

New York State Energy Research and Development Authority

# Wind Turbine-Related Noise and Community Response

April 2013

NYSERDA Report 13-03b



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# Wind Turbine-Related Noise and Community Response

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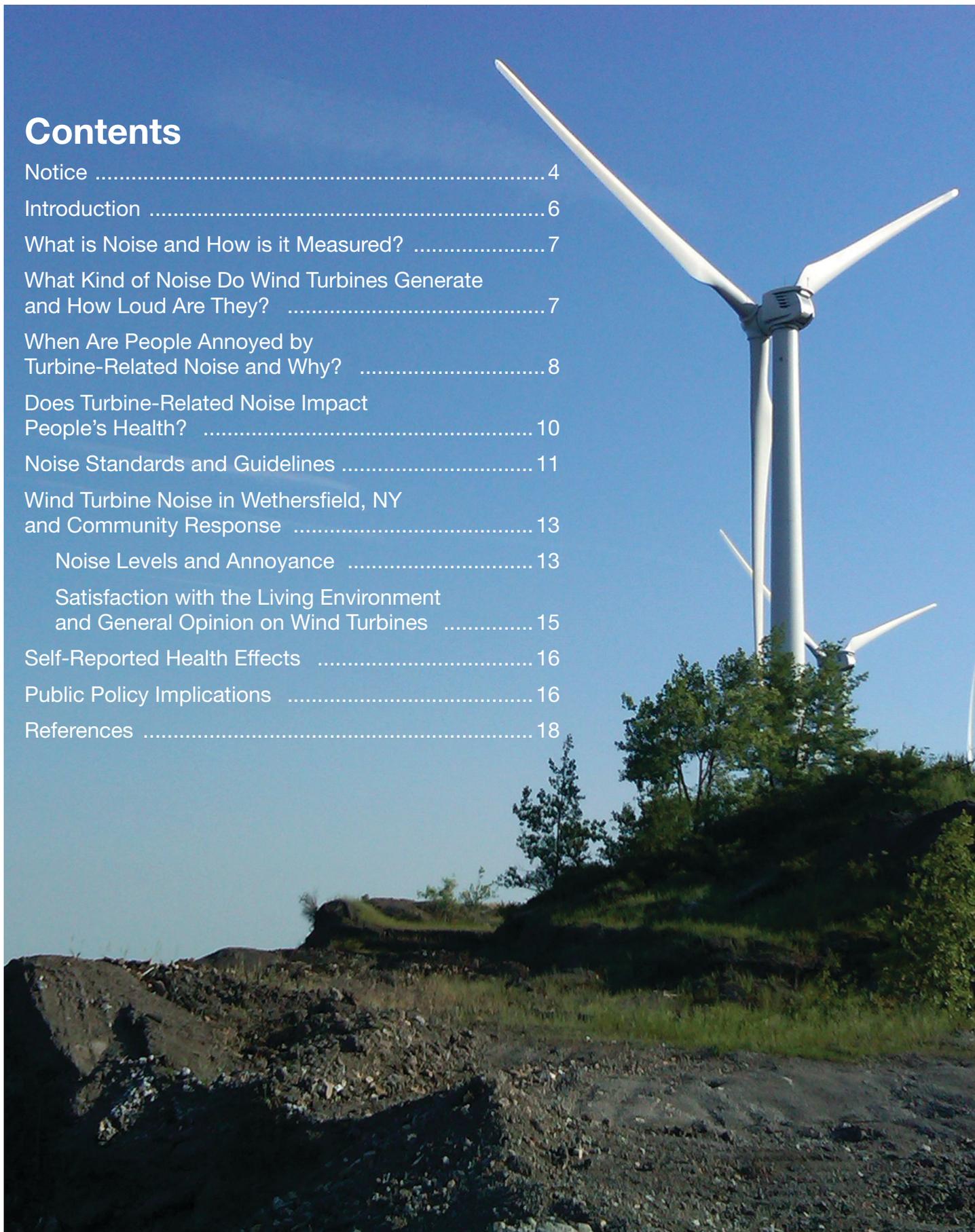


Photo Courtesy of Steel Winds II



## Introduction

Wind power constitutes a small, but growing source of electric power for New York State. According to the American Wind Energy Association and the New York Department of Environmental Conservation (DEC), New York State ranks 12th in the nation for installed wind capacity, it is the 15th windiest state in the nation, and the state's wind resources could fulfill more than half of its current electricity needs (DEC n.d.). As wind farms spread across the State, communities are debating the benefits and costs of wind development. In general, the public is highly supportive of wind power, but concerns remain about the potential impacts of wind development on communities, including the effects of turbine-related noise on those living near the structures. Indeed, several communities around the state have passed, or are considering, relatively strict noise regulations in response to proposed wind farms. These local policy responses will shape the future of wind development in New York State.

This paper summarizes existing research on wind turbine noise and community response, with the goal of clarifying what is known and what is still unknown. It also describes the results of a study conducted at a 126-megawatt (MW) wind park in Wethersfield, New York. The study monitored turbine noise levels within the park and surveyed residents who live in close proximity to gauge their reactions to the wind farm. The study's results should help state and local officials better understand how turbine noise may affect communities, and the origin and nature of noise complaints.

