice to be able to go to bed and sleep". He is much less defiant. He has become the kind gentle little boy he was before the windfarm nearly destroyed his life.

Freedom, Maine: 1000 and 1400 feet from wind turbines

Local resident Phil Bloomstein used a sound meter to record decibel levels at his home. The results, which Bloomstein captures on a laptop, show a **mean sound level of over 52 decibels, never dropping below 48 and peaking at 59 decibels.** "When the turbines were being proposed to be put up," he says, "we were told that 45 decibels would be as loud as it

would get except for ... no more than eight days a year." Neighbor Jeff Keating, a bit further from the closest turbine, said, to date, the noise has woken him up three times at night. He likened the experience to hearing the furnace kick on, then lying awake mad about having been woken. "It's not just a physical thing," he said, "there's an emotional side." Keating's neighbor Steve Bennett said he hears the turbines at all times of day. "It's like a jet plane flying overhead that just stays there," he said.

From a distance, the jet plane analogy fits the sound produced by the turbines - a white noise suggestive of a plane that never entirely passes. Closer to the turbines the sound quality changes. Each turbine rotates to face the wind and **the sound varies in relation to one's orientation to the blades**. At close range, facing the turbine head on, the sound is low and pulsing like a clothes dryer. From the side the blades cut the air with a sipping sound. Either way, when the wind is blowing, there is noise.

"They simply do not belong this close to people's homes," Bennett said. "Our property values have been diminished, and our quality of life has been diminished."

SEE YOUTUBE VIDEOS POSTED BY PHIL BLOOMSTEIN: <http://tinyurl.com/7gpvlc>

Lincolnshire, UK: 900m from wind farm with eight 2MW turbines

Julian and Jane Davis spent 60 nights away from home in the first six months of the wind farm's operation, due to lack of sleep, then moved out permanently at the end of 2006. Mrs. Davis says, "It sounds like a train coming toward you that never arrives, or a toy stuck in a tumble drier." They blame Amplitude Modulation as the issue; the local South Holland District Council recorded the noise, but reported that "the noise does not equate to statutory nuisance at this time."

Update: In spring 2008, they attempted to put it on the market, but local **real estate agents refused to list the property due to the noise**. Russell Gregory wrote to Mr. and Mrs. Davis saying until the problems with wind turbines were resolved it was impossible to put a current market value on the property as no prospective buyer would want to live there and no mortgage lender would be prepared to lend on it. He said: "I don't think I have ever refused one before. We have a duty towards the buyer but if you can't sleep there then it is uninhabitable."

Juniata Township, Altoona, PA: 600m and 1km from Allegheny Ridge Wind Farm with 40 turbines

A two-year old wind farm was stirring new noise complaints. One noise study put the sound below the township limit of 45dB, but residents claim their readings are higher. Tape on the trailing edge of turbine blades had come loose, and was causing much of the excess noise; a new owner is doing repairs, starting with turbines closest to homes.

Resident Jill Stull (turbines 2000ft/600m from her house) said, "You know when you're standing outside and you hear a plane coming about 30,000 feet overhead, then it goes off in the distance? It sounds like those planes are 5,000 feet above your house and circling and never land." The Stulls said they could move, but they aren't going to. "We're not going anywhere. I just want them to be quiet. **I'm not going to jump on the 'I hate windmills' bandwagon because I don't,**" Jill Stull said. "I'm just tired of nobody listening. My point is **what is your peace of mind worth? I can't play outside with my kids back at the pond in the woods because it gives me a headache.**" "I know it's going to make some noise, but a lot of times, it sounds like a jet," resident Myrle Baum said.

"On a calm day, you come outside and try to enjoy a nice peaceful day, and all you hear is the noise all the time and you can't get away from it," said Bob Castel, who has two

turbines behind his house. "The first time they started them up, I didn't know what it was. I was like man, that's a weird noise. It was that loud." said Castel.

While some neighbors said they aren't exactly bothered by the noise from the windmills, they said there's never peace and quiet either. "You notice them more at night, but you can't really hear them inside," said Charles Holland.

Greenfield Supervisor Ed Helsel, whose property borders the Stulls, said the noise varies. On a morning when Helsel considered it to be loud, he said he shut the window and could barely hear it. Jill Stull, whose property is closer to turbines, said she shuts her windows and stills hears the noise. "They're loud enough to make me wake up," Todd Stull said. "This is noise pollution."

Brownsville, Wisconsin: 1500-2000 feet from two turbines, three others sometimes audible within 4000 feet

Noise diary by a family during first two months of operation of the new Blue Sky Green Field wind project **READ DIARY:** <http://tinyurl.com/76o5fn>



Blue Sky Green Field Wind Project

Photo: WE Energies <http://tinyurl.com/425x3u>

April 16: From 6PM to 10PM the turbines were loud. I could hear #'s 4, 73, and 74a. Jet sound or like waiting for two trains to crash. We house a 360 (cubic inch) sprint car at our house. Tonight it was run for the first time this year. **One of the guys mentioned he could hear the turbine (#4) over the sound of the race car engine while it idled.** He was standing between the tire and the engine or right next to the engine. The car has no muffler.

