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To: THE PUBLIC UTILITIES COMMISSION OF THE STATE OF SOUTH DAKOTA

Re: Docket No. EL 18-053
APPLICATION BY DEUEL HARVEST WIND, LLC FOR A PERMIT OF A WIND ENERGY FACILITY AND A 345-kV TRANSMISSION LINE IN DEUEL COUNTY, SOUTH DAKOTA FOR THE DEUEL HARVEST NORTH WIND FARM

On request of Christina Kilby I respectfully submit this professional opinion of the Application By Deuel Harvest Wind, LLC For A Permit Of A Wind Energy Facility And A 345-Kv Transmission Line In Deuel County, South Dakota For The Deuel Harvest North Wind Farm. This opinion includes attachments and focuses on noise impact assessment.

1. Documents reviewed included:

- Application to the South Dakota Public Utilities Commission for Energy Facility Permits, Deuel Harvest Wind Energy LLC, Burns McDonnell, November 30, 2018.
- Application Appendix D - Pre-Construction Wind Turbine Noise Analysis, Hankard Environmental, Inc. November 2018.
- Application Appendix D - Revised Pre-Construction Wind Turbine Noise Analysis, Hankard Environmental, Inc. January 2019.
- Direct Testimony of David M Hessler, Docket EL 18-053, dated 14 March 2019.
- Deuel County Ordinance B2004-01 dated 6 July 2004.
- Deuel County Ordinance B2004-01-23B dated 23 May 2017.
- Deuel County Comprehensive Plan effective date 5 May 2004.
- General review of Administrative Rules of South Dakota (ARSD).

2. Professional opinion summarized: **The application noise analysis, both original and revised, reveals professional omissions and does not assure compliance with regulatory requirements and limits. The application appears incomplete.**

3. **Breached, ARSD 20:10:22.18 (3):** ***"An analysis of the compatibility of the proposed facility with present land use of the surrounding area, with special attention paid to the effects on rural life and the business of farming;"***

3.1 The application omitted assessment of compatibility for operational noise levels. Application Section 15.1.2 Land Use Impacts / Mitigation identified the presence of rural residences and noise sensitive land uses, yet did not assess for noise compatibility. The Application Section 15.1.2 did not identify what or where the noise sensitive land uses are not, nor did it assess for compatibility for those land uses, nor mitigation.

3.2 The application omits design-review assessment of goals and intent in the Deuel County Comprehensive Plan:
- "*To promote compatible development in the rural area.*"
- *"Promote only responsible residential, commercial and industrial development based upon sound siting criteria.*"

3.3 The American National Standards Institute (ANSI) S12.9 Parts 4&5 provide siting criteria for compatibility of unfamiliar intrusive noise in various land uses.

3.4 ANSI S12.9 Parts 4&5 establish that for quiet rural areas, unfamiliar intrusive noises are incompatible when their average nighttime noise levels exceed 35 dBA (see attachment).

3.5 The application predicts average noise levels exceeding 35 dBA that breach ANSI night noise thresholds for rural residential land use compatibility at multiple nearby rural residential homes. Daytime ANSI compatibility limits are exceeded at participating homes.

3.6 When assessed using ANSI standards for noise compatibility, the facility falls into "*incompatible development*" status at multiple rural residences, breaching ARSD 20:10:22.18 (3) and violating the goals and intent established in the Deuel County Comprehensive Plan.

4. **Breached, ARSD 20:10:22.18 (4):** ***"A general analysis of the effects of the proposed facility and associated facilities on land uses and the planned measures to ameliorate adverse impacts."***

4.1 Despite identifying "rural residences" and "noise sensitive land uses" as land use classifications occurring within the project area, the application did not provide an analysis of the effects of the proposed facility noise levels on rural residences or noise sensitive land uses, thus failing to identify potential adverse impacts; nor were any planned measures provided to ameliorate adverse impacts.

4.2 The sole function of the application Appendix D seems to have been to report predicted sound levels based on finely adjusted wind turbine locations to just-meet the Deuel County sound level limits by 0.1 dB, a design margin so small it is dwarfed by the +/- 1-dB tolerance of Type 1 sound level meters used in noise surveys. There was no noise impact assessment.

The revised January 2019 noise analysis figure E-2 is so poorly rendered, only the 45 dBA contour shown, as to make assessment of wind turbine noise levels versus distance virtually impossible. The figure quality is degraded so markedly from the November 2018 report as to suggest a deliberate obscuring of the facility noise information.

4.2 The application failed to compare expected project noise levels at rural residences to pre-existing background L90 sound levels for assessing noise impact. This deficiency stems from the apparent failure to comprehend ARSD 20:10:22.18 (3) & (4) which, for intrusive noise, requires a sound survey of the existing rural background acoustical environment.

4.3 Noise impact assessment is best practice for noise control consulting for several decades and is supported by ANSI and ISO standards. The absence of a sound survey and impact assessment was noted by PUC sound consultant Mr. Hessler. Omitting impact assessment appears on its face to fail the requirements of ARSD 20:10:22.18 (3) & (4), and opens the question of ancillary breach of law in Deuel County Ordinances B2004-01, 1) Section 104 (promote ***health and welfare***), 2) Section 504.5.c Utilities, with reference to locations, availability, and ***compatibility***, and 3) Section 504.5.g. General ***compatibility*** with adjacent properties and other property. (emphasis added).

4.4 The application failed to assess for community response via ISO TC/43.

4.5 The ISO TC/43 scale for community response is a "first-cut" analysis for project fit that is widely used for decades in project noise assessments (see attachment). When assessed using the ISO TC/43 scale for community response, the predicted levels exceeding 35 and 40 dBA for non-participating homes, all the way up to 50 dBA for participating homes, intruding onto typical quiet rural background sound levels of 20 to 30 dBA at nearby rural residences, result in expected community response ranging from "Widespread Complaints" to "Vigorous Community Action". In my professional experience working on power generation noise control starting back in 1980 at Stone & Webster, this level of adverse community response would never be allowed to go out the door. Management would be notified. Noise control budgets would be developed and applied to reduce expected community response.

4.6 For wind turbines, to date the only effective and reliable noise control option permitting full power operation at all hours is sufficient distance scaled to size and power output secured prior to permit. If there isn't sufficient distance due to pre-existing residential use or other constraints, turbines must be reduced in size or located elsewhere, or power generation accomplished with other technology that readily accommodates or is furnished turnkey with sufficient noise controls to operate at full power with compatible noise levels for the locale and nearby residences.

4.7 The application failed to assess via WHO 2009 and WHO 2018 if predicted noise levels exceed sleep disturbance thresholds below the regulatory limit at nearby rural residences.

4.8 The World Health Organization in 2009 published noise levels thresholds for sleep disturbance for healthy individuals of 40 dBA (L,night).

4.9 The application predicts noise levels that breach WHO noise thresholds for sleep disturbance by exceeding 40 dBA at multiple nearby rural residences.

4.10 The World Health Organization in 2018 published a wind turbine noise guideline not to exceed 45 Lden (guideline issued prior to the application Appendix D). By EC Directive 2002, the Lden includes an L,night average noise level defined as 10 dB below the Lden figure; a night noise guideline not to exceed L,night = 35 dBA.

4.11 The application predicts noise levels that breach the L,night portion of the 45-Lden guideline limit by exceeding a nighttime average 35-dBA noise level at multiple nearby rural residences. The application breaches the 45-Lden guideline limit whole at nearby participating rural residences, with predicted noise levels as high as just under 50 dBA.

4.12 The facility predicted noise levels exceed sleep disturbance thresholds and breach WHO wind turbine noise guidelines intended to protect public health and welfare at multiple residences in the vicinity of the proposed facility.

4.13 The facility predicted noise levels exceed known thresholds for significant high noise annoyance established by Health Canada in their landmark study of 2014. Predicted noise levels exceed 35 dBA at multiple rural residences. High noise annoyance was defined in 2008 by Director Michaud as "one of the measures of the magnitude of an adverse health effect caused by project related noise" [1].