The results of the Wethersfield study indicate that sound levels in some areas of the park have the potential to exceed the noise guidelines outlined by organizations such as the World Health Organization (WHO) and the U.S. Environmental Protection Agency (EPA). Despite this, the large majority of the 62 residents surveyed (over 90%) were satisfied or very satisfied with their living environment. Considering turbine-related noise in particular, the majority of sampled residents did not notice the wind turbine noise, or noticed it but were not annoyed by it when outside and inside (55% outside; 68% inside). Most surveyed residents (about 80%) were not concerned about negative health impacts associated with living near the turbines, but about a quarter of the participants said they had experienced sleep disturbances and about 9% of the surveyed residents had issued a noise complaint in response to the wind turbines. It appears from this study that wind turbine noise may negatively affect a portion of residents living near the turbines, and that these effects range from simple annoyance to other health impacts like sleep disturbance and headaches. Research suggests that such impacts can be minimized through careful siting processes.

*Photo (above) Wind Farm in Upstate New York*

*Cover: Wethersfield Wind Park, photo courtesy of NYSERDA*

## What is Noise and How is it Measured?

Noise is typically defined as unwanted sound, and sound is generated by fluctuations in air pressure that are noticeable to the human ear (Berglund et al., 1999). Sound pressure level refers to the loudness of these disturbances and because the human ear can register a wide range of sound pressures, it is measured on a logarithmic scale in decibel (dB) units. People with normal hearing can detect sound at zero dB and most would experience pain if exposed to sound at 140 dB. Any increase of 3–5 dB is clearly noticeable, and most people perceive a volume increase of 10 dB as being twice as loud (Alberts 2006).

**Table 1. Environmental sounds and their approximate decibel levels at a few feet away**

Sound	Decibel Level
Whisper	30dB
Refrigerator hum	40 dB
Normal conversation	50-60 dB
New York subway station	90 dB

While decibels are a common method of measuring sound, we do not always perceive sounds with the same decibel levels as equally loud. For this reason, sounds are also described by their frequency, a reference to the number of vibrations per second in the air. Frequency is measured in Hertz (Hz) and the audible range is from 20 to 20,000 Hz. Sound in the range of about 20–200 Hz is considered to be low frequency sound, and anything lower than 20Hz is labeled as either infrasound or infrasonic sound. Natural sources of infrasound include wind, rivers, waterfalls; the most common artificial source is vehicular traffic.

People are not equally sensitive to all sound frequencies. To account for this, the decibel scale is adjusted by frequency to better approximate how people experience sound. The A-weighted scale (dBA) de-emphasizes the very high and very low frequency components of a sound and is typically used for assessing community noise and setting exposure limits (Alberts 2006). The measurement LAeq (sometimes expressed as LAeq dBA) is used to describe sound levels that vary over time, resulting in a single measurement that can be thought of as a type of average for the measurement period.

## What Kind of Noise Do Wind Turbines Generate and How Loud Are They?

Wind turbines generate both mechanical noise, caused by a turbine’s internal gears and controls, and aerodynamic noise, caused by the blades passing through the air. Mechanical noise on utility-scale turbines is minimized by the use of insulation, and while it can produce some minor tones, it is not the main source of noise from turbines (Hessler and Hessler 2011).

Most of the sound from wind turbines comes from the aerodynamic sound produced by the blades moving through the air. As a turbine blade moves downward, it generates higher levels of sound, thus accounting for the “swishing,” “whoosh,” or pulsing sounds often associated with modern turbines (Alberts 2006; Hessler and Hessler 2011). The rise in sound level occurs about once every second for a typical three-bladed turbine. People perceive this kind of rhythmic noise (also referred to as “amplitude modulation”) more easily and therefore may be more annoyed than they would be by constant noise of the same or higher sound level (Pedersen and Waye 2007).

Aerodynamic sound from turbines occurs at all frequencies, from infrasound and low frequency, to frequencies in the normal audible range (Colby et al., 2009). Modern wind turbines (typically generating anywhere from 1.5 to 3 MW of electricity) produce mostly mid-frequency aerodynamic noise; studies have shown that modern wind turbines do not produce high levels of perceptible infrasound and low frequency sound (Colby et al., 2009; Jakobsen 2005).



*Wethersfield Wind Park, photo courtesy of NYSERDA*

The actual level of turbine-related noise is affected by a variety of factors, including:

- Size and make of turbines.
- Number of turbines.
- Maintenance condition of turbines.
- Distance from the turbines: Sound levels decrease with distance.
- Direction of the wind: Sound levels from the turbines are higher downwind and lower upwind.
- Wind speed: Generally, higher wind speeds produce greater sound pressure levels.
- Atmospheric conditions: Certain conditions may attenuate noise or fail to do so. For example, noise may travel further in calm night air.
- Topography of the land: Hills, ground cover, barriers, and other landscape features affect noise levels.
- Outside vs. inside: Noise levels from turbines are usually lower when inside a building than outside.

Modern wind turbines are designed to keep noise levels at or below 45dB at distances of 350 meters (1,000 feet), and noise levels should drop to 35–40dB at 1,000 meters, a bit over half a mile (Cummings n.d.).



*Photo courtesy of Dutch Hill Wind Farm*

## When Are People Annoyed by Turbine-Related Noise and Why?

Research on community reaction to turbine-related noise is not extensive, but a handful of studies in Europe and the United States provide some insight into the levels of annoyance experienced by those living near turbines and the sources of their annoyance. A recent review by Hessler and Hessler (2011) of eight operational wind turbine sites in the United States concluded that the “vast majority of people had apparently no objections to noise, even people who consistently experienced turbine sound levels in the 45 to 50 dBA range.” In the Wethersfield study, for which findings are reported in more detail below, greater numbers of people reported some level of annoyance by the turbine noise when outside and inside. In general, community studies indicate that a minority of people living near turbines may be annoyed by their sound, while some individuals are profoundly disturbed.