During the day the wind is strong. The weather man says the wind will be 25-35 miles per hour. So strong that I don't hear the turbines very much. **Earlier my wife said she worked outside all afternoon in the wind and her ears were fine. When the wind died down and could hear three of the turbines her ears hurt.** She also mentioned the whooshes between turbines were out of sync.

April 12: At breakfast asked (my son) if he could hear the turbines in the house. "Yes, and **I hear them in my room", he said. "Some nights I can't sleep"**. His room is upstairs on the SW corner of the house. As I sit below his room (inside the house) I can hear the turbine at this moment.

9:30PM #4 not running, however I can hear the jet sound of #6.

Two farmers I have talked to are really angry about how they were treated. That is, once the contract was signed it meant the contractors could go where ever they wanted to on the farmer's land. One also had issues as to the placement of the tower road, he wanted it on

the fence line or to take out the fence line to minimize land loss. He was told it would cost too much to re-survey the land. The farmers said they were not told about the interduct or collection system that would be going through their land. Any complaints made to (the wind developer) was met with "it's in your contract."

Goderich, Ontario: 550m from a 80m turbine

Ernest Marshall moved from his home of thirty years, driven out by the noise of a wind turbine built two years ago, which scares his ponies and purrs incessantly through his bedroom window, keeping the Marshalls from a good night's sleep. Marshall suffered a stroke not long after the new the turbine began operation and, on the advice of his neurologists, has sold his home and is moving. "I'm a nervous wreck," Marshall, 65, said. "We've got to leave ... You can't know how it affects your nerves." Marshall is quick to clarify he's not against what it stands 80 metres high for -- clean energy. "The problem is they're putting them too close to people."

King City, Missouri: 2000 feet from several turbines

"It's like someone swinging a rope over your head," says Gentry County horse breeder Charlie Porter of the several wind turbines within about 2,000 feet of his home near King City. "It's not really a loud noise. It's just a constant noise." Porter, 53, claims the 260-foot turbines installed by St. Louis-based Wind Capital Group near his 20-acre spread have been making his family sick since they started rolling last year. Their symptoms include sleeplessness, anxiety and dizziness. "It's immediate," he says. "If they're running, you're miserable. If they're not you can try to stay outside and enjoy it all you can. It's like a day off."

A neighbor, Larry Sealey has two windmills within about 750 feet of his house and feels no ill effects. (A key factor not addressed in this article is whether Sealey is upwind or downwind of the turbines.)

Bothel, West Cumbria, UK: 800m (half-mile) from Wharells Hill Wind Farm

Ron Williams, 73, reports: "The swush, swush, swush as each blade breaks the flow of the wind past the tower, obviously three times per revolution, is extremely debilitating. The affect is worse at nights when ambient noise level from traffic on the A595 is low." Mr. Williams said that wind farm operators claimed that turbine noise levels were within legal limits but he questioned whether the effects of this low frequency noise had been thoroughly investigated.

Mars Hill, ME: 2600+ feet from turbine

Disturbance from noise is undoubtedly subjective: After recently visiting Mars Hill, Richard Jennings of Fayette said he did not see the wind turbines there as ugly or bad. His visit brought him to a home 3,000 feet from seven of the turbines and **the noise was no worse than his sleep apnea machine at night.** He urged the board to accept a proposed 44-turbine wind farm in Kibby Township because alternative energy is a necessity.

On the other side of the subjective coin, from Mars Hill resident Wendy Todd (house is 2600 feet from the nearest turbine): Unfortunately for us, the very mountain that has provided the wind facility with a class 3-wind resource often acts like a fence protecting us from the upper level winds that push the turbines. **There are many times when winds are high on the ridgeline but are near calm at our homes. The noise and vibrations from the turbines penetrate our homes. At times there is no escape from it.** It doesn't matter which room you go to, there is no escape from the noise. The noise ranges from the sound of a high range jet to a fleet of planes that are approaching but never arrive. When it's really bad it takes on a repetitive, pulsating, thumping noise that can go on for hours or even days. It has been

described as a freight train that never arrives, sneakers in a dryer, a washing machine agitating, a giant heartbeat, a submariner describes it as a large ship passing overhead.

People think that we are crazy. They drive out around the mountain, stop and listen, and wonder why anyone would complain about noise emissions. But, believe me when we are having noise problems you can most assuredly hear the justification of our complaint. **We have had people come into our yard get out of their vehicles and have watched their mouth drop. We have had company stop in mid conversation inside our home to ask, "What is that noise?" or say "I can't believe you can hear those like that inside your house."**



Two views of the Mars Hill wind farm, showing proximity of rural landowners. It is not hard to imagine noise blanketing the fields, especially when the hill is sheltering the lowlands from wind.