4.14 It is worth noting that obtaining noise easements is a tool used by the wind industry that permits unfettered wind turbine noise immissions on participating properties. Noise easements do not control noise: they permit it. Easements raise questions of protection for children and elderly living on participating properties. Does the regulating authority understand and agree that children and elderly on participating properties, not signatories

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1 Michaud et al. Canadian Acoustics, 36(2): 13-28 (2008). "Defining high noise annoyance as an adverse health effect is certainly consistent with Health Canada’s definition of what constitutes “health”. ... "a change in %HAn

on easements, may be subjected without informed consent to sleep disturbance or high annoyance at noise levels exceeding known impact thresholds.

4.15 The County Ordinance Section B2004-01 Section 103 requires, "***In their interpretation and application, the provisions of this Ordinance shall be held to be minimum requirements, adopted for the promotion of the public health, safety, morals, or general welfare.***" (emphasis added). This County law requirement is taken to mean that a predicted noise level, even if under the regulatory noise limit, that exceeds sleep disturbance thresholds or is incompatible with the land use, shall not be considered in compliance with the regulation whole; where public health and welfare are concerned, a lower limit than the maximum standard in the law may be needed to protect public health and welfare.

INCE members are *required* by the INCE Canon of Ethics to *hold paramount the safety, health and welfare of the public*. "Paramount" means "above all other considerations". The application Appendix D appears to have breached professional requirements and responsibilities by failing to report potential noise effects on sleep and failing to design the facility to prevent a likely adverse community response.

4.16 The County rests its regulatory maximum allowed average sound level on the A-weighted metric. The County is mute on prevention of low frequency impacts which comprise the bulk of residential complaints from industrial noise. Wind turbines produce low frequency sound pressures that oscillate in time, from the barometric oscillations at blade pass rates documented at Shirley Wisconsin and other surveys, up through the infrasonic range of 8 to 20 Hz associated to house resonances and vibration loading, into the low frequency range of 20 to 200 Hz, and beyond into mid-and high-frequencies.

5. Summary of findings

Due to professional omissions and other deficiencies, the application:
1) appears certain to exceed regulatory noise limits some portion of the time,
2) ignores requirements for compatible development listed in State and County law,
3) fails to assess for effects of noise on rural residences, and
4) predicts noise levels exceeding thresholds for sleep disturbance, high noise annoyance, and adverse community response with "Widespread Complaints" or stronger response at multiple nearby rural residences.

If regulators permit this facility and complaints occur, the engineers, consultants and regulators have failed.

The application review shows there is insufficient distance from turbines to neighbors. At this time, the only reliable noise control option for large three-bladed wind turbines is sufficient distance established prior to permit. So-called "noise reduction options" have not proved reliable for noise reduction and exact tremendous reductions in power output. NRO controls were tested extensively with GE's technical assistance at a 3x1.5MW-turbine wind facility in Vinalhaven, Maine. No significant reduction in loudness was obtained [2] in real-world operation. I have seen no news reports or technical reports anywhere in the last eight years confirming that NRO works *reliably* in all atmospheric conditions in the real world outside test facilities. However the Deuel County regulation is exacting. No exceedance of the average levels, regardless of averaging time (averaging time is unspecified), is permitted.

This review analysis is based in part on relevant American National Standards Institute (ANSI) standards and International Standards Organization (ISO) standards, and on years of experience evaluating predictive models and measuring noise levels for power generation, industrial, commercial and wind turbine facilities.

Professional opinions in this letter are given to a reasonable degree of scientific certainty. These opinions are based on the information available at the time of drafting this review. I reserve the right to supplement or revise should additional information come to light.

INCE Rules of Practice require approving only noise control engineering studies, reports, or work which, to the best of the reviewer's knowledge and belief, is safe for public health, property, and welfare and in conformance with accepted practice.

As INCE Member I must recommend the application be withdrawn or turned down as unfit for purpose and unresponsive to requirements in State and County law.

Thank you for your consideration of this letter. If you have any questions, please contact me.

Respectfully Submitted,

Robert W. Rand, ASA, INCE

rwr/Attachments

2 Ben Hoen et al, "Assessing the Impacts of Reduced Noise Operations of Wind Turbines on Neighbor Annoyance: A Preliminary Analysis in Vinalhaven, Maine", Lawrence Berkeley National Laboratory, LBNL-3562E, June 2010. https://emp.lbl.gov/sites/all/files/lbnl-3562e.pdf

ATTACHMENT 1: ISO 9613-2 ESTIMATED ACCURACY OF CALCULATION

1.1. Deuel County's current Ordinance B2004 01 23B, Section 1215.03, paragraph 13. a) prescribes sound limits for wind turbine projects as follows: "13. a) Noise level ***shall not exceed*** 45 dBA average A weighted sound pressure at the perimeter of existing residences, for non participating residences." (emphasis added.)

1.2. GE typically has published a 2 dBA "uncertainty factor" in its IEC 61400-11 test reports for turbines in the 1.5 to 2 MW range. Technically this factor is not a "safety margin" but an accounting of the variability for test results from turbine to turbine.

1.3. Based on comparisons of predicted and measured sound levels, ISO 9613-2 provides an *estimated accuracy of calculation* for the long-term average sound level, listed in ISO 9613-2 Table 5: *+/- 3 dBA from 100 to 1000 meters* (328 to 3280 feet), and no estimate of accuracy beyond 1000 meters (3280 feet). ISO 9613-2 Table 5 is shown for reference below.

Height, h *)	Distance, d *)	
	$0 < d < 100$ m	100 m $< d < 1\,000$ m
$0 < h < 5$ m	± 3 dB	± 3 dB
5 m $< h < 30$ m	± 1 dB	± 3 dB

*) h is the mean height of the source and receiver.
d is the distance between the source and receiver.

NOTE — These estimates have been made from situations where there are no effects due to reflection or attenuation due to screening.

The *best* that one should expect from predictions based on ISO 9613-2 are actual long-term sound levels that range +/- 3 dB compared to the long-term average sound level computed using the ISO 9613-2 method from a distance of 100 to 1000 meters (328 to 3280 ft). In ISO 9613-2 Table 5, an estimate of accuracy is not provided for distances ("d") greater than the 1000-meter (3280-ft) upper limit.

1.4. The application failed to mention or factor in the 3 dBA estimated accuracy of calculation listed in ISO-9613-2 Table 5.

1.5. There is no support in ISO 9613-2 for omitting the estimated accuracy of calculation or asserting that the model perfectly predicts measured levels to a 1/10 of a decibel, or even a decibel. As stated in the ISO 9613-2 standard, the estimates of accuracy in ISO 9613-2 Table 5 "*should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter* ***can be expected to be considerably larger*** *than the values in table 5.*" On any given day, the accuracy may be much poorer (noise level ranging much higher or lower) than the estimates in the standard. For this review the concern is for noise levels ranging higher than predicted.

1.4. Omitting the estimated accuracy of calculation is a professional error that results in predicted long term average noise levels that may underestimate probable measured long term average noise levels by as much as 3 dBA, or more beyond 1000 meters (3280 feet).

ATTACHMENT 2: STANDARD UNCERTAINTIES IN WIND TURBINE SOUND LEVELS

2.1. The prediction standard ISO 9613-2 used for noise modeling, references ISO standard 1996-2. "Standard Uncertainties" defined in ISO 1996-2 relate to the variability experienced when acquiring a noise level at locations near wind turbines, locations which may be some distance away compared to the close-in measurement locations used to establish the Leq long term average sound level in IEC 61400-11. In arguably the largest wind turbine noise investigation to date, Standard Uncertainties for wind turbine noise emissions were assessed and published by Health Canada in 2014.