The extent to which people are annoyed by environmental sound is determined in part by the level and duration of noise exposure. Studies in the Netherlands and Sweden have modeled wind turbine noise and levels of annoyance by surveying residents who live in proximity to turbines. They found a statistically significant relationship between A-weighted sound pressure levels and annoyance (Pedersen and Waye 2004, 2007; Pedersen et al., 2009). Using these data, the researchers concluded that 5% of people were annoyed at noise levels between 35–40 dBA and 18 percent were annoyed at 40–45dBA.

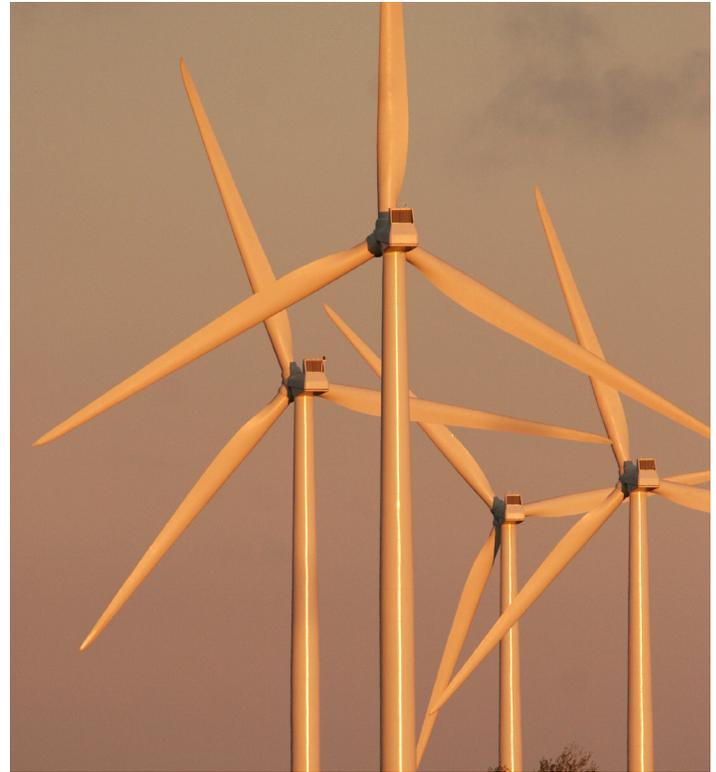
While it seems common sense that louder noises will annoy more people, it is not always easy to predict how many people will be annoyed by wind turbine noise and at what levels of sound. Annoyance is a subjective and individualized reaction to sound, so a number of factors (besides actual noise levels) affect whether people living near wind turbines will be annoyed by the noise. These factors are summarized in Table 2.

**Table 2. Potential factors affecting level of annoyance with turbine-related noise**

Potential Factors
Sound pressure level of noise
Sound frequency
Individual sensitivity
Existing background (ambient) noise levels
Time of day
Characteristics of noise
Novelty of noise source
Visibility of wind turbines
General views on wind farms
Economic and community benefits associated with wind farm

It is important to recognize that certain individuals are more sensitive to noise than others, and this can account for some of the differences in reported annoyance levels. The Wethersfield study found a statistically significant relationship between being sensitive to noise in general and being annoyed with wind turbine noise inside and outside, a finding that is to be expected.

Existing background noise levels and expectations regarding noise should also affect noise annoyance. Rural areas, for example, tend to have less background noise than urban and suburban areas, and people may associate rural areas with a relative lack of artificial sound. Some European studies of turbine-related noise have found annoyance levels higher in rural areas (Pedersen and Wayne 2007), while others have found that annoyance was highest among people living in built-up areas such as small towns (Pedersen et al., 2009). What seems clear is that high levels of ambient sound from other environmental and industrial noise may mask turbine-related noise, leading to less turbine-related noise annoyance. There is some indication that personal expectations about one’s living environment also affect response to turbine noise (Pedersen and Wayne 2007). If people value their residential environment because it offers peace and quiet, then they may be more annoyed by artificial sources of noise.



*Wind Farm in Upstate New York*

Noise levels and expectations also vary by time of day. Studies of turbine-related noise have found that the largest differential between background noise and turbine-related sound often occurs during nighttime hours (Hessler and Hessler 2011). Low levels of ambient noise enhance the perception of turbine noise, potentially increasing annoyance levels. Moreover, many people expect noise levels to drop off during the night, and may be annoyed when noise interferes with their sleep. In short, noise annoyance is more likely during evening and nighttime hours than during the day, implying that design and regulatory goals should consider nighttime sound levels to determine limits (Hessler and Hessler 2011).

As suggested earlier, the particular characteristics of a noise may affect the level of noise annoyance. Unpredictable and uneven sound may increase annoyance levels. Because turbine noise is amplitude modulated, and therefore more noticeable, people may be more annoyed by turbine-related noise than they would by other sources. In fact, one study (Pedersen et al., 2009) found that people were more annoyed by wind turbine noise than by transportation and industrial noise at similar levels, and suggested that this may be due in part to its rhythmic and uneven quality.