Images source: <http://tinyurl.com/8hta88>

(Wendy Todd, continued): Visiting a wind facility, or sitting at the end of someone's driveway once or twice for 2, 3 or even 10 minutes to listen does not make that person an expert on turbine noise. To be an informed witness could take days or weeks for one to know and experience what we are living. Not until an individual has been in a home and has heard turbine noise emissions of 45 decibels or higher does that individual have any right to judge how turbine noise truly affects the lives of people. Even noise experts should be talking to residents who are living next to turbines to ensure they are collecting data that is relevant to the burdensome noise emissions heard by those who live closest to them. Let us tell the sound experts when we are having a noise issue.

18 families, each with homes less than 3000 feet from the nearest turbine, are experiencing disturbing noise levels; the next closest home is about 5200 feet away, and are only occasionally bothered when inside their homes.

Nick Archer, our Regional Director with the Maine Department of Environmental Protection thought we were all crazy, too. But he finally made it to our homes and heard what we were talking about. I don't believe he has ever heard a 50+decibel day but he has heard close to that on more than one occasion and has made statements like these: "This is a problem," **"We need to figure out what is going on with these things before we go putting anymore of them up,"** "I thought you were crazy at first but you are not crazy," "The quality of life behind the mountain is changed." Did he say these things just to appease us? I don't believe so.

READ WENDY TODD'S FULL STATEMENT TO THE MAINE WIND TASK FORCE:

<http://tinyurl.com/9xlyhw>

READ CONCISE WENDY TODD LETTER SENT TO OTHER MAINE TOWNS WHO REQUESTED INFORMATION: <http://tinyurl.com/67krr9>

For an **archive of news reports that often quote residents affected by wind turbine noise**, and to follow the efforts of residents and local officials to grapple with wind farm permitting and regulation, see the Industrial Wind Action Group's news archives, noise section: <http://www.windaction.org/news/c43/>

Video of Wind Turbine noise, with commentary: <http://www.windaction.org/videos/15829>

Possible Factors in Noise Complaints

Predicted Noise is Unrealistically Optimized

Manufacturer measurements of the noise emission of their units is often based on optimized laboratory conditions and perfectly new machines; thus, the predicted noise output is likely the lowest that could occur with that particular turbine design. As units age, it is also to be expected that mechanical noise at least will increase (and perhaps aerodynamic noise as well, depending on wear of the blades themselves); a visit to most wind farms will confirm that some towers are louder than others.

In addition, most noise impact studies assume spherical spreading of sound, which is a rather idealized pure-physics approach to estimating how sound energy decreases as it is dispersed over distance, expanding outward in an ever-expanding sphere. While useful in some situations, or as a starting point, the topographic and atmospheric effects mentioned below tend to shatter the simple picture on which these numbers are based.

(Spherical spreading is based on the fact that the total sound energy spreads over an increasingly large sphere as a sound moves outward from its source. Any doubling of distance—whether from 100m to 200m or from 1000m to 2000m—will be marked by a decrease in sound intensity of 6dB, which to our ears, is perceived as cutting the volume almost in half. Higher frequencies are reduced more than this, by atmospheric attenuation, while lower frequencies stay pretty close to this model).

In attempt to account for these and other factors, manufacturers often add 2db to their manufacturer's sound emission estimates when applying for permits.

Note: A 2007 study in the UK, comparing modeled sound levels to measured sound levels, indicates that some models are more reliable predictors of sound transmission. Specifically, the researchers found that when they used a conservative (worst-case) factor for ground hardness (and thus sound transmission) the actual recorded sound was nearly always lower than predicted at close and mid range (100m-500m), with a bit more variation and scattered higher measured sound at longer range (750m) . When using a "mixed cover" factor for ground cover, measured sound was more often louder than predicted, sometimes by as much as 5-7dB (the mixed cover results were only reported at 750m). [Bullmore, Addock, Jiggins, Cand. Wind Farm Noise Predictions: The Risks of Conservatism. Second International Meeting on Wind Turbine Noise, Lyon, France, September 2007]]

Topographical Effects

Sloping landforms can create unusual sound propagation conditions, especially in consort with atmospheric fluctuations. Near the Vancouver Airport, hills rising from a flat plain caused **sound levels to be 20dB higher at 5500m than at 4000m**, because of the way the increasing ground angles caused sounds to combine, more than nullifying what, in a standard model, would be expected to be a 3dB decrease over that distance.

A different topographical effect is the one reported at Mars Hill, above, where noise from turbines atop a ridgeline is made "worse" by the fact that the ridge blocks the wind at homes along its foot, eliminating the masking effect that is often assumed to drown out the sound of turbines in high wind conditions.

Atmospheric Effects

Researchers looking more deeply into the readily apparent problems with noise that many residents are experiencing have uncovered a few possible atmospheric factors that deserve further investigation and due consideration from local authorities, as well as inclusion in noise models used to predict likely acoustic impacts of new wind farm developments. Most noise modeling is based on simplified wind speed models, and it is often assumed that higher winds will create higher ambient noise, thus hiding the increased sound of turbines. Among the recent findings:

Night time atmospheric stability

In the daytime, warming air rises, both carrying sound aloft and creating turbulence that scatters turbine noise, as well as creating more ground-based ambient noise that masks turbine sounds. At night, however, when the air stabilizes it appears that noise from wind turbines can carry much farther than expected. This effect can occur with light winds at turbine height and the ground, or, with light winds at turbine height and very little or no wind at ground level.

