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Re: Proposed Machias wind energy facilities siting law

Dear Mr. Knoer:

As you requested, on behalf of Concerned Citizens of Cattaraugus County, Inc., (CCCC), enclosed please find a number of reports and studies in support of the following assertions I made in an email letter to you: "wind farm noise is distinctively annoying, results in chronic sleep disturbance for a significant fraction of those who live within a mile away (these are typically 25 sq. mi. project areas[1]), and chronic sleep disturbance results in serious health effects." The enclosures are listed at the end of this letter.

Research into wind turbine noise is relatively new and complex. Accordingly, I am offering an executive summary of the enclosures under the following headings:

1. wind farm noise is distinctively annoying;

2. wind farm noise results in chronic sleep disturbance for a significant number of those who live within a mile away, and chronic sleep disturbance, in turn, results in serious health effects.

In addition, I will discuss briefly:

3. Horizon's background noise assessment in Machias.

In addition, CCCC member Bradley Parker requested a study of background sound levels and likely noise impacts of a wind farm in Machias from acoustic engineer Richard R. James. Mr. James' report (James 2009b) is among the enclosures. Mr. James' resume can be found at the end of a paper he co-authored and presented last year, recently modified for the Ontario Ministry of the Environment, also among the enclosures. Kamperman and James (2008).

[1] This is based on the 67-turbine wind farm proposed for the Allegany County town of Centerville by Noble Environmental Power, LLC.

1. Wind farm noise is distinctively annoying

A number of reports find that, at the same sound pressure (decibel) level or less, wind turbine noise is experienced as more annoying than airport, truck traffic or railroad noise. Pedersen (2007, p. 24, reviewing literature).

It is not clear whether the distinctive **rhythmic, impulsive or modulating character of wind turbine noise** (all synonyms for "thump" or "swoosh" or "beating" sounds), its characteristic low frequency component (both audible and inaudible, and also impulsive), health effects of chronic exposure to wind turbine noise, especially at night (*see below*, page 2), in-phase modulation among several turbines in a wind farm (this can triple the impulse sound level when impulses of three or more turbines become synchronized), (Bowdler 2008, p. 5), or some combination of these factors explains the annoyance. One or more of these characteristics are likely present depending on atmospheric and topographic conditions, especially at night. Van den Berg (2006). Nevertheless, reports based on surveys of those living near wind farms consistently find that, compared to surveys of those living near other sources of industrial noise, annoyance is significantly higher for comparable sound levels among wind farm residents. This provides objective evidence in support of an expectation that a substantial number of those living near wind projects will complain that the noise level they experience is annoying. Pedersen (2007); Bajek (2007); Kamperman and James (2008); James (2009b); Minnesota Department of Health (2009), pp. 19-20.[2]

The impulsive character of wind turbine noise is caused by **air turbulence around the turbine blades**. Van den Berg (2006, pp. 35-36); Bowdler (2008). There are a number of explanations for this fact, and more than one may apply at any specific wind farm site. For example, eddies in the wind, wind shear (different wind speeds at the higher reach of the blades compared to the lower reach), slightly different wind directions across the plane of the blades, interaction among turbines, and the interaction of the blades of a turbine with the tower have each been identified as causes of modulating wind turbine noise. Bowdler (2008).

Impulsive sound was considered more problematic for older turbines that had rotors mounted downwind from the tower. Rogers (2006, p. 10). The sound was reduced by mounting the rotor upwind of the tower, common now on all modern turbines. *Id.*, pp. 13, 16; Van den Berg (2006), p. 36. However, in a landmark study now referred to in all serious discussions of wind turbine noise, Van den Berg (2006, p. 36) found the impulsive swishing sound increases with size because larger modern turbines are subject to "wind shear" during times of ground level "atomospheric stability," resulting in sound fluctuating 5 dBA between beats, up to 9 dBA. *Id.*,

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[2] To compensate for the added annoyance of fluctuating or impulsive sound, the convention is to add a penalty of 5 dBA to modeled sound or to subtract an equivalent amount from the allowable numerical sound level. Van den Berg (2006), p. 106; Minnesota Department of Public Health (2009), p. 21. *See also* Pedersen (2007, p. 24) ("Amplitude-modulated sound has also been found to be more annoying than sound without modulations.").

pp. 81, 85, 142. *See also* Bajek (2007); Kamperman and James (2008); Cummings (2009, p. 7) ("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."). *Cf.* Rogers (2006, p. 12) (blade tip noise at that time was "not fully understood").

The phenomenon of wind shear coupled with ground level atmospheric stability refers to the boundary between calm air at ground level and turbulent air at a higher altitude. "A high wind shear at night is very common and must be regarded a standard feature of the night time atmosphere in the temperate zone and over land." Van den Berg (2006, p. 104). *See also* Cummings (2009).