*Wethersfield Wind Park, photo courtesy of NYSERDA*

It is possible that some people experience more annoyance when a noise source is new and unfamiliar. For many communities, wind turbines are a new source of environmental noise (Pedersen et al., 2009). Research on wind turbine noise and annoyance, however, has not examined changes in annoyance over time, so we do not know whether people become habituated to the noise over time and therefore, less annoyed by it.

Interestingly, some studies show that annoyance with turbine-related noise is also affected by non-acoustic factors. In particular, Pedersen and her colleagues (2009) found a strong correlation between noise annoyance and negative feelings about the visual and aesthetic impacts of wind turbines on the landscape. In another study, seeing one or more turbines increased the odds of perceiving turbine sound and being annoyed by it (Pedersen and Waye 2007). This kind of visual effect was not found in the Wethersfield study, however. There was no correlation between the number of turbines survey respondents could see and annoyance levels, although it is worth mentioning that all respondents could see at least one turbine from their homes. However, there was a statistically significant correlation between survey respondents' general opinion on wind turbines and their opinion on whether the turbines altered the landscape. Residents who felt more negative toward how turbines looked in the landscape were more likely to negatively assess wind turbines in general.

Notably, the individual economic and community benefits associated with a wind park may influence levels of annoyance with wind turbines, including noise annoyance. The Netherlands study (Pedersen et al., 2009) showed that people who benefitted economically from the wind turbines had a slightly decreased risk of being annoyed by turbine noise. As described in more detail below, those individuals in the Wethersfield study who benefitted economically from the wind park were more likely to be satisfied with their living environment, but not necessarily less annoyed by wind turbine noise. It appears that direct economic benefits can have a positive impact on residents living near wind turbines, either by increasing their general satisfaction with their living environment and/or decreasing their noise annoyance.

## Does Turbine-Related Noise Impact People's Health?

One of the controversies surrounding wind energy is whether wind turbine noise has adverse health effects on those living near turbines. In the popular press and on various Internet sites, a variety of health effects are attributed to wind turbine noise, including so-called "wind turbine syndrome," a set of symptoms that allegedly include things like sleep problems, headaches, dizziness, nausea, anxiety, memory loss and a host of other maladies (Pierpoint 2009). At this time, there is no credible scientific evidence for "wind turbine syndrome". According to an expert panel review commissioned by the American Wind Energy Association and the Canadian Wind Energy Association, studies designed to investigate this proposed syndrome are unlikely to be done due to the weaknesses of the basic hypotheses (Colby et al., 2009).

While the medical community does not recognize "wind turbine syndrome" as a legitimate medical diagnosis, some of the listed symptoms can be associated with noise exposure more generally. It is important to note that at this time, experts do not believe that the levels of noise produced by wind turbines are high enough to cause hearing loss, speech interference, heart disease, a weakened immune system or other adverse reactions to excessive noise exposure (Alberts 2006; Colby et al., 2009). Turbine-related noise may, however, cause sleep disturbance. About one-quarter of participants in the Wethersfield study reported sleep disturbance from the wind turbines. According to the WHO, noise exposure can impact sleep by increasing the time needed to fall asleep, by altering the sleep cycle, and by decreasing the quality of REM sleep (Alberts 2006). In turn, poor sleep can lead to a number of physical and psychological problems including increased blood pressure, fatigue, depressed mood, and decreased performance (Berglund et al., 1999).

As already noted, people living near modern turbines are not exposed to high levels of infrasound and low frequency sound, and the typical levels of exposure would not cause any adverse health effects. According to several experts, “wind turbines do not produce significant or even remotely problematic levels of low frequency noise and a link between health complaints and turbine noise has only been asserted based on what is essentially anecdotal evidence without any valid epidemiological studies or scientific proof of any kind” (Hessler and Hessler 2011; see also Colby et al., 2009). In a recent article, researchers found no link between actual noise levels from small-scale wind turbines and individuals’ reported adverse health symptoms (Taylor et al., 2013). Instead, people’s perception of turbine-related noise was associated with increased symptoms, but this effect occurred only for those high in negative oriented personality traits (Taylor et al., 2013).

A minority of surveyed residents living near the wind park in Wethersfield were concerned about the health effects associated with living near the turbines. It is important to note that only two survey respondents out of 62 sought medical attention as a result of their symptoms, which may indicate a quite low occurrence of serious health complaints of those living in proximity to wind turbines.

## Noise Standards and Guidelines

Noise is regulated by many countries in recognition of the fact that community noise impacts people’s quality of life. The WHO has issued community noise guidelines to help policymakers establish design targets for industrial facilities and transportation projects. Moreover, many countries, U.S. states, regulatory bodies, and experts have established standards, and issued recommendations for noise generally and wind turbine noise in particular. These are summarized in Table 3.

The U.S. federal government does not directly regulate environmental noise (except for major transportation systems), but the agency issued a landmark report in the 1970s suggesting guidelines for all environmental noises in residential areas (Hessler and Hessler 2011). This report is often referred to as the “Levels” document and it included a recommendation of 45 dBA at night as adequate for preventing sleep interference. About a dozen U.S. states have issued noise regulations of some variety, and most allow a higher limit for daytime hours than nighttime hours.