With light and steady breezes capable of spinning the turbines, but not stirring up much ambient noise, sound levels measured at homes a half mile to nearly two miles away are often 5-15dB higher than models would suggest. Making matters worse, this same atmospheric stability tends to allow multiple turbines to settle into a synchronous rhythm (in more turbulent conditions, small differences in wind between the turbines keeps them out of synch). In this case, the "whish" of the blades as they pass the tower often turns into a more annoying rhythmic "thump;" in quantitative terms, the change in sound level creating the whish or thump can rise from 2dB to 5dB or as high as 9dB, making a clearly audible rhythmic pattern. These rhythmic pulses are likely the strongest factor in annoyance.

Inversion layers

While the quantitative effect of inversion layers on sound levels has not been systematically studied, many opportunistic reports suggest the obvious: that **when an inversion layer forms above the height of turbines, it can facilitate longer-range sound transmission** by reflecting some of the sound back toward the ground, or by forming (with the ground) a channel for sound propagation. In many locations, this will be a relatively rare occurrence, but **in areas with frequent inversion layer formation, it should be considered.**

Coherence

Wind turbines are often placed in a row; the sound emanating from each one will move outward in concentric circles. There will be places where the sound waves from one turbine interact with the sound waves from another turbine; in these locations, they sound waves may be out of phase, thus reducing the perceived loudness, or in phase, thus increasing the localized sound levels. You might more easily picture this if thinking of pebbles dropped in water; the expanding circles of waves will cross each other, creating a more dynamic pattern of higher and lower waves. *Note: the same factors that can disrupt the idealized spherical spreading models, as noted above, also will tend to create a more chaotic pattern of sound waves from each turbine, thus also limiting the impact, and certainly the predictability, of coherence effects.*

Amplitude Modulation (also known as "Aerodynamic Modulation" or "Amplitude Modulation of Aerodynamic Sound")

As noted briefly in the introduction, it appears that a common source of noise complaints by nearby residents is a repeating "thumping" noise, rather than the constant whir of the blades. The physics of this phenomenon are not fully understood; it has long been assumed that this thumping is the result of a slight pressure differential caused by the tower of the turbine: as each blade passes the tower at the bottom of its arc, it passes through this lower-pressure region and creates the thumping sound. Depending on the wind direction, this sound is loudest in different directions at different times. There has been some speculation that modern turbine designs, with the rotors on the upwind side of the tower, should reduce or eliminate the problem, though ongoing reports of such pulsing sounds suggest otherwise.

A group of turbines can, at times, turn in synch with each other, causing any Amplitude Modulation to be accentuated, especially at locations equidistant from any two or more turbines.

UPDATE: New research indicates directional noise vectors may be key to Amplitude Modulation - A new line of research questions the old "blades passing the tower" theory behind amplitude modulation, and instead suggests that there are two extremely directional noise vectors that come off the back of each blade as it turns. This research finds that the trailing edge of the blade sends sound out in two directions, 90 degrees apart from each other. Dick Bowdler, *Amplitude Modulation of Wind Turbine Noise: A Review of the Evidence*. **DOWNLOAD THIS PAPER:** <http://tinyurl.com/6smm2w>

Icing

Icing on the leading edge of blades can cause a 3-5dB increase in the source level of noise from the turbine.

At the end of an intensive two-year period of studying the complexities of atmospheric turbulence and stability on wind turbine noise, G.P. van den Berg offered this sage advice:

"There is much more to discover: indeed, it looks like wind turbines have become more fascinating now their sound has proved to be more complex than a simple constant noise from the sky, driven only by wind with a constant profile. This may motivate researchers and consultants to put more effort in better predictions of wind turbine noise, and considering again noise exposure to local residents.

"Several technical possibilities to minimize the noise have been outlined in this book, but we need not just depend on technical solutions. **A change in public relations can also make a difference: proponents must accept that wind turbine noise is not (always) 'benign', that the noise may affect people, and that people who are complaining are not always just a nuisance.** And no, we still do not understand wind turbine noise emission entirely, so proponents should watch their WARYDU (we are right, you don't understand) attitude. "

Likewise, a 2007 report commissioned by the UK government to investigate noise complaints noted that "'Unrealistic expectations' was thought to be a factor in at least one case, i.e. the complainant believed that the noise would be less noticeable than it actually proved to be. In this case the local authority considered that the complaint could possibly have been avoided by more accurate information from the developer at the planning stage....Finally, for five of the sites having received complaints, the site met planning conditions. We do not know whether these comments indicate that complaints were unjustified, or alternatively that planning conditions were too lenient."