Based on a full year of measurements every half-hour at a wind farm in Germany, Van den Berg found:

> the wind velocity at 10 m[eters] follows the popular notion that wind picks up after sunrise and abates after sundown. This is obviously a 'near-ground' notion as the reverse is true at altitudes above 80 m. . . . after sunrise low altitude winds are coupled to high altitude winds due to the vertical air movements caused by the developing thermal turbulence. As a result low altitude winds are accelerated by high altitude winds that in turn are slowed down. At sunset this process is reversed. (Van den Berg 2006, p. 90)

In other words, when ground-level wind speed calms after sunset, wind speed at typical hub height for large wind turbines (80 meters, or 262 feet) commonly increases. As a result, turbines can be expected to operate, generating noise, while there is no masking effect from wind-related noise where people live. "The contrast between wind turbine and ambient sound levels is therefore at night more pronounced." *Id.*, p. 60. In addition, as the turbines sweep from top to bottom under such conditions the blade tip encounters slightly different wind velocities creating unexpected turbulence that results in rhythmic swishing noise. *Id.*, p. 61. *Cf. also* Minnesota Department of Public Health (2009), pp. 12-13 and Fig. 5. Such calm or stable atmosphere at near-ground altitude accompanied by wind shear near turbine hub height occurred in the Van den Berg measurements 47% of the time over the course a year on average, and most often at night. Van den Berg 2006, p. 96.

The level of annoyance by noise also increases substantially for **low frequency sound**, compared to more audible mid-frequency sounds. Sound measured as dBA is biased toward 4,000 Hz, the center of the most audible frequency range of sound pressure. Low frequency sound is in the range below 500 Hz and is measured as dBC. Sound below 20 Hz, termed **infrasound**, is generally not audible. *See* Leventhall (2003, pp. 31-37); Minnesota Department of Public Health (2009, p. 10); Kamperman and James (2008, pp. 23-24).

Wind turbine noise includes a significant low-frequency component, including inaudible infrasound. For example, according to the manufacturer, under ideal test conditions at a distance of 200 meters (656 feet), a single 2.5 MW Nordex N80 wind turbine generates 95 decibels at 10 Hz. Nordex (2004, p. 4). This at the threshold of human hearing. Rogers et al. (2006, p. 9, table 5).

At the less-audible and inaudible range, low-frequency sound is often felt rather than heard. Unlike the A-weighted component, the low-frequency component of wind turbine noise "can penetrate the home's walls and roof with very little low frequency noise reduction." Kamperman and James (2008), p. 3. Acoustic modeling for low frequency sound emissions of ten 2.5 MW turbines indicates "that the one mile low frequency results are only 6.3 dB below the 1,000 foot one turbine example." *Id.*, p. 12.

Apart from the distinctive characteristics of wind turbine noise, including its low frequency component, state environmental guidelines indicate the level of industrial sound wind turbines would generate in very quiet rural residential settings is unacceptable. The New York State Department of Environmental Conservation (NYSDEC) has issued guidelines on how to assess noise impacts that is very useful because it was written for DEC staff who lack a background in acoustics but are often called upon to evaluate noise assessments. The DEC guidance states:

(1) "In non-industrial settings the SPL [sound pressure level] should probably not exceed ambient [pre-construction] noise by more than 6 dB(A) at the receptor." NYSDEC (2001, p. 14).

(2) "An increase of 10 dB(A) deserves consideration of avoidance and mitigation measures in most cases." *Id.*

(3) Among the accepted mitigation measures is: "Increasing the setback distance." *Id.*, p. 24.

(4) "SPL increases approaching 10 dB result in a perceived doubling of SPL." *Id.*, p. 14.

(5) An SPL increase over 20 dB will be experienced as: "Very objectionable to intolerable." *Id.*, p. 15.

(6) "If the goal is not to raise the future noise levels the new facility would have to operate at 10 dB(A) or more lower than the ambient." *Id.*

(7) "$L_{(90)}$ is often used to designate the background noise level." *Id.*, p. 12. *See also* James (2009, p. 2) ("ANSI/ASA standards for measurement of the long term background sound levels" call for the use of the L_{90} measure).

It is important to recognize that an increase of 6 dBA above pre-construction sound levels (representing over 50% increase in loudness) is enough to cause project sounds to be heard, but not enough to cause any damage to hearing. Kamperman and James (2008, p. 5). The annoyance of such a relatively small change in the acoustic environment is due to the modulating and low frequency character of the noise, together with its constancy during night times, not its absolute sound pressure level. *Id.*

Wind developers commonly assume wind speed at ground level sufficient to create masking noise when wind speed at hub height is operating the turbines, but as Van den Berg's research into the effect of wind shear shows this is frequently not the case. *Cf.* Rogers (2006), p. 23 (assuming 8 m/s ground wind speed will be accompanied by 45 dBA background sound level). *Compare* Van den Berg (2006), p. 56 (when wind velocities are low at a height of 10 meters, the wind velocity at turbine hub height at night is "up to 2.6 times higher than expected").