2.2. As Health Canada stated in 2014 for calculations using ISO 9613-2, "*The standard uncertainties in these results are +/- 30m for the distances to the nearest wind turbine and +/-5dB for the dBA and dBC noise levels for residences that are situated up to 1.6 km [~1 mile] to the closest wind turbine. After 1.6 km, the uncertainties, evaluated according to the ISO 1996-2 standard, are derived according to the following formula: 1 + d/0.4, where d represents the distance to the nearest turbine (in km). As such, the uncertainty for a dwelling that is situated 10km away [~32800 ft] would be +/- 26 dB.*"

2.3. The Standard Uncertainties determined by Health Canada for wind turbines using ISO 1996-2 are consistent with abundant research on long-range noise propagation and specifically with a report by industry consultants Hessler Associates with whom I worked in 2012 [3]. In their 2011 report to the Minnesota Public Utilities Commission, Hessler Associates stated that short-term sound levels "commonly fluctuate by roughly +/- 5 dBA about the mean" with maximum levels running 15-20 dBA over average noise levels [4].

2.4. It should be understood that once informed of the uncertainties inherent in long-range noise propagation, no reasonable person could believe that measured sound levels would never exceed the predicted long-term average levels in the application. Whereas the applicant asserts with conviction that facility noise levels predicted at 44.9 dBA will never ever increase, for example +0.2 dBA to 50.1 dBA, or +5 dBA as found by Health Canada.

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3 Channel Islands Acoustics, Camarillo, CA, Principal: Dr. Bruce Walker; Hessler Associates, Inc., Haymarket, VA Principals: George F. and David M. Hessler; Rand Acoustics, Brunswick, ME, Principal: Robert Rand; Schomer and Associates, Inc., Champaign, IL, Principal: Dr. Paul Schomer, "A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin", Wisconsin PSC REF#:178263, December 24, 2012.
4 Hessler, D., "Assessing Sound Emissions from Proposed Wind Farms & Measuring the Performance of Completed Projects", National Association of Regulatory Utility Commissioners (NARUC), DOE DE- OE-0000123, Hessler Associates, October 2011. "Wind turbine sound levels naturally vary above and below their mean or average value due to wind and atmospheric conditions and can significantly exceed the mean value at times. Extensive field experience measuring operational projects indicates that sound levels commonly fluctuate by roughly +/- 5 dBA about the mean trend line and that short-lived (10 to 20 minute) spikes on the order of 15 to 20 dBA above the mean are occasionally observed when atmospheric conditions strongly favor the generation and propagation of noise. "

ATTACHMENT 3: ANSI SITING CRITERIA FOR COMPATIBILITY

The tables below summarize the calculation utilized to determine land use compatibility noise criteria for the proposed facility using ANSI S12.9 Parts 4&5 assuming a quiet rural area. "Criteria" means the level that should not be exceeded- the highest allowable long-term average noise level. The calculation concludes that for unfamiliar intrusive noise in quiet rural areas, long-term average noise levels lower than 30 dBA are compatible; noise levels between 30 and 35 dBA are "marginally compatible"; noise levels exceeding 35 dBA at night are *incompatible*.

Criteria for "Compatibility" per ANSI S12.9:

Factor	**Day-Night Sound Level (DNL)**	***Day Sound Level:***	***Night Sound Level:***	***Average Level (Leq*):***
Part 5 Figure A.1 Residential Urban/suburban, Single Family Marginal Compatibility:	55	*55*	*45*	*49*
Adjust: 10 dB for quiet rural settings (Part 4 F.3.4.1):	-10	*-10*	*-10*	*-10*
Adjust: 5 dB for unfamiliar intrusive noise (Part 4 F.3.4.3):	-5	*-5*	*-5*	*-5*
Criteria for "Compatibility", dBA:	**40**	***40***	***30***	***34***

Criteria for "Marginal Compatibility" per ANSI S12.9:

Factor	**Day-Night Sound Level (DNL)**	***Day Sound Level:***	***Night Sound Level:***	***Average Level (Leq*):***
Part 5 Figure A.1 Residential Urban/suburban, Single Family Marginal Compatibility:	60	*60*	*50*	*54*
Adjust: 10 dB for quiet rural settings (Part 4 F.3.4.1):	-10	*-10*	*-10*	*-10*
Adjust: 5 dB for unfamiliar intrusive noise (Part 4 F.3.4.3):	-5	*-5*	*-5*	*-5*
Criteria for "Marginal Compatibility", dBA:	**45**	***45***	***35***	***39***

* The energy-equivalent average level (Leq) equivalent to a day-night level (DNL) is 6 dB less than the day-night level due to level weighting of -10 dB from 10 pm to 7 am.

ATTACHMENT 4: ISO SITING CRITERIA FOR COMPLAINTS

A commonly applied criterion for estimating the community response to an intrusive noise source is found in the scale developed by the International Standards Organization (ISO) [5] based on the projected change in noise levels, shown in the table below.

Change (dBA)	Category	Description
0	None perceptible	No observed reaction
5	Little noticeable	Sporadic complaint
10	Medium	Widespread complaints
15	Strong	Threat of community action
20	Very Strong	Vigorous community action
Note: 1. ISO 150/TC43. 1969. Noise Assessment with respect to Community Response.		

Table 4.1. ISO Community response to increases in noise levels.

This community response scale supports direct estimation of the likely community response to a projected increase in noise levels over the normally occurring minimum background (L90) sound level, which is generally accepted in acoustics as the level associated to a quality of place such as a quiet rural area.

Years of power generation noise control experience taught that successful noise control design resulting in no complaints rests on comparing the expected noise levels to the background L90. At Stone & Webster, the benchmark criterion for community response assessment was based on "the L90 of the L90" over a year's time. The basis was to ensure design for the worst case scenarios when background is quiet, so that noise control dollars were effective. Like designing a road for the widest typical vehicle rather than the narrowest, designing to prevent complaints based on the recurring L90 rather than on the highly variable Leq proved to be best practice.

In rural areas such as Deuel County it is generally found that background sound levels in the absence of industrial noise, traffic or insects falls in around 35 dBA or lower during the day and 25 dBA or lower at night. Widespread complaints could occur if new and unfamiliar noise was introduced at night at levels of 35 dBA or higher in a quiet rural area.

For an *urban residential* area, already experiencing a high degree of transportation noise day and night with background L90s of 40 to 45 dBA, a 45-dBA noise limit could be effective at limiting adverse community response. However, a regulatory standard of 45 dBA in a *quiet rural* area with minimum nighttime background sound levels of 20 to 30 dBA, allows a *15 to*

5 ISO 150/TC43. 1969. Noise Assessment with respect to Community Response.

25 dB increase over the pre-existing nighttime levels. The ISO TC/43 scale predicts a community reaction of Widespread Complaints to Vigorous Community Action.

In a quiet rural area, an *average* sound level (Leq) taken over 10 minutes or an hour near a country roadway that includes occasional car and truck passbys is a much higher number than the background sound level occurring when there is no momentary intrusive noise. Most rural residents have indicated it's the natural quiet in the evening and night quiet that defines the rural quality of place at their home, not the traffic. Farming noise occurring generally during the day is an accepted part of agricultural use.

Similarly, a night noise measurement acquired with frogs croaking some parts of the year is not representative of the quiet nighttime at other parts of the year. This is equally understood for suburban or thickly settled suburban areas where there may be higher background sound levels than in rural areas but it is typically diffuse transportation noise arriving from some distance over a large area.

Thus the background L90, the level exceeded 90 percent of the time, has for decades represented the levels associated with what people expect in the acoustical character of an environs. Most would agree that the degree of quiet is significant for identifying quality of place.

Methods of removing the high frequency sounds from frogs, birds and other insects and fauna not active other times of year are provided in ANSI S12.100.

ATTACHMENT 5. WHO CRITERIA FOR HEALTH AND WELFARE

In 2009 the World Health Organization (WHO) published guidelines for outdoor noise levels in residential areas, based on comprehensive peer review of medical evidence of health effects from noise [5]. The WHO designated a yearly average noise level outdoors of 30 dBA, night, outdoors is the level below which there are no observed health effects, the "No Observed Effects Level" or NOEL. Above the 30 dBA NOEL, health effects including sleep disturbance were found, mild at lower levels for healthy individuals and more adverse with higher levels for "vulnerable groups"; children, the elderly, and people with disease or pre-existing health conditions. Above 40 dBA, the "No Observed Adverse Effects Level" (NOAEL), adverse health impacts are clearly evident and more severe for vulnerable groups.