**Table 3. Noise guidelines and standards for typical wind turbine projects**

Source of Standard	Effective Limits	Comments
World Health Organization	40 dBA nighttime, outside of residences	Ideal design goal to avoid sleep disturbance
Consensus of international limits specific to wind turbine noise	40dBA nighttime; 45dBA daytime	Arithmetic average of all standards
U.S. Environmental Protection Agency	45dBA nighttime outside	To avoid sleep interference
U.S. state standards*	47.7 dBA nighttime	Arithmetic average of nighttime noise regulations of selected U.S. states
New York State	38 to 40 dBA nighttime	The regulation specifies that noise levels cannot be higher than 5 dBA above the ambient sound level
Wethersfield, New York	50dBA limit	Local standard in study area for wind development; noise may not exceed this for any period of time
Hessler and Hessler (2011)	45dBA day and night	Recommendation for regulatory limit; design goal is 40dBA during nighttime hours

Source: Hessler and Hessler 2011

\* Hessler and Hessler (2011) list 14 states with codified regulations, including the District of Columbia.

The states are: MD, DE, IL, CT, MN, NJ, OR, CO, ME, MA, WA, CA, and NY.



*Wind Farm in Upstate New York*

New York is one of three states (Massachusetts and California being the other two) that sets noise limits based on ambient sound levels. This approach uses existing background sound levels to calculate acceptable noise limits, a better approach than setting absolute limits because it takes into account different geographies and environments. A typical rural environment, for example, has lower ambient sound levels than an urban environment. The New York State regulation limits any increase in sound levels to five dBA above existing background levels. Using a generic background level of 33 dBA for rural areas, Hessler and Hessler (2011) estimate that the design level for a new wind project would range from 38 to 40 dBA in rural areas where wind projects are typically sited.

Numerous counties and localities in the U.S. regulate community noise and many have done so in response to existing or proposed wind farms. According to Hessler and Hessler (2011), an absolute limit of 50 dBA is commonly used. These authors have identified 45 dBA for as a reasonable level that could minimize

annoyance while not constraining development too greatly. For these authors, 40 dBA would be an appropriate design goal for nighttime levels, but it should not be used as a firm regulatory limit because it may unduly restrict wind projects without delivering substantial decreases in annoyance. These levels represent a mean, long-term value and not a maximum value. Because wind turbine noise naturally fluctuates, it may exceed the limits for brief periods, thereby making absolute regulatory limits somewhat impractical.

Several communities around New York State have considered or are considering strengthening their noise ordinances, presumably to prevent wind farms from locating in their communities. For example, Cape Vincent, NY, proposed a new zoning law that limited daytime noise to 45 dBA, evening noise to 40 dBA, and nighttime noise levels to 35 dBA. These levels are lower than most of the international and existing state standards, and would restrict wind development more than other standards.

# Wind Turbine Noise in Wethersfield, NY and Community Response

The study of wind turbine-related noise in Wethersfield is the first comprehensive evaluation of its kind in the state. The study's results should add to the discussions taking place around the state about wind development, in part, because the site is representative of potential development sites and wind projects in central New York State. The 126-MW park consists of 84 1.5-MW turbines spanning about 19 square miles of rural farmland.

The Wethersfield study generated data on sound pressure levels and frequencies, including low frequency and infrasound, at an operating wind facility. Monitoring was conducted at two background sites and five locations in the wind park over three distinct seasons. In addition, 62 individuals were asked about their experience living in proximity to the wind turbines. The study design is an improvement over previous studies in several ways. To begin, sound monitoring was conducted at differing distances from wind turbines and during different meteorological and seasonal conditions, providing a more comprehensive picture of noise exposure. Sound levels at several locations that were not impacted by wind turbines were also measured to enable a qualitative comparison between pre- and post-development noise. Finally, short-term sound measurements were taken at residents' houses when the community survey was conducted. As a result, the study was able to seek correlations between short-term sound levels with residents' annoyance levels and self-reported health effects.

## Noise Levels and Annoyance

The measured sound levels within the park were higher than the measured background sound levels, indicating that the wind turbines increased the level of noise exposure of those living in proximity to the turbines. At a wind speed of seven meters per second (ten meters above the ground), the background sound pressure levels ranged from a low of 41.2 dBA to a high of 47.9 dBA, depending on the season and weather conditions. Sound pressure levels within the wind park were higher on average, ranging from a low of 44.8 dBA to a high of 51.6 dBA, depending on the location of the monitoring, the season, and weather conditions.

To provide a more specific example, consider the difference between background sound levels and noise levels at one of



*Wind Farm in Upstate New York*

the monitored locations within the park during August 2011 (again, at wind speeds of seven meters/second). The measured ambient sound level was 42.3 dBA; at monitoring location “C” (more than 1,000 feet from the nearest wind turbine), the sound pressure level was 48.2 dBA—an increase of about six decibels. The greatest difference between background sound levels and monitored sound levels within the park was at location C during the February 2012 monitoring. In this case, the difference between the two was a little more than ten dB—41.2 dBA compared to 51.6 dBA. As noted above, most people experience an increase of 10 dB to be about twice as loud.

More generally, the sound pressure levels within the park, as measured across the three seasonal monitoring campaigns and five monitoring stations, occasionally exceeded the Wethersfield turbine noise limit of 50 dBA measured as an LAeq. During the winter campaign at wind speeds near seven m/s, the speed at which the maximum sound power is generated by these turbines, the measured LAeq ten-minute interval sound pressure levels ranged from 47.0 dBA to 53.6 dBA. As wind speeds reached 12 m/s during the winter campaign, the campaign with the strongest winds, the measured LAeq ten-minute interval sound pressures ranged from 53.7 dBA to 54.3 dBA.