In addition, developers include "such things as local traffic, industrial sounds, farm machinery, barking dogs, lawnmowers, children playing and the interaction of the wind with ground cover, buildings, trees, power lines, etc." in their measurement of pre-construction baseline sound levels, (*id.*, p. 20), but this approach departs from acoustics standards. Kamperman and James (2008), p. 4; James (2009b), p. 2 (current standards specify that "the proper metric for describing the pre-operational sound levels is Long-Term Background sound level usually measured using a statistical process to identify the quietest one minute of a 10 minute sample taken during the time when the new noise source is most likely to generate complaints").

The measured baseline sound levels at four locations in the vicinity of the proposed Horizon wind project in Machias are between 24 and 31 dBA and, for low frequency sound, between 47.4 and 49 dBC. James (2009b, p. 4, table). *Cf.* Cummings (2009, p. 6) ("night-time ambient noise levels in rural areas are often 35dB or lower"). Thus, under DEC guidelines, allowing wind project sound to impose 50 dBA on residents could be "intolerable." NYSDEC (2001, p. 15). *See also* Van den Berg (2008) (study results show prevalent sleep disturbance at 45 decibels or higher).

As other standard setting agencies have indicated, setbacks of about one kilometer (3,280 feet) would be necessary to avoid sound levels more than 6 dBA above background. Kamperman and James (2008), pp. 13-14 (recommending setbacks at least 1 km, and attaching a model wind facility ordinance); Davis (2007), p. 12 (supporting French National Academy of Medicine standard for setbacks 2 km or more). *See also* Minnesota Department of Public Health (2009), p. 25 ("if a turbine is subject to aerodynamic modulation because of shear caused by terrain (mountains, trees, buildings) or different wind conditions through the rotor plane, turbine noise may be heard at greater distances" than one-half mile, or 2,640 feet). This is consistent with the Van den Berg study:

> in quiet nights the wind farm can be heard at distances of up to several kilometers when the turbines rotate at high speed. In these nights, certainly at distances from 500 to 1000 m [1,640 to 3,280 feet] from the wind farm, one can hear a low

> pitched thumping sound with a repetition rate of about once a second (coinciding with the frequency of blades passing a turbine mast), not unlike distant pile driving, superimposed on a constant broad band "noisy" sound. A resident living at 1 km from the nearest turbine says it is the rhythmic character of the sound that attracts attention: beats are clearly audible for some time, then fade away to come back again a little later. A resident living at 2.3 km from the wind farm describes the sound as "an endless train". In daytime these pulses are usually not audible and the sound from the wind farm is less intrusive or even inaudible (especially in strong winds because of the then high ambient sound level). (Van den Berg 2006, p. 42)

At these distances, the mid-frequency range sounds diminish because they are more readily absorbed by the air, but the low frequency ranges do not. Wind turbines at such distances will generate "a louder and more low frequency 'thumping' sound and less the swishing sound that is observed close to a daytime wind turbine." *Id.*, p. 65.

Thus, the annoyance of wind turbine noise is the result of its rhythmic or modulating character, its low frequency component, and its presence during times of calm surface atmosphere, most commonly at night when sound travels farthest.

2. Wind farm noise results in chronic sleep disturbance for a significant number of those who live within a mile away.

It is important to distinguish recent studies that link low frequency noise impacts to impairment of the vestibular system or other organs[3] from well-established findings that wind farm noise is a cause of sleeplessness, and the health effects of chronic sleeplessness. The discussion in this section is limited to sleeplessness and health problems associated with sleeplessness.

The World Health Organization (WHO) considers sleep disturbance to be an adverse health impact. WHO (1999), pp. 44-46. Chronic sleeplessness, in turn, causes a variety of health effects, including "primary physiological effects . . . induced by noise during sleep, including increased blood pressure; increased heart rate; increased finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and an increase in body movements." *Id.*, p. 44. "Exposure to night-time noise also induces secondary effects, or so-called after effects . . . includ[ing] reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance." *Id.*, pp. 44-45. Waking up in

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[3] *See* Alves-Pereira and Branco 2007; Pierpont 2009 (linking the low-frequency component of wind turbine noise is linked to abnormal growth of collagen and elastin in the blood vessels, cardiac structures, trachea, lungs, and kidneys of humans and animals exposed to infrasound (0–20 Hz) and low-frequency noise (20–500 Hz), in the absence of an inflammatory process). *See also* Minnesota Department of Public Health (2009), pp. 7-8.

response to nighttime noise decreases as people get habituated to the noise; however, "habituation has been shown for awakenings, but not for heart rate and after effects such as perceived sleep quality, mood and performance." *Id.*, p. 45.