Average night noise level over a year $L_{night, outside}$	Health effects observed in the population
Up to 30 dB	Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night, outside}$ of 30 dB is equivalent to the NOEL for night noise.
30 to 40 dB	A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night, outside}$ of 40 dB is equivalent to the LOAEL for night noise.
40 to 55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
Above 55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

It is worth noting that the "year" used in WHO noise planning was defined in the European Commission Directive of 2002. Although some consultants have asserted that the "year" means 365 days or nights, the EC defined "year" as "relevant year", specifying noise assessment for periods when noise sources were operating (for example at rated power, or at documented traffic flow rates) and discouraging mindless averaging of times when noise sources were not operating which would artificially reduce the apparent increase due to the intrusive noise.

Similarly, the EC defined Lden (day-evening-night sound level) as consisting of three parts, the day, evening and night average sound levels outdoors. The EC defined the L,evening and L,night sound levels as 5 and 10 dB below the Lden, respectively.

In 2018 the WHO issued a wind turbine noise guideline not to exceed 45 Lden. By EC Directive definition, the L,night portion of the Lden-45 guideline is 10 dBA below the 45 Lden, or L,night = 35 dBA.

There have been a number of studies on the effects of wind turbine noise on health and welfare. To date, there has been no confirming research finding that wind turbine noise conveys *less* noise impact than transportation noise. Most studies have found that wind turbine noise is 1) more annoying than cars, airplanes, and trains, 2) more audible than transportation noise (wind turbine noise is audible as much as 10 dBA below background [6]).

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6 Bolin, K., "Wind Turbine Noise and Natural Sounds- Masking, Propagation and Modeling", Doctoral Thesis, Royal Institute of Technology, Stockholm, Sweden, 2009.

ATTACHMENT 6. EPA SITING CRITERIA FOR NOISE IMPACT ASSESSMENT: COMPLAINTS

6.1 Noise-producing facilities are usually required to meet certain noise limits or "criteria" when operating in order to protect the welfare of nearby residents. In many cases criteria are taken directly from local ordinances or State regulations that specify noise limits at specific locations such as property lot lines. However "just meeting" these limits may not prevent an adverse community reaction, depending on the apparent loudness of the noise source when compared to the existing expected background sound levels.

6.2 By now most people are aware of the reports of adverse community reactions near some wind turbine facilities. From investigations made around New England, adverse community reactions appear to occur mostly when there are residential homes in quiet rural areas within a mile or so of a wind turbine facility. The noise limits for these sites are always above 35 dBA. Coincidence? No.

6.3 Many ordinances and regulations in the United States developed in the last thirty years took their guidance from the EPA's 1974 "Levels Document" [2] and used some portion of the EPA's "guideline" of the *Ldn55* (55 dBA day, 45 dBA night), maximum permissible sound level (for *urban residential* areas) as a noise limit or criterion, whether the ordinance or regulation was applied to urban residential, rural, or wilderness areas. In developing its guidelines, the EPA's primary focus (as expressed in the Levels Document) was on preventing hearing loss and speech interference, writing that "*The level of 55 dB [note: Ldn- 55 dBA day, 45 dBA night] is identified as maximum level compatible with adequate speech communication indoors and outdoors. With respect to complaints and long-term annoyance, this level is clearly a maximum serving a large majority of the population. However specific local situations, attitudes and conditions may make lower levels desirable for some locations.*"

6.4 The "large majority" that the EPA wrote of can be seen below in Figure 2. Of the roughly 214 million people living in the US in 1974, some *100 million* lived in areas with existing background sound levels *above* Ldn 55. Over *10 million* lived with background sound levels above *Ldn 70*.

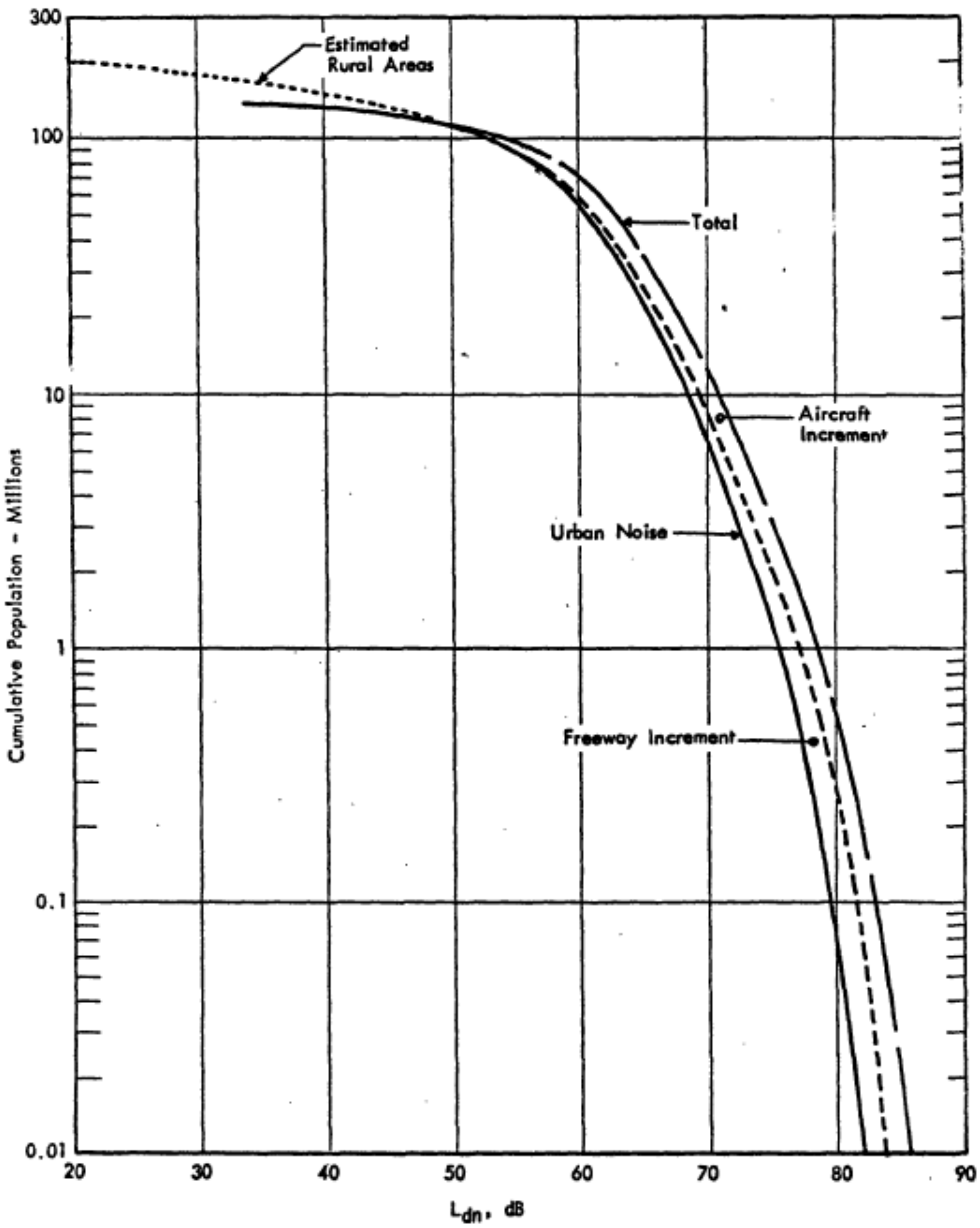

Figure 2 Residential Noise Environment of the National Population As A Function of Exterior Day-Night Average Sound Level (Ref B_5)