Nighttime sound levels may be of particular interest because of their potential to disturb residents' sleep. Nighttime LAeq sound levels measured at location “D” during the winter campaign ranged from a low of 28.4 dBA at 0.4 m/s to a high of 56.1 dBA at 9.8 m/s. As wind speeds increased, sound levels did as well. At wind speeds of three meters per second and higher, calculated sound pressure levels were predicted to be above the WHO's recommended nighttime limit of 40 dBA.

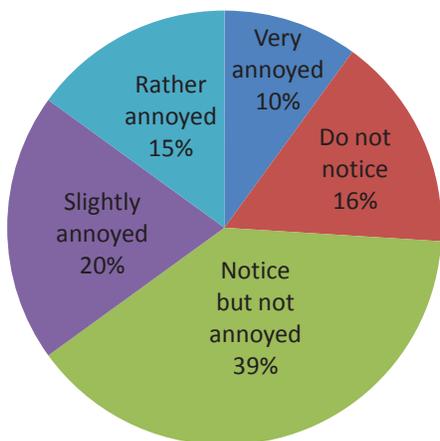
Short-term sound monitoring was conducted within and outside people’s homes when researchers were conducting surveys. These data give us an idea of the levels of noise residents living within the park experience in their day-to-day lives. It is important to note that these measurements include all noises in the environment, including wind turbine-related noise. While residents were asked to turn off their electronics during the monitoring, some indoor noise sources (e.g., refrigerators and heating systems) were present and therefore measured. On average, the sound level outdoors was 45 dBA and the sound level indoors was 47 dBA during the short-term monitoring. These levels are below the levels that the WHO predicts would cause moderate annoyance and are below the Wethersfield noise limit, but it is important to note that these numbers represent short-term averages of spot measurements. At times during the monitoring, noise levels rose quite a bit higher. In the surveys themselves, a minority of the study participants were annoyed by the turbine noise outside and inside their homes. The sounds coming from the turbines were described in various ways, including “pulsing/throbbing,” “whistling,” “swishing,” and “scratching/squeaking.” Figure 1 summarizes the participants’ responses to the question of whether and how they were affected by turbine noise outside of their homes; Figure 2 reports the same data for inside the home.

An important indication of the degree of annoyance is the rate at which residents issue noise complaints in response to the turbine noise. Issuing a noise complaint takes effort, and we can assume

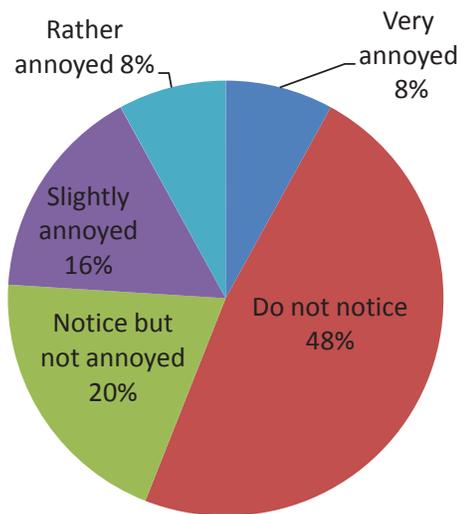
that only the most annoyed individuals would take the time to lodge a formal complaint. In Wethersfield, the complaint rate was relatively low. Of the 62 individuals surveyed, six individuals (representing five households) had issued noise complaints in response to wind turbine noise. This represents a complaint rate of 8.1% if calculated by home, and a 9.6% rate if calculated per person.

The levels of reported annoyance in the survey were not associated with the short-term sound level measurements collected at the time of the surveys. It seems likely that long-term noise levels are more relevant to annoyance than short, one-time samples. Consequently, we may have found different results if long-term monitoring at homes had been conducted and these measurements had been tested against reported levels of annoyance.

For the surveyed residents in Wethersfield, levels of noise annoyance were statistically correlated with an individual’s general opinion on wind turbines, their opinion on whether the turbines altered the landscape, their concern over health effects associated with the turbines, and their sensitivity to noise in general. This suggests that people who felt negatively about the wind turbines and were worried about their aesthetic and health impacts were also more likely to be annoyed by turbine noise. Those who felt more positively toward the turbines and were not as concerned by the aesthetic and health impacts were less likely to be annoyed by the noise.



**Figure 1. Levels of reported annoyance to wind turbine noise outside**



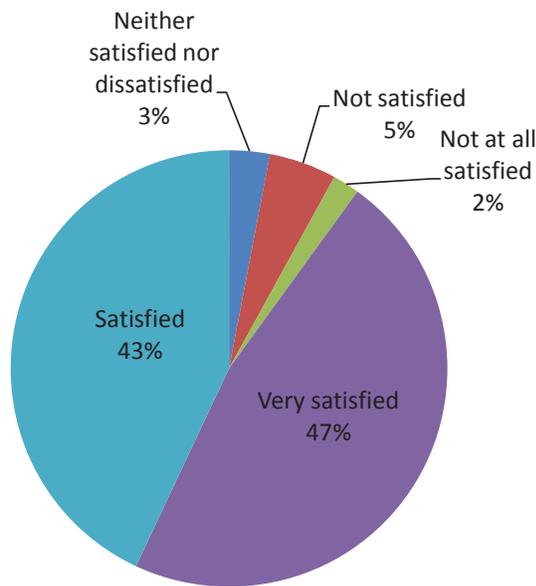
**Figure 2. Levels of reported annoyance to wind turbine noise inside**

## Satisfaction with the Living Environment and General Opinion on Wind Turbines

In addition to gauging residents' levels of annoyance with turbine noise, the community survey asked about their general opinion on wind turbines and satisfaction with their overall living environment. This information allowed a broader assessment of the community's response to the wind park, beyond the more narrow focus of noise annoyance.