In 2007 WHO issued Night Time Noise Guidelines (NNGL) to preserve the ability to sleep, recommending that to avoid adverse health effects outdoor sound levels in rural areas at night not exceed 30 dBA. WHO (2007), pp. 24-25 (and recommending an interim limit of 40 dBA in communities "where the NNGL cannot be achieved in a short period for various reasons, and where policy-makers choose to adopt a stepwise approach at the local or national levels."). *See also* James (2009b, pp. 5-6) (discussing WHO's NNGL); Cummings (2009, p. 6) ("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").[4]

Because sound levels in Machias are already 31 dBA or lower, (James 2009b, p. 4, table), WHO's NNGL goal can be met in Machias with properly crafted legislation that protects all residents from intolerable noise pollution.

3. Horizon's background noise assessment in Machias

I understand Horizon has completed an assessment of background sound levels in Machias that differs substantially from Mr. James' assessment. The author of Horizon's assessment Hessler Associates, Inc., has completed numerous noise assessments for wind developers in New York criticized by independent acoustic engineers for departing from several well-established standards in acoustics in order to obtain a result. Hessler achieves results supporting conclusions that background sound levels are around 45 dBA, wind sound will mask turbine noise, and total noise impacts will be insignificant for nearly everyone within one mile of a project. Each of these conclusions relies on a novel approach to acoustics and cannot be sustained on professional grounds.

I am enclosing not only Mr. James' measurements and analytical report for background sound levels in Machias, (James 2009b), but Mr. James' criticism of Hessler's approach to noise assessment for a wind project in the Town of Allegany; criticisms of Hessler's approach by acoustic consultant Richard Bolton for a wind project in the Town of Jordanville; and criticisms of Hessler's approach by acoustic engineer Gregory Tocci for a wind project in the Town of Cape Vincent, all New York projects. James (2009a); Bolton (2006); Kavanagh Tocci (2008). Despite receiving substantially the same criticisms of his approach by three different acoustic consultants, Hessler continues to provide noise assessments that depart from accepted acoustic standards.

[4] This modifies the finding of Rogers (2006, p. 21) ("At the present time, there are no common international noise standards or regulations for sound pressure levels.").

For example, commenting on Hessler's method of adding to background sound levels "masking noise" created by the sound of the wind in ground-level vegetation, in an attempt to show that wind project noise will result in an insignificant increase in the community's sound level, James (2009a, p. 4) states:

> This interpretation is contrary to the generally accepted understanding of a community's "background sound level." This is a defined term in acoustics. To alter its meaning to be the noisiest conditions and not the quiet conditions as generally accepted for land use planning and evaluating a community's reaction to a new noise source is truly novel. It is clearly at odds with ANSI standards and procedures for assessing background sound levels and for assessing the impact of a new noise source on a community.[5]

Background sound level as the baseline against which project impact sound should be assessed requires that transient sounds be excluded from the measurements used to calculate L_{A90}. James (2009b, p.2). This is in contrast to L_{Aeq}, an average sound level favored by wind energy facility developers, "which may include the effects of near-by and short term sounds." *Id.*, p. 5. The relevant consideration is the need to capture the quietest period of time that will be commonly experienced, because that is the time complaints can be expected about an intrusive noise source. Using a different measure for background, ambient or pre-construction baseline sound will underpredict complaints. *Id.*

Hessler's approach supports wind industry recommendations and model local ordinances prepared by the industry. *See id.*, pp. 2-3. This approach worked for some years before research became available addressing the high level of complaints about noise levels exceeding the modeling results provided by wind developers at the pre-construction phase of many projects in Europe and U.S. However, now that such research is available and provides confirmation that Hessler's approach seriously underestimates wind turbine noise, there can be no excuse for failing to consult this literature.

Thank you for this opportunity to offer supporting information for my recent email. Please feel free to contact with any additional questions or concerns.

Sincerely yours,

Gary A. Abraham

gaa/encs.

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[5] As noted in his report, (James 2009b, p.1.n.1), Mr. James was a member of the committee that developed the ANSI standards applicable to noise assessments.

Enclosures:

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Pedersen, Eja (2007). *Human response to wind turbine noise: Perception, annoyance and moderating factors* (Diss., Göteborg University, Sweden), available at <http://dspace.hh.se/space/handle/ 2082/1925>.

Rogers, Anthony L. et al. (2006). *Wind Turbine Acoustic Noise: A White Paper*, Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering University of Massachusetts at Amherst (June 2002, amended January 2006), available at <http://www.ceere.org/rerl/publications/whitepapers/Wind_Turbine_Acoustic_Noise_Rev2006.pdf>.

Rudolph, Erik (2003). *Wind turbine noise emission. Wind speed measurements below hub height give poor accuracy*, Proceedings of the Nordic Acoustical Meeting, Stockholm (Sweden).

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