6.5 For those living with elevated background sound levels in urban areas, the EPA's guideline of a maximum Ldn 55 (55 day, 45 night) was well positioned to assure no hearing loss, nor any speech interference within a reasonable speaking distance, and would bring relief. However, for the some 100 million people living *outside* urban areas, with existing background sound levels *below* Ldn 55, the EPA's guideline has no protective effect. Indeed, the use of Ldn 55 as a "permitted" maximum level can serve to *degrade* the acoustic environment in quiet rural and wilderness areas by allowing *much higher* intrusive sound levels where existing background sound levels were much lower and create adverse community reactions and nuisance. ***This was never the EPA's intent.*** In its 1977 publication "Towards a National Strategy," the EPA indicated very clearly its wish to preserve the lower sound levels outside the urban areas:

> *"Encourage and assist Federal, State and local agencies in the adoption and implementation of a long-range noise control policy designed to prevent significant degradation of existing noise levels or exposure in designated areas. Such a "non-degradation" policy could be incorporated into land-use and development planning processes in an effort to reduce potential increases of noise level or exposure in area where quiet is at a premium, e.g., hospital zones, quiet residential areas, and wilderness areas."*

6.6 However the EPA's Office of Noise Abatement was defunded in the early 1980s, and this long-range noise control policy was never implemented. While the Noise Control Act remains in effect to this day, few if any took the time to fully understand the EPA's findings and cautions. Counties and towns that took the literal number of 55 dBA day, 45 dBA night, without considering the context as a guideline to reduce excessive noise in *urban residential* areas, inadvertently adopted noise limits that expose quiet rural residential areas to large changes from quiet background sound levels, potential degradation of the rural acoustic environment from natural to industrial sounds dominating the environment, adverse community reactions and potentially, health effects from intrusive noise sources including sleep disturbance and high annoyance *inside* the home.

Responding to the absence of noise impact assessment by wind industry sound consultants, Ambrose and Rand provided recommendations [7] to the Acoustical Society of America in 2015 for community noise impact assessment of wind turbine in quiet rural areas. A summary of the Ambrose/Rand EPA criteria assessment, coupled with the peer-reviewed research from Pedersen et al 2009 [8], was presented to the Acoustical Society of America technical panel 4aNS7 in Pittsburgh in 2015. The chart is shown below.

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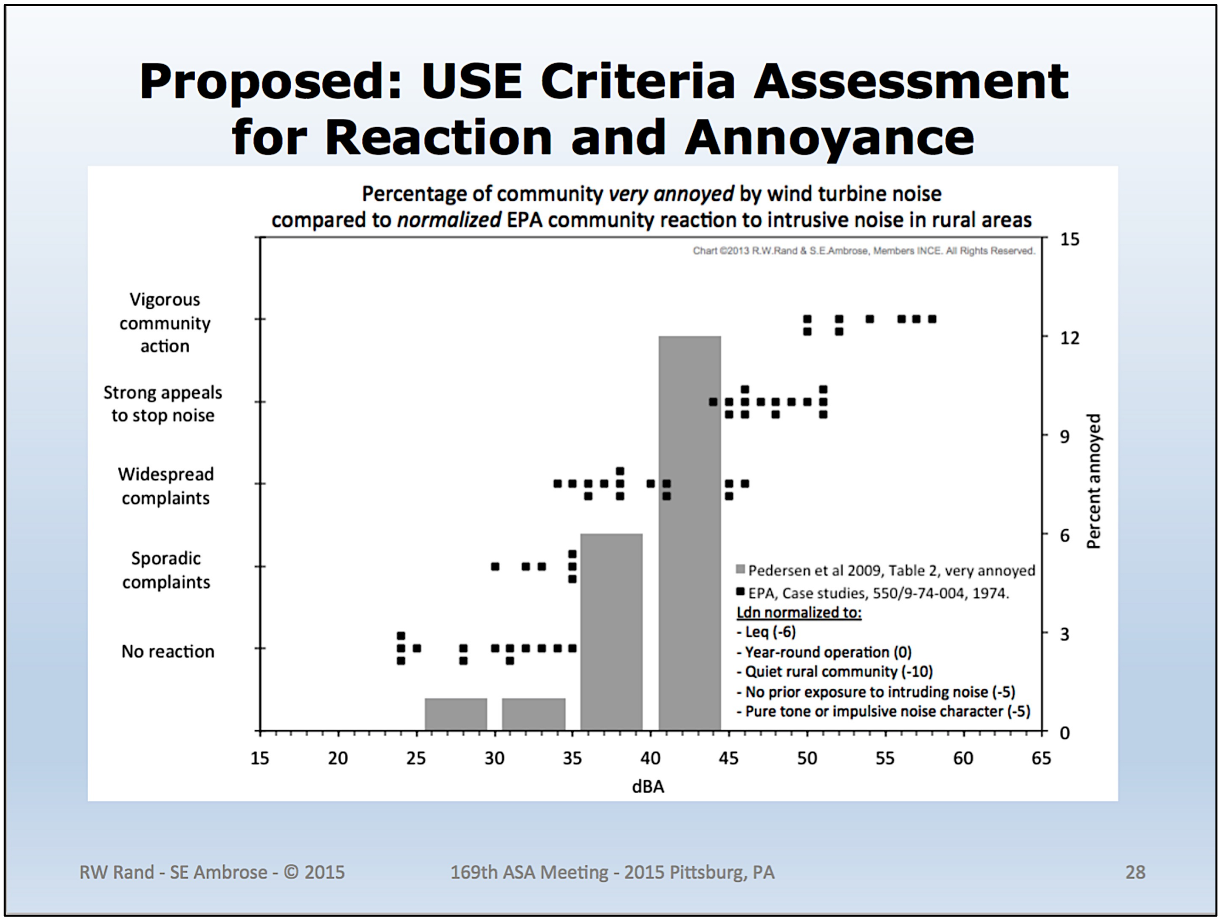
7 Ambrose, S. and Rand, R., 4aNS7. Why are regulators, communities, neighbors, and acousticians annoyed by wind turbines? https://acousticalsociety.org/wp-content/uploads/2018/02/Pittsburgh_Thursday_sessions.pdf.
8 Pedersen, E. et al, Response to noise from modern wind farms in The Netherlands, J. Acoust. Soc. Am. 126 (2), August 2009.



Comparing 1) complaints potential determined using EPA case studies adjusted to quiet rural areas and 2) wind turbine noise annoyance (percent "very annoyed") from Pedersen et al 2009, finds that widespread complaints and annoyance scale up equally and definitely above the mid-30s dBA. Regulatory noise limits at 60, 55, 50, 45 and even 40 dBA at quiet rural property lines or homes are unequipped to protect health and welfare; similar to ANSI.

ATTACHMENT 7. REVIEW OF HESSLER PRE-FILED TESTIMONY

A portion of Mr. Hessler's testimony is quoted below.

"Q. Can you please summarize your overall opinion of the noise analysis study submitted on behalf of the project?
A. In general, the quality of the work and noise modeling is perfectly satisfactory and consistent with good industry practice. I agree with the modeling methodology and believe that the predictions are realistic and accurate. However, ***I would fault the study for focusing exclusively on regulatory compliance and failing to evaluate or assess the potential noise impact of the project on the community****. For example, it is common, but by no means universal, industry practice to perform one or more baseline sound surveys of the existing conditions within the site area and then compare the expected project sound levels at residences to this pre-existing sound level. The amount by which the project sound level exceeds the background level generally determines the project's perceptibility and potential impact and it is good practice to attempt to minimize this differential. A 5 dBA increase above the baseline background level is often used as an ideal design goal because it limits the prominence and audibility of the project relative to the natural environmental sound level. Such a relative, ambient-based approach can, and often does, lead to an ideal design target that is lower than the applicable absolute regulatory limit(s)." (emphasis added)*

Q. Does that mean you believe a survey should have been done?
A. A survey and a subsequent impact analysis, while not absolutely essential in all cases, would have demonstrated a concern for the community's welfare and acceptance of the project. This approach is sometimes combined with optimization modeling where turbines are iteratively moved or eliminated early in the design process when significant changes are still practical in an effort to minimize the community noise impact and perhaps realize unilaterally adopted design targets. It is in everyone's best interest, including the project owner/operator, to minimize the potential for noise issues irrespective of any regulatory noise limits.