Indeed, **official noise standards can very easily fail to protect nearby residents from disruptive levels of noise.** It is crucial that everyone involved (industry, government, residents) resists the easy temptation of relying on "paper" assurances that wind turbines will not create acoustic impacts. **Working from a realistic foundation, siting and permitting decisions can proceed in a manner that protects both local residents and the long-term potential for wind energy generation.**

Possible solutions

It is hard to escape the implication that setback distances may need to be increased in many places where the prevalence of such night time effects suggest sound will often remain at annoying levels for larger distances. It could also help to monitor for synchronous blade patterns and add random variations at night, to mimic the random variations that atmospheric turbulence causes in the daytime. Finally, noise modeling studies should include calculations based on night time stable atmospheres; G.P. van den Berg, whose 2006 Ph.D. thesis is a comprehensive study of these effects, concludes that **"With current knowledge, the effects of stability on the wind profile over flat ground can be modelled satisfactorily." (his measurements indicate that more sophisticated sound models were accurate to within 1.5dB)**, while simpler models missed the mark by up to 15dB). He goes on to note: "In mountainous areas terrain induced changes on the wind profile influence the stability-related changes and the outcome is less easily predicted: such terrain can weaken as well as amplify the effect of atmospheric stability."

There are certainly many suitable sites for wind farms that are remote enough to avoid even the possibility of noise issues in people's homes. At this crucial stage in the development of the wind power industry, it would be sadly short-sighted to insist on placement of turbines in the "grey area" between what noise models suggest is enough (perhaps 1500 feet) and the zone in which complaints have cropped up (up to a mile or so). Taking a big-picture view, the power generating potential in areas that are marginally close to people's homes is a very small proportion of the nation's wind power capacity. Let's start where we know turbines will not disturb neighbors, rather than risk a generation of vocal complaints that may impede future development as turbines become quieter.

Detailed Documents Of Note

The above sections draw on several detailed reports by others. Those wishing to learn more, or to inform themselves so as to discuss these issues in depth with regulatory authorities, company representatives, acousticians, or neighbors, will benefit from reading the source material below.

G.P. van der Berg's 200-page Ph.D. thesis, published as **The sounds of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise**, is a treasure-trove of detailed acoustic analysis and clear lay summaries, regarding both atmospheric stability issues and the challenges of recording effectively in high-wind conditions (i.e., avoiding wind noise on mics so as to more accurately capture ambient noise levels).

DOWNLOAD VAN DEN BERG THESIS (pdf): <http://tinyurl.com/78baby>

Christopher Hanning. **Sleep disturbance and wind turbine noise**. June 2009. Perhaps the most important recent paper, from a UK expert on sleep disturbance. Includes key pieces of data from previous studies, and introduces a central aspect of sleep research that most laymen are not aware of: noise can cause repeated "arousals" that do not wake us, yet disrupt the restful stages of sleep and may explain many of the health effects reported by those living near wind farms.

DOWNLOAD HANNING PAPER (pdf):<http://www.wind-watch.org/documents/wp-content/uploads/Hanning-sleep-disturbance-wind-turbine-noise.pdf>

World Health Organization Night Noise Guidelines for Europe. 184 page report that offers a comprehensive overview of research into the various effects of noise on sleep quality and health (including the health effects of non-waking arousal), and is highly recommended reading for anyone working with noise issues.

WEBSITE TO DOWNLOAD REPORT:

http://www.euro.who.int/eprise/main/WHO/Progs/NOH/Activities/20040721_1

Soysal and Soysal, **Wind Farm Noise and Regulations in the Eastern United States**. Paper presented at the Second International Meeting on Wind Turbine Noise, Lyon, France, September 2007. A well-done and concise (12p) summary of wind farm noise sources, sound levels measured at one typical wind farm in Pennsylvania, and noise regulation challenges.

DOWNLOAD SOYSAL PAPER(pdf): <http://tinyurl.com/9eztax>

Kamperman and James, **How To Guide to Wind Turbine Siting**, August 2008. Two acousticians who have become roaming expert witnesses for rural towns facing wind development submitted these proposed limits at the July 2008 national Noise Control conference. In brief, they suggest limiting turbine noise to 5dB above night-time ambient noise levels, at any neighboring property boundary, or a total of 35dB within 30 meters of any occupied building.

DOWNLOAD GUIDE(pdf): <http://tinyurl.com/8uyq87>

Charles Komanoff, **Whither Wind**. A typically thoughtful and sensitive essay from Orion Magazine, examining the personal and social issues at play as we move toward embracing the potentials of wind power.

READ ARTICLE: <http://tinyurl.com/7hdfj9>

OTHER WIND-RELATED WRITINGS FROM KOMANOFF: http://www.komanoff.net/wind_power/

Frey and Hadden. **Noise radiation from wind turbines installed near homes: effects**

on health. This is a detailed annotated review of research and accounts of noise disturbances from wind farms, primarily in Europe. Includes relatively cogent assessment of low-frequency effects on health, notable in that many citations are for low and moderate levels of LF noise, rather than industrial facilities in which LF is much higher than that experienced by wind neighbors. Not peer reviewed, but well-documented.