Overall, the surveyed residents were overwhelmingly satisfied with their living environment, with 91% of the residents reporting they were either "very satisfied" or "satisfied." The results are summarized in Figure 3.

Of those dissatisfied with their living environment (a total of four individuals), three of these listed wind turbines as being the cause of their dissatisfaction. A greater number of those surveyed (18 individuals out of 62) indicated that the presence of the turbines represented a change for the worse in their environment. Some participants in the survey listed specific impacts that they associated with the turbines, including: deteriorated roads, an increase in traffic, static on landline phones, shadow flicker from the turbines, decreased property values, and negative aesthetic impacts on the landscape.

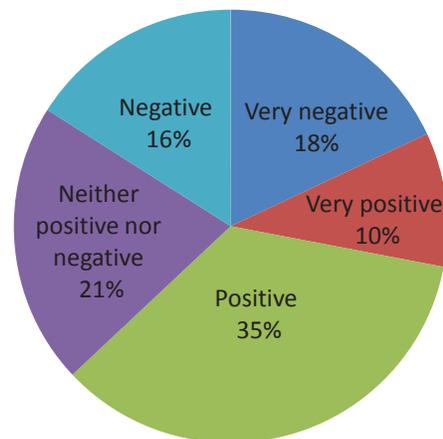


**Figure 3. Surveyed residents' satisfaction with their living environment**

On the other hand, 23 individuals indicated that the wind park had improved their living environment in some way. More specifically, they cited various individual and community benefits associated with the wind park. For example, 12 individuals appreciated the reduced (or no) town taxes; nine individuals cited improved roads; four were grateful for free garbage service; three noted a direct financial gain from the turbines; and two thought that the wind park had created more jobs in the community. As already noted, those who had some kind of relationship with the energy company were more likely to be satisfied with their living environment. In short, the arrival of the wind park brought with it some welcome benefits to individuals, households, and the community at large, which about a third of survey participants cited as improvements to their living environment.

The participating residents were somewhat split when asked about their general opinion on the wind turbines. More respondents felt "very positive" or "positive" about the turbines than felt negative toward them. Figure 4 provides the specific results from the survey.

It is worth noting that an individual's general opinion on the turbines was highly correlated with their opinion on how the turbines altered the landscape, suggesting that the aesthetics of wind turbines factor into people's attitudes toward them. Those who see the turbines as a blight on the landscape are less likely to feel positive toward them.

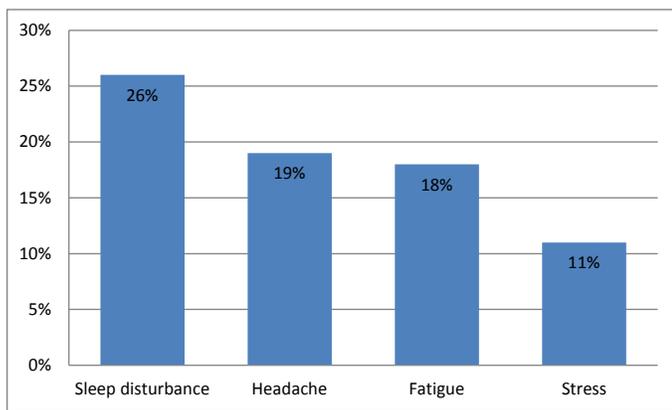


**Figure 4. Surveyed residents' general opinion on wind turbines**

# Self-Reported Health Effects

Participants in the survey were asked about their health concerns related to living near the turbines. The large majority (80%) were not concerned about potential health effects. However, 12 respondents (representing about 20% of the survey participants) were concerned about health effects, and residents listed symptoms like sleep disturbance, headaches, fatigue, and stress. About the same number felt that their symptoms were related to the turbines and that the frequency of their symptoms had increased since the turbines had started operating. However, only two individuals had visited a doctor due to their symptoms. Figure 5 shows the number of surveyed residents who reported health effects.

People who were concerned about potential health impacts had a more negative view of wind turbines generally and their impact on the landscape, and were more sensitive to noise in general. However, there was no statistically significant correlation between noise levels inside and outside (as measured during the short-term monitoring) and an individual’s level of concern about health effects.



**Figure 5. Self-reported health effects by residents living near turbines**

# Public Policy Implications

This research has provided valuable data on the levels of sound produced by a typical wind park in central New York State and a community’s reaction to the wind turbines and turbine-related noise. As wind projects spread around New York State, policymakers and citizens are seeking studies that accurately measure wind turbine sound levels and that compare them to existing background noise. Much of the previous research on wind turbine noise estimates noise based on turbine manufacturers’ specifications rather than measuring actual sound levels within a wind park. Such a method may not inspire confidence in residents who question whether turbine manufacturers are underestimating actual sound levels. This study can therefore be used as a reference for policymakers and community members who want to understand how much noise turbines produce in different weather conditions and across the seasons.

Another benefit of this study is derived from its survey of residents living within the park. This survey was designed to gauge residents’ reaction to living near the turbines and whether they attributed any negative health effects to the turbine noise. This survey information should help planners, policymakers, and project leaders better understand the nature and origin of noise complaints, how turbine noise may affect a community, and how they can work more effectively to minimize negative impacts.