Q. In Intervenor John Homan's responses to Staff's first set of data requests Mr. Homan outlines quite a number of concerns about the project and, with respect to noise, says he would like to see a noise limit of 35 dBA at non- participating residences, among other things. Do you believe that's a reasonable condition that the Commission should consider imposing on the project?
A. No. While I would certainly like to see such a low sound level at all non-participating properties, I can only think of one wind project that I have been involved with that could have ever made that noise target and that project was located on an uninhabited island. From a

practical standpoint, such a level cannot be realistically achieved at this project, or at virtually any project located in a populated area.

Q. Be that as it may, do you believe the project will at least meet the County Zoning Ordinance noise limit?
A. Yes. The modeling indicates that the Deuel County Zoning Ordinance noise limit of 45 dBA at non-participating residences will be met, although just barely in two cases where the predicted level is 44.9 dBA.

Q. Michael Hankard's supplemental direct testimony proffers and supports a sound condition consistent with several past projects of 45 dBA at non- participating residences and 50 dBA at participants. Do you believe the Commission should agree to these noise limits and make it a condition of the permit?
A. Yes. I think that's a reasonably fair condition for this project taking into account what I just said about participants with predicted sound levels above 45 dBA. In general, I would have strongly preferred to see predicted sound levels that did not run right up to the 45 and 50 dBA limits. At this point, I don't see any way of significantly reducing receptor sound levels short of thinning the turbine density to the point of likely economic non-viability.

<u>Comments on Hessler pre-filed testimony:</u>

7.1 I agree with Mr. Hessler's statement that a survey should have been done. However it is far more than an optional step as his writing might suggest.

For facilities with no significant external noise producing equipment, a background sound survey may not be necessary. However: Because wind turbines are powerful and especially low-frequency noise emitters, South Dakota ARSD 20:10:22.18 (3) & (4) cannot be responded to adequately without a background noise survey, needed to supply the requested information in those sections of South Dakota law.

The lack of a background sound survey prevents comparison of expected noise levels to actual minimum quiet rural background L90 sound levels [9], blocks assessment of changes in noise level and background soundscape (rural natural ambient to 24/7 industrial) and neuters proper consideration of the application with regard to the aforementioned regulatory filing requirements.

The omissions suggest a troubling lack of respect for the law and the community's health and welfare from the applicant and their sound level consultant Hankard Environmental. As Mr. Hessler wrote, "*It is in everyone's best interest, including the project owner/operator, to minimize the potential for noise issues irrespective of any regulatory noise limits.*"

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9 Quiet rural background L90s typically fall in the range of 20 to 25 dBA obtained per ANSI S12.100.

7.2 I do not share Mr. Hessler's apparent confidence that the predicted noise levels will never ever exceed 44.9 dBA during field testing.

7.3 Data from the MassDEP Study show that short term noise levels can exceed long term average noise levels by 6 to 11 dBA. The MassCEC study found 5-minute measured average noise levels generally were at or under predicted levels ***but occasional noise levels exceeding predicted levels by 1-3 dBA***; see notations on Figure below for 330 and 660 meters distance, 1082 and 2164 ft, the same modeling used in the Hankard report; ISO 9613-2, G=0. Neither Hankard nor the MassCEC accounted for manufacturer text uncertainties.

7.4 The applicant has elected to build "to the wire" at 44.9 dBA, using tenths of a dB in the forecast, with no design safety margin. Mr. Hankard has assured in Appendix D that the facility will ***never*** exceed 44.9 dBA. An occasional 1 to 3 dBA exceedance may not seem like much. However the Deuel County regulation is exacting. No exceedance of the average levels, regardless of averaging time, is permitted. Is it possible that the facility could be measured at 45.1 dBA? The MassCEC study results support the potential for exceeding.

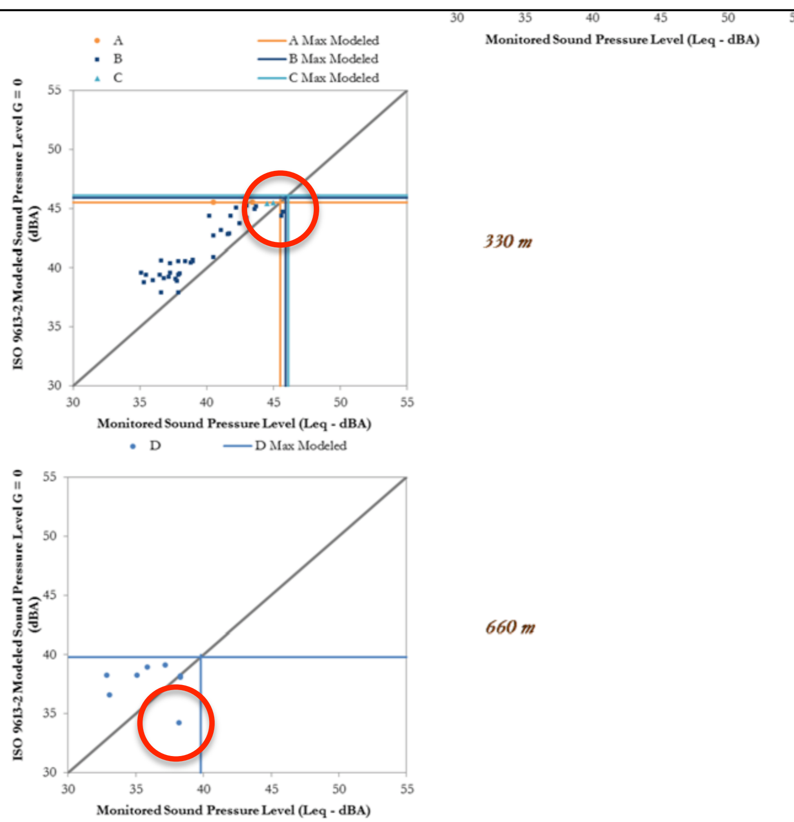


FIGURE 18: COMPARISON BETWEEN MONITORING RESULTS (FIVE-MINUTE LEQ) AND MODELING RESULTS (ISO 9613-2, G=0)

7.5 The County's standard "Noise level shall not exceed 45 dBA Average" brings up the issue of average over what time period. The wind industry has settled on 10-minute averages. However the human ear does not wait 10 minutes to process a noise level. The ear's response to noise is on the order of 1/8 second or faster.

Longer averaging times such as 10-minutes, 1-hour, or longer have the effect of allowing higher modulating wind turbine maximum sound levels over the noise limit to average in with lower sound levels at or lower to the noise limit, and arrive at an average which technically meets the limit but allows much higher noise levels to impact the property in the meantime. The reading of Deuel County Zoning Ordinance "to promote health and the general welfare ... " would normally preclude allowing excessive noise levels at residences. However the wind industry use of long-term averaging hides the high intrusive noise levels emitted by the turbines, levels which the law ostensibly is intended to prevent.

7.6 I agree with Hessler's assessment that predicted levels at participants compare with the regulatory limit very unfavorably with expected average sound levels up to 49.8 dBA (50 dBA in common use) and at least a dozen residences above 47 dBA. In my experience, wind turbine noise levels above 40 dBA and especially above 45 dBA outdoors have led to serious complaints, appeals to stop the noise residents sleeping outside in tents, or homes vacated. The prediction does not assess for nighttime audibility indoors, physical sensation of pressure or low frequency noise or sensation inside homes, all factors in noise complaints.

7.7 A 35-dBA noise limit was discussed in Mr. Hessler's testimony. A 35-dBA noise limit prevents an *incompatible* noise environment for an intrusive, unfamiliar noise at rural residential homes (ANSI S12.9). A 35-dBA noise limit is consistent with preventing high annoyance for a significant portion of the population (Health Canada). A 35-dBA noise limit reduces potential for exceeding WHO sleep disturbance thresholds for impacts on motility, duration of various stages of sleep, in sleep structure and fragmentation of sleep (WHO 2009 Table 2).