DOWNLOAD PAPER (pdf): <http://www.wind-watch.org/documents/wp-content/uploads/wtnoisehealth.pdf>

Christopher Bajdek, **Communicating the Noise Effects of Windfarms to Stakeholders.** Very interesting paper presented at NoiseCon 2007 (major noise control engineering conference). Includes consideration of creating realistic expectations, with an overall tone of providing rational information to counter over-reactions on some websites. It notes higher annoyance responses to wind farms than to other similarly loud industrial noises, such as roads and railroads, with the supposition that visual impacts elevate reported annoyance. Two key graphics chart dB measurements and percentage of residents that are "highly annoyed" by the noise: 44-50% of people under a half mile away were "highly annoyed" (over a third of those between a quarter and half mile away had been awakened by turbine noise); only as sound levels drop below 40dB do annoyance levels drop substantially; as sound drops below 35dB (a bit under a mile from nearest turbines), annoyance drops to 4% and less.

DOWNLOAD PAPER: <http://tinyurl.com/9lm7e7>

Wind Turbine Noise 2007 International Conference

<http://www.windturbineoise2007.org/> Read abstracts of all papers

DOWNLOAD ABSTRACTS(pdf): <http://tinyurl.com/8vh4xk>

Noise 2009 International Conference <http://www.windturbineoise2009.org/>

2005 CONFERENCE WEBSITE: <http://www.windturbineoise2005.org/>

2011 CONFERENCE WEBSITE: <http://www.windturbineoise2011.org/>

Nina Pierpont, M.D. **Wind Turbine Syndrome.** Book to be released late 2009. Pierpont's short book-length summation of research into the health effects of low-frequency noise, and more specifically of audible as well as low-frequency noise emitted by wind turbines, is garnering impressive praise from some fellow physicians and plenty of critiques from others.

READ EXCERPTS: http://www.windturbinesyndrome.com/?page_id=932

READ TESTIMONIALS: http://www.windturbinesyndrome.com/?page_id=922

Terry Matilsky, Professor of Physics, Rutgers University, in detailed 2005 comments on an industry noise impact analysis, discusses atmospheric stability, aging of turbines, and topographic considerations, as well as critique of models and statistical analysis. By

DOWNLOAD MATILSKY COMMENTS: <http://tinyurl.com/2mtah3>

Catherine Lawton, a Wisconsin-based business consultant, in detailed 2004 comments submitted to the Oregon Department of Environmental Quality, provides a good introduction to the physics behind wind turbine mechanical and aerodynamic noise, as well as some suggestions for improving regulation of wind turbine noise.

DOWNLOAD LAWTON COMMENTS (pdf): <http://tinyurl.com/7t5est>

Amanda Harry, **Wind Turbines, Noise, and Health.** This 2007 report is centered on interviews with 39 people who have been disturbed by noise at their homes near wind turbines in the UK. It also includes reviews of research into the health effects of noise; while citations are not up to academic standards, extensive interview quotes and basic health factors make it worth reading.

DOWNLOAD HARRY PAPER(pdf): <http://tinyurl.com/9nvq4j>

Moorehouse, Hays, von Hunerbein, Piper, Adams. **Research Into Aerodynamic Modulation of Wind Turbine Noise: A Final Report.** DEFRA, 2007.

DOWNLOAD REPORT: <http://tinyurl.com/8xkypq>

Bowdler, Dick. **Amplitude Modulation of Wind Turbine Noise: A Review of the Evidence.**

DOWNLOAD REPORT: <http://tinyurl.com/6smm2w>

WHO (World Health Organization) Night Noise Guidelines meeting reports

DOWNLOAD 1ST MEETING REPORT (pdf): <http://tinyurl.com/7btr33>

DOWNLOAD 2ND MEETING REPORT: <http://tinyurl.com/7g2jgk>

Champaign County, Ohio, **Wind Turbine Study Group Report** - Pages 21-33 cover noise issues, including lots of back and forth (point/rebuttal) comments from study group members

DOWNLOAD REPORT(pdf): <http://tinyurl.com/8yo285>

Emerging Technologies

While there are legitimate noise concerns associated with current wind energy development, this is a vibrant and ever-growing field, and several emerging technologies offer promise of making significant reductions in the acoustic impact of turbine construction and/or operation.

Blue H Floating Offshore Platform - This platform, based on designs used by the oil and gas industry, is being pitched as a way to place wind turbines far enough offshore to overcome resistance to seeing wind farms from shore or placing wind farms in productive near-shore fisheries. But perhaps more significant, this approach avoids the construction noise of pile-driving, which is necessary for traditional permanent bottom-mounted turbines. <http://www.bluehgroup.com/>

See video of prototype: <http://www.bluehgroup.com/sitedevelopment.php>

News, 3/15/08: Blue H Leases MMS site far offshore, proposes alternative Martha's Vineyard project with Cape Wind opponents on board <http://www.windaction.org/news/14689>

Sway Deepwater Turbine - Another emerging approach to siting turbines further offshore, from a Norwegian company. Their approach uses a long floating tower underwater to provide stability, with the whole thing tethered to the sea floor; they claim to be able to withstand severe waves with ease.