The study confirms, unsurprisingly, that operating wind turbines tend to increase noise levels above existing background sounds in rural areas. The levels of noise within the Wethersfield wind park were generally within the recommended limits as expressed by various international organizations, government agencies, independent experts, and New York State. However, noise levels sometimes exceeded these limits when wind speeds were high. This could help explain the fact that about a quarter of the surveyed residents complained about sleep disturbance.

It is important to note that there was a good deal of variation in turbine noise levels, with sound levels fluctuating above and below the means depending on time of year, weather conditions, wind speeds, and other factors. Therefore, to get an accurate picture of overall sound levels in an existing wind park, monitoring and measurements must be done over longer periods of time and during different atmospheric conditions.

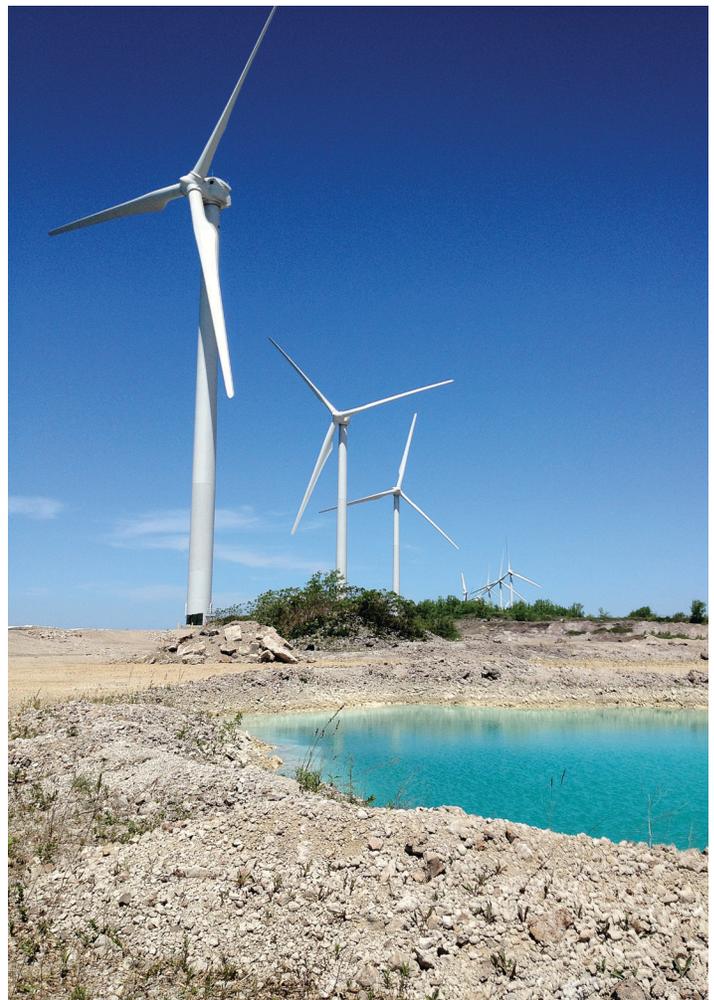
The variation in sound levels in the Wethersfield Park also suggests that noise ordinances, which specify maximum sound limits, may unduly restrict wind development. A hypothetical regulation that prohibits any source of environmental noise from exceeding 45 dBA at any time, for example, may limit wind development because noise levels will sometimes exceed this level for brief periods of time. Most experts also recommend regulating based on existing ambient noise levels in order to account for differences in how people experience sound in urban versus rural environments.

As with any public policy, the potential benefits of noise and zoning ordinances must be weighed against their potential costs. A highly restrictive noise ordinance could prevent a wind development project that would benefit the community while providing little in the way of decreased annoyance. As the Wethersfield study shows, many residents felt that the wind park had improved their living environment in some way, and the majority of residents were not annoyed by the wind turbine noise. Perhaps more significant is the overwhelming number of residents who felt positive about their living environment.

On the other hand, wind parks must be thoughtfully designed to minimize negative impacts, including noise annoyance and potential health effects. Public policies, along with industry standards and practices, can help avoid conflict and complaints, and protect public health. Ideally, turbines should be sited at adequate distances from non-participating residences so that day and nighttime noise levels stay within the general limits recommended by the WHO, New York State, and other regulatory bodies. As Hessler and Hessler (2011) recognize, “a reduction in the predicted sound levels at residences, can almost always be realized—as long as it is early enough in the design process that significant changes can be made.” Noise impacts should therefore be evaluated early in the design process so that changes can be made to the basic layout of a wind park. For existing wind parks, or for plans that cannot be altered, some noise reductions can be made by selective employment of “low noise operating modes,” which can lower decibel levels by up to five dB (Hessler and Hessler 2011).

Even with careful siting and well-crafted noise regulations, some individuals will be annoyed by turbine noise. It is therefore impractical for policymakers to set complete elimination of noise annoyance as a goal. Rather, efforts should be made to fully and accurately inform residents about potential noise impacts, to respond to community concerns, and minimize noise levels especially during evening and nighttime hours.

This study also indicates that individuals and communities near wind parks should realize some sort of economic and/or community benefits as a way to compensate for any negative impacts from the turbines. In Wethersfield, such benefits increased an individual’s satisfaction with their living environment, a laudable goal for public policy.



*Photo courtesy of Steel Winds II*

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