7.8 I can understand Mr. Hessler's apparent professional interest as P.E. and INCE Member in considering a 35-dBA noise limit for this project. I must disagree with Mr. Hessler's ultimate recommendation of 45 and 50 dBA. Mr. Hessler is a Member of the Institute of Noise Control Engineering and is required by membership to "hold paramount the safety, health and welfare of the public". I understand this requirement is equally strong or perhaps stronger for licensed professional engineers. The word "paramount" means "above all other considerations"; including the consideration Mr. Hessler stated earlier in his testimony, "***I don’t see any way of significantly reducing receptor sound levels short of thinning the***

turbine density to the point of likely economic non-viability". As INCE Member I must take issue with this statement by Mr. Hessler, a P.E. and INCE Member.

7.9 It appeared that Mr. Hessler's argument for rejecting lower noise limits was based on evaluating the economics of the project and giving that consideration sufficient weight to override the health and welfare of the public. If true, that line of thinking breaches the INCE Canon number 1, "hold paramount", and equivalent ethical requirements for licensed professional engineers.

It is not up to the noise control engineer to determine that economics outweigh the public health and welfare they are pledged to hold paramount. By professional understanding, the INCE Member has no authority whatsoever to recommend policy that would result in a member of the public being harmed by excessive noise levels. For this project, "the public" includes *every nearby resident*. And indeed, Mr. Hessler has cautioned his client for this project, the South Dakota Public Utilities Commission, about excessive noise levels forecast at participating properties.

By INCE Rules of Practice, the INCE Member *shall* hold paramount the safety, health, and welfare of the public in the performance of their professional duties. Further, they *shall* "Notify their client and such other authority as may be appropriate, if their professional judgment is overruled under circumstances where the public safety, health, property, or welfare are endangered."

Mr. Hessler's *client* may elect to protect public health and welfare, or, may overrule caution and approve excessive noise levels, but the INCE Member does not have that authority or professional license. If the project is too noisy or too big for a locale, it is not the job of the noise control consultant to recommend increased noise limits. It is the paramount job of the noise control consultant to protect public safety, health and welfare, above all other considerations. As Mr. Hessler said, "*It is in everyone's best interest, including the project owner/operator, to minimize the potential for noise issues irrespective of any regulatory noise limits.*"

10. In this respect (see point 8 above), as INCE Member I depart from and must advise strenuously against Mr. Hessler's nod to 45 and 50 dBA noise limits for non-participating and participating residents. The sufficient evidence provided in the WHO research of 2009, the County's legal requirement for *compatibility* in Ordinance B2004-01 Section 104 coupled with ANSI standards for compatibility, and Health Canada's findings of high-annoyance ramping above 35 dBA coupled with medical research tying high-annoyance to health effects (Vermont 2014) present consistent validation for lower criteria protecting health and welfare and complying with Deuel County law; a long term average not to exceed 35 dBA.

ATTACHMENT 8. REVIEW OF PREDICTED LEVELS

Figure 8.1 Predicted average noise levels scaled into Google Earth. From November 2018 noise analysis. The revised analysis of January 2019 omitted 50 dBA noise contours, and cluttered the chart with enlarged shadowed symbols, preventing review of facility noise levels versus distance. It is not clear whether the facility wind turbine locations are fixed. The original layout figure was used for purposes of estimating noise level versus distance.

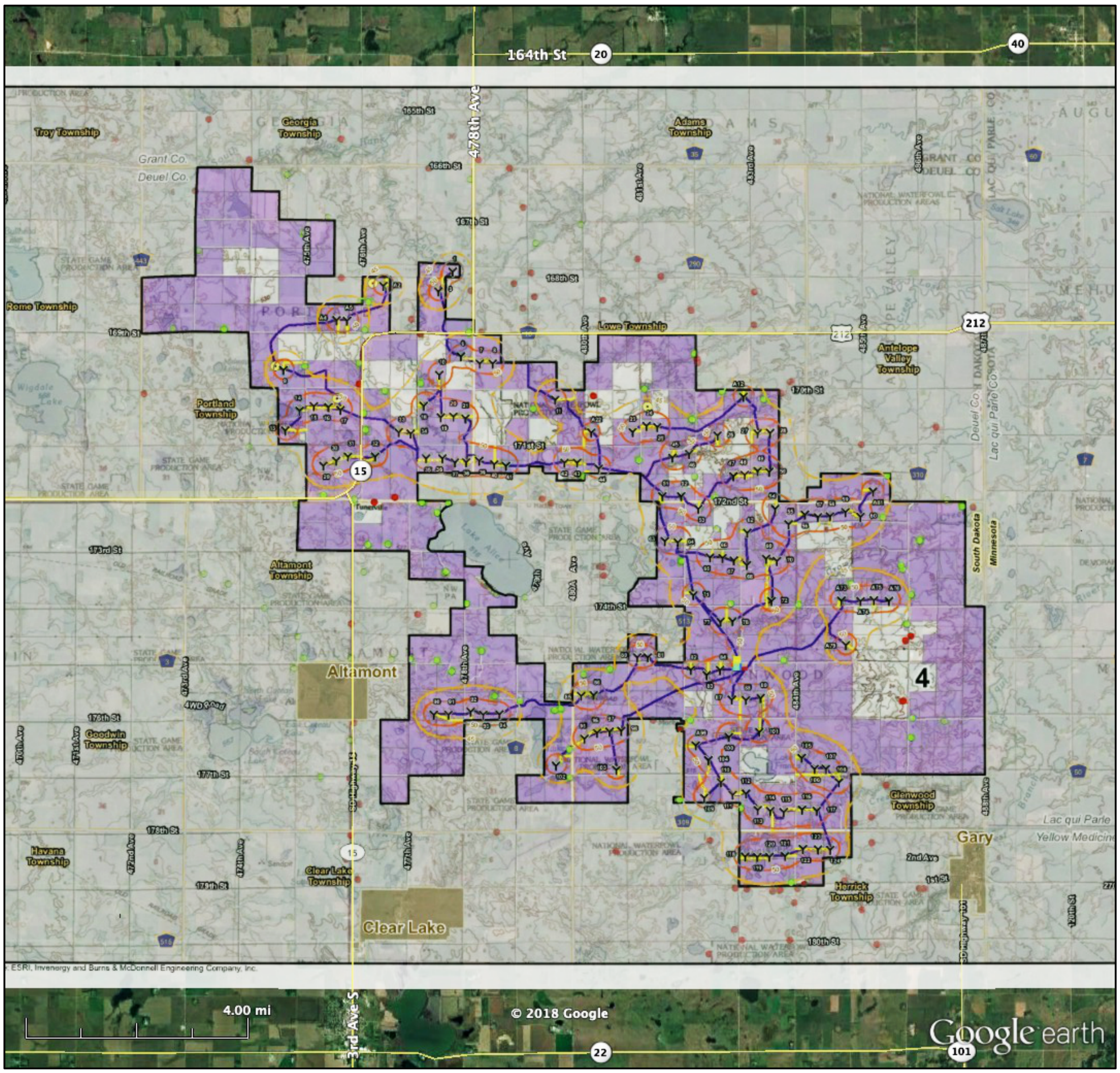


Figure 8.2 Predicted average noise levels including south of WTs 118-121, 50 and 45 dBA contours. Red dots are non-participating residences; green dots are participating. From November 2018 analysis. Yellow arrow shows analysis path.