<http://www.sway.no/>

See animation of concept: <http://www.sway.no/media/25okt05.avi>

Selsam Superturbine - An innovative new approach to offshore wind turbines, still in the conceptual stage, which would employ many small turbines on a single tower. Benefits include a much smaller visual impact.

<http://superturbine.net/>



FloDesign Turbine - This new approach is based on principles from jet engines, and while still in the early phases of development (first prototype is yet to be produced), could lead to important breakthroughs. The small size and less disruption of air currents would allow wind farms to be built much more densely (and so use less land), and would likely be much quieter, especially in low frequencies.

<http://www.flodesignwindturbine.org/>

See video: <http://www.flodesignwindturbine.org/turbine/index.php>




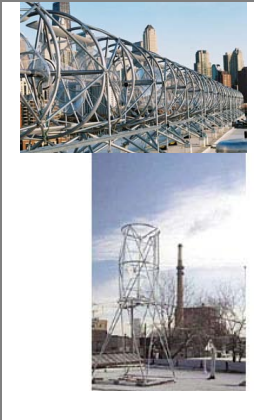






WhalePower Serrated Turbine Blades - A Pennsylvania biology professor discovered that the serrated edges of humpback whale fins actually create a more efficient flow of water, and has adapted the design to create a new approach to fan and wind turbine blades. The first commercial result are factory fans up to 24 feet in diameter, which use 20 percent less energy and are significantly quieter than previous designs, while distributing the air more evenly. The first field trials of WhalePower's wind turbines based on the new design are underway in Canada, and early results indicate they generate more power from a given wind speed than traditional turbines, while also being quieter.

<http://www.whalepower.com/drupal/>



Vertical Axis Turbines - This new approach looks somewhat like a corkscrew, and promises much lower noise impacts. Several companies are developing prototypes and doing initial commercial installations. So far, **these designs are sized for home, office building, or apartment building applications. None have been scaled for use in wind-farm settings.** While some of these companies brag of higher output thanks to operating at lower wind speeds, others claim that such "drag" designs are inherently more inefficient than traditional "lift" designs. Bear in mind, as well, that while noise on the tips of traditional spinning blades can be an issue, often the mechanical noise of a turbine's "insides" is a large contributor to the noise signature of smaller turbines located close to homes.

	<p>Windstor - Installation of its second unit in Ishpeming, Michigan, was derailed in 2006 by lack of capital; in Dec 2007 MTI Energy announced it had paid the project's debt and was moving forward with plans to complete the installation. http://web.mckenziebay.com/ http://www.mti-energy.com/</p>
	<p>Windhaus - tight closed design http://windausenergy.com/</p>
	<p>Windside - Lightweight, silent turbines modeled on principles of sails; they manufacture several variations, meant for differing conditions. http://www.windside.com/</p>
	<p>Aerotecture - Their "aeroturbines" are designed for turbulent urban conditions. Several designs, some which stand and some which lie on the roof. http://www.aerotecture.com/</p>
	<p>Turby - A Dutch company, also touting effectiveness in urban settings. They claim to combine the best features of horizontal axis (efficiency) with the best of vertical. http://www.turby.nl/</p>

	<p>Carbon Concepts - Another approach that attempts to combine the benefits of horizontal and vertical designs. http://www.carbonconcepts.co.uk/windpower/windturbine.htm</p>
	<p>TMA - Unique wind-concentrating design especially useful at high speeds. Aiming for large applications, up to 500kW, though the design is scalable to 1MW. http://www.tmawind.com/</p>
	<p>Stormblade - new design, prototype stage, initial interest from manufacturers. Concentrates wind inside housing; quiet, efficient. http://www.treehugger.com/files/2007/01/stormblade_the.php</p>

Wind Energy Advocates, Pro and Con

Trade Organizations

Danish Wind Industry Association

<http://www.windpower.org/en/core.htm>

Site includes quite a bit of discussion of noise and includes a noise calculator grid in which you can place one or more turbines and set acceptable noise levels to determine set-backs

NOISE PAGES: <http://tinyurl.com/9uks5k>

CALCULATOR PAGE: <http://tinyurl.com/9qajec>

German Wind Energy Institute (DEWI, Deutsches Windenergie Institut)

<http://www.dewi.de/dewi/index.php?id=1&L=0>

British Wind Energy Association

<http://www.bwea.com/index.html>

UK WIND PROJECTS DATABASE: <http://www.bwea.com/ukwed/>

American Wind Energy Association

<http://www.awea.org/>

US WIND PROJECTS MAP: <http://www.awea.org/projects/index.html>

AWEA SITING HANDBOOK: <http://tinyurl.com/9b6m8o>

World Wind Energy Association

<http://www.wwindea.org/>

An association of national and regional wind energy associations.

