SUMMARY OF WIND TURBINE NOISE

By Carolyn Weed for the Centerville Township Commercial Wind Ordinance Committee
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The dictionary definition of noise is any sound that is undesired or interferes with one's hearing of something.

Wind turbine noise is related to aerodynamic sounds produced by air flow over blades and mechanical sounds from the interaction of turbine components such as gears and brakes. Most of the noise produced by newer upwind turbines is broadband sound over a range of frequencies caused by the interaction of wind turbine blades with atmospheric turbulence. This noise is characterized as a "swishing" or "whooshing" sound that is modulated and varies in amplitude. In a Swedish study, this sound has been found to be annoying at sound pressure levels above 35 dB(A). (See Pedersen report.) Wind turbines can also generate tonal sound at discrete frequencies caused by "components such as meshing gears, non-aerodynamic instabilities interacting with a rotor blade surface, or unstable flows over holes or slits or a blunt trailing edge." (See Wind Turbine Acoustic Noise by Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts at Amherst.)

Wind turbine noise varies with terrain, atmospheric conditions, wind speed and direction. Sound volume decreases quickly upwind, but, downwind, beyond about 300 meters from the source, sound volume can actually increase for some distance before decreasing. This effect, known as ground effect, results from the fact that sound curves back toward the earth, which results in interference downwind between direct and reflected sound waves. High wind speeds can mask wind turbine sound, but hilly or mountainous terrain can focus noise and/or channel it to distant residences. Nuisance noise is more perceptible at low wind-turbine cut-in wind speeds when the wind is insufficient to mask blade swishing. The greatest noise nuisance often occurs when wind speeds are low at a residence and high at the source. These conditions can occur when a residence has a wind-sheltered location, and they can occur at night when winds are high at rotor heights but low near the ground.

Low frequency components of wind turbine noise (which is mainly broadband noise) will travel farther than higher frequency components. Low frequency sound and infrasound (2-100 Hz) are perceived as a mixture of auditory and/or tactile sensations. Light frame construction (i.e. typical house construction) will not block or attenuate low frequency components as effectively as higher frequency components, so low frequency noise can cause problems inside buildings where the sound resonates and is amplified.

As noted in the Otsego County White Papers, the effects of noise can range from annoyance and nuisance to interference with sleep, learning and speech. High levels of noise can cause physiological damage, and low frequency noise can cause stress, dizziness and nausea, headaches and cardio-vascular problems. Biomedical engineers and doctors in Europe have examined wind turbine noise data and have made recommendations to protect residents by government regulations that include more accurate measurement of noise at low frequencies.

There is compelling evidence that noise problems have occurred with wind turbine installations. Otsego County White Papers refer to the noise problems associated with wind turbines in Kewaunee County, Wisconsin. After 22 turbines installed by Wisconsin Public Service Commission (WPSC) and Madison Gas and Electric generated many noise complaints, WPSC conducted a noise study showing that the turbines added 5-20 dB(A) to the ambient sound. The Lincoln Township Supervisor, Arlin Monfils, verified these noise problems in my phone conversation with him on March 8, 2006. He specifically mentioned headaches and frequent nosebleeds, and he told me that the Public Utility had resolved the problem by buying properties and by agreeing to shut down turbines at low wind speeds. Mark has spoken with Kelly Alexander about his family's experiences, including the noise problems suffered by his parents notwithstanding their hearing loss. (Low frequency noise can be particularly annoying for persons suffering from hearing loss and persons wearing hearing aids. See Shawano's ordinance.) In another story covered by Canadian Broadcasting and the Canadian press earlier this year, Daniel d'Entremont, a Nova Scotia fisherman who lives 1200 feet from a public utility wind turbine, finally moved his six children out of his house and into the home of his in-laws. According to the Hamilton Spectator, his family couldn't sleep, his children were constantly tired and suffering headaches, and nobody in the house could concentrate. In a report issued this March, the French Academy of Medicine recommended wind turbines be considered an industrial use and identified noise as a safety issue.

There also is evidence of inaccuracies associated with the assessment and modeling of wind turbine sound. In the Journal of Sound and Vibration, Dutch physicist, G.P. van den Berg, summarizes conclusions from his thesis study of the Rhede Wind Park in northwestern Germany. The park was modeled to be within the 45 dB(A) German regulatory limit. Measurements showed that, in fact, wind speeds at hub heights at night were 2.6 times higher than expected using reference wind speeds, resulting in high rotational speeds that produced impulsive noise up to 15 dB louder than anticipated. Noise at ground level, where wind speeds were lower, caused strong reactions from residents at distances of 500 meters or more and even caused annoyance in residents at distances of 1900 meters.

In addition, the commonly used A-weighted sound pressure scale, which uses the notation dB(A), adjusts sound pressure at different frequencies to reflect the way people perceive sound and does not adequately describe annoyance caused by noise dominated by low frequencies and infrasound. Low frequency noises are better described using the C-weighted scale, dB(C), which more closely resembles sound pressure, and infrasound is better described using the G-weighted scale, dB(G). However, because international noise standards are commonly expressed on the A scale, engineers specify non adjusted decibel (dB) limits for ranges of frequencies, and these can then be converted to the A scale. Annex A of IEC (International Electrotechnical Commission) Standard 61400-11: Wind Turbine Generator Systems — Part 11 Acoustic Measurement Techniques notes the following:

> Low Frequency Noise— A disturbance can be caused by low-frequency noise with frequencies in the range from 20 to 100Hz. The annoyance caused by noise dominated by low frequencies is often not adequately described by the A-weighted sound pressure level, with the result that nuisance of such a noise may be underestimated if assessed using only an LAeq value. It may be possible to decide whether the noise emission can be characterized as having a low-frequency component. This is likely to be the case if the difference between the A and C-weighted sound pressure levels exceeds approximately 20dB.

Wind turbine noise issues are controversial. Not only does the sensitivity to the loudness and frequency of sound vary among individuals, but also the perception of sound as noise is affected by subjective factors ranging from mood to vested interest. Measurement and regulation of wind turbine noise is complex, as evidenced by the Shawano ordinance and the Environmental Noise Guidelines issued by the Environmental Protection Authority of South Australia.

While preparing these materials, I have been in email contact with Daniel Alberts, the engineer from Lawrence Technological University, who made presentations on noise to the Michigan Wind Working Group that worked on the Michigan Siting Guidelines for Wind Energy Systems. Because of the substantial differences I found between Michigan standards and international standards, I spoke with him at length by phone on the evening of June 26, 2006. He emphasized several important points with respect to developing adequate noise regulations:

- Michigan guidelines reflect industry standards instead of community noise guidelines because the state is looking for new industry.
- Noise is probably the most complex area to regulate. A simple set of standards may not be adequate to protect residents. Predicting and modeling noise, especially in hilly terrain, is difficult and needs to be regulated, as does the measurement of sound as well as ongoing compliance and enforcement of the noise regulations. Ambiguity leads to litigation.
- It is likely that township wind noise regulations will not be adequate if they have not been reviewed by an acoustical engineer.

We should have an acoustical engineer who is an expert on community noise help us refine our noise regulations.

Sources include ordinances being considered by the Wind Ordinance Committee of the Centerville Township Planning Commission and the following:

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