WWEA Technology and Planning Website: <http://www.world-wind-energy.info/>

Overview of wind turbine engineering and project planning

Governmental Entities

World Health Organization

WHO Guidelines for Community Noise: <http://tinyurl.com/96qmvz>

US Dept of Energy Wind Powering America Program

<http://www.eere.energy.gov/windandhydro/windpoweringamerica/>

Or <http://tinyurl.com/3c3nok>

Through its state Wind Working Groups, programs at the National Renewable Energy Laboratory, and partnerships, this initiative will establish new sources of income for American farmers, Native Americans, and other rural landowners and meet the growing demand for clean sources of electricity.

US Bureau of Land Management - In 2006, the BLM released a Programmatic Environmental Impact Statement governing wind energy development on BLM lands in 9 western states.

<http://windeis.anl.gov/>

[[DOWNLOAD EIS](#)]

[[DOWNLOAD BIOLOGICAL OPINION\(pdf\)](#)]

US National Academies of Science - The NAS's National Research Council released a 2007 report, Environmental Impacts of Wind Energy Development, focusing on the mid-

Atlantic mountains. The report is available for purchase at the NAS store, in whole or by chapter.

WEBSITE: http://books.nap.edu/catalog.php?record_id=11935

or <http://tinyurl.com/3dchh8>

4-PG REPORT IN BRIEF(pdf): <http://tinyurl.com/7m24mn>

EXECUTIVE SUMMARY(free pdf): <http://tinyurl.com/5s3xqa>

US Forest Service - In late 2007, the US Forest Service announced plans to revise its Wind Energy Directive. They have not set up a dedicated web page to track the process, but the Federal Register Notice contains the text of the proposed directive.

FED REG NOTICE: <http://tinyurl.com/8pnz9t>

US Fish and Wildlife Service Wind Turbine Guidelines Advisory Committee -

ADVISORY COMMITTEE WEBSITE: <http://tinyurl.com/8shzfq>

Or http://www.fws.gov/habitatconservation/windpower/wind_turbine_advisory_committee.html

FWS WIND ENERGY WEBSITE: <http://www.fws.gov/habitatconservation/wind.htm>

Landowner Support

Resources/Advice for landowners signing lease and easement agreements with energy companies

Iowa State University Center for Agricultural Law and Taxation

<http://www.calt.iastate.edu/windenergy.htm>

Legal Issues and Related Concerns for Landowners

Ontario Federation of Agriculture

<http://tinyurl.com/8lrell>

30 Suggestions on Wind Power Leases for Farmers

Wind Advocacy Organizations

National Wind Coordinating Collaborative

<http://www.nationalwind.org/>

A U.S. consensus-based collaborative formed in 1994, NWCC members include representatives from electric utilities and support organizations, state legislatures, state utility commissions, consumer advocacy offices, wind equipment suppliers and developers, green power marketers, environmental organizations, agriculture and economic development organizations, and state and federal agencies. They've issued many Issues Briefs, some of which address noise, but none of which focus on it.

Wind Energy Works!

<http://www.windenergyworks.org/>

A national alliance of state wind energy industry groups, state agencies supporting wind development, and clean energy advocates.

Wind Works

<http://www.wind-works.org/>

Longtime wind energy advocate Paul Gipe's website, replete with many of his articles and information on his books.

Wind Turbine Noise Activists

National Wind Watch

<http://www.wind-watch.org/>

Collects news reports, new research, and most interesting, several videos documenting community response to wind farm projects in the United States.

VIDEO PAGE: <http://www.wind-watch.org/videos.php>

Wind Action

<http://windaction.org/>

Impressively comprehensive news-archiving project, featuring media reports on wind farm development, links to research reports, and more. Can search on "noise" and get a great starting point for nearly all the primary concerns.

Nina Pierpont

<http://www.windturbinesyndrome.com/>

An MD who has been investigating "Wind Turbine Syndrome," a cluster of stress-related physiological effects of turbine noise, for several years. She has compiled two concise, annotated pages of papers and letters, and will release a 100-page report in August 2008. She recommends a 2km (1.5 mile) buffer between turbines and homes.

Rock County (WI) Better Plan

<http://betterplan.squarespace.com/>

Regional activist group with wide-ranging online resources and a rambunctious tone

Windbyte

<http://www.windbyte.co.uk/>

This UK group uses maps to track the "Klondike Wind Rush" sweeping northern England and southern Scotland, where wind farm applications, proposals, and scoping studies far outnumber existing wind farms, prompting fears of a "wind energy landscape".

The Acoustic Ecology Institute works to increase personal and social awareness of our sound environment, through education programs in schools, regional events, and our internationally recognized website, AcousticEcology.org, a comprehensive clearinghouse for information on sound-related environmental issues and scientific research. Our over-arching 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.

AcousticEcology.org is an unparalleled resource for issue updates and reliable background information. The site features a News Digest, science summaries, Special Reports, and extensive lists of research labs and advocacy organizations on all sides of sound-related environmental issues, including ocean noise, motorized recreation in wildlands, oil and gas development, wind turbines, and more.

Contact Jim Cummings at 505-466-1879, [via email](#) or visit AEInews.org and AcousticEcology.org