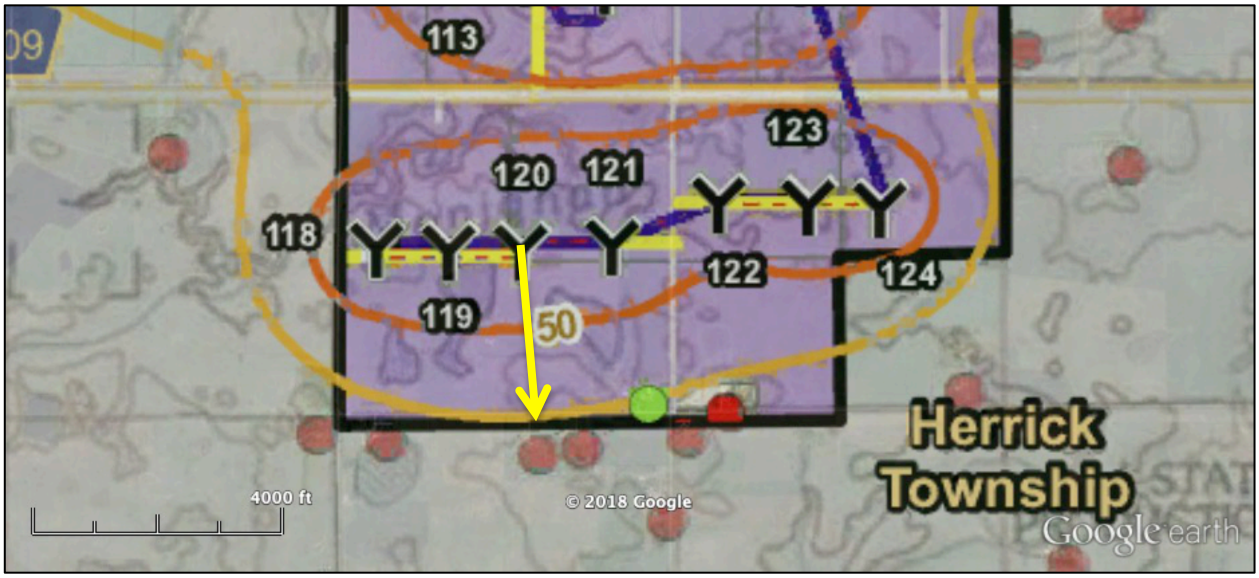


Figure 8.3 Predicted average noise levels including east of WT11, 50 and 45 dBA contours. Red dots are non-participating residences; green dots are participating. From November 2018 analysis. Yellow arrow shows analysis path.

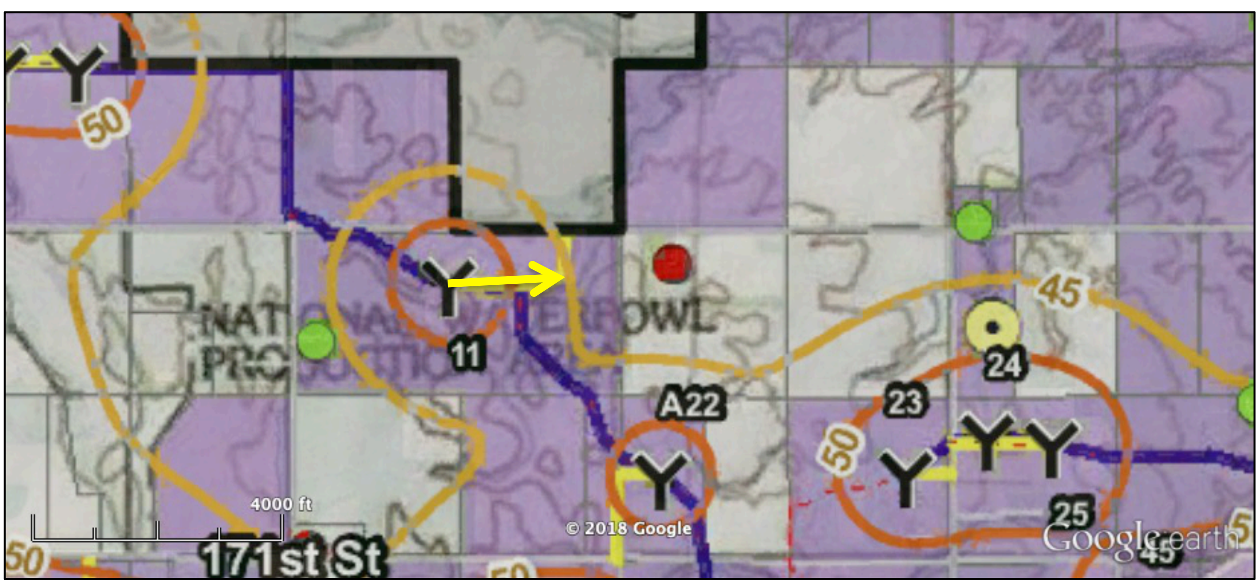
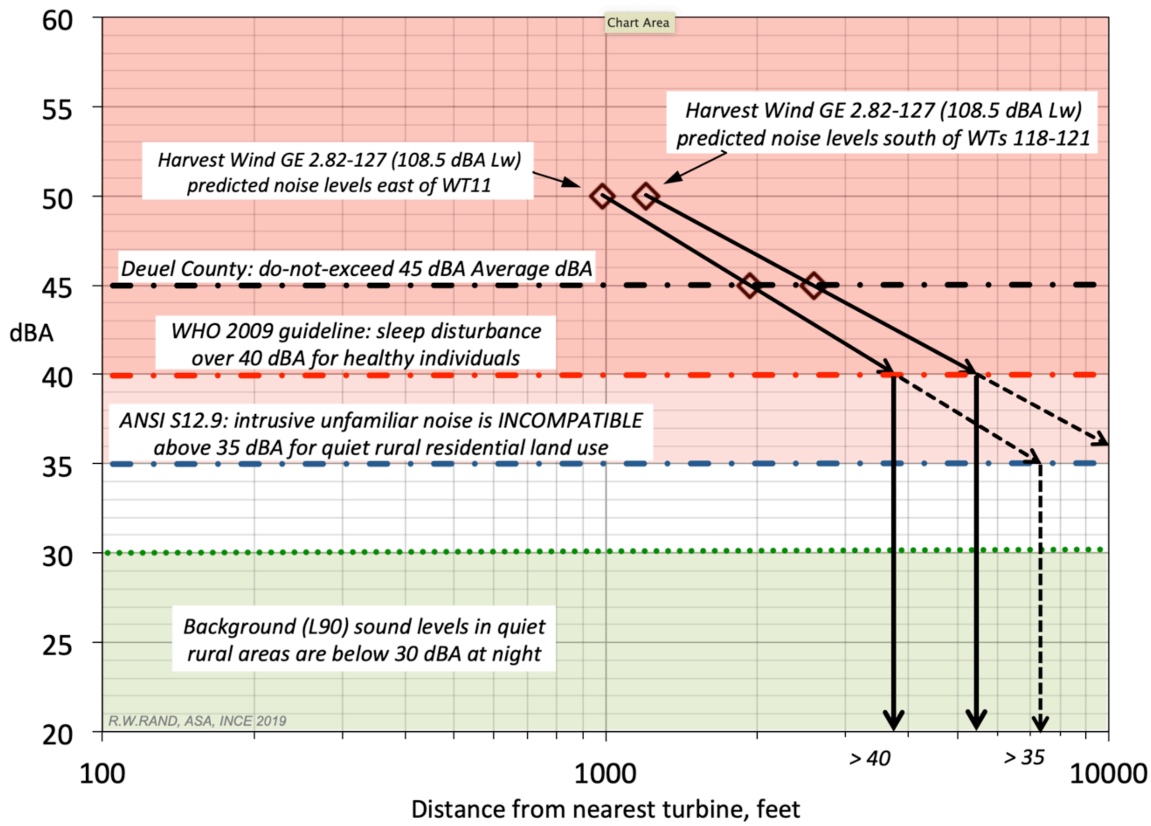


Figure 8.4 Distances associated to predicted noise levels.



8.1 Two paths leading away from the turbine locations (see Figures 8.1-8.3) were measured for noise level versus distance and plotted on Figure 8.4 to estimate distances to 40 and 35 dBA levels from the facility. Levels near WT11 are representative of those near a single turbine with many further away. Levels near WTs 118-121 are representative of those near a number of turbines nearby in a row. As a preliminary analysis, noise level drops with distance linearly on a semi-log chart. The distance to 40 dBA ranges from roughly 3800 feet (2/3 mile) to a little over 1 mile. The distance to 35 dBA ranges from roughly 7200 feet (1-1/3 mile) to 2 miles. Thresholds shown include:

- Black dashed line: Deuel County sound limits.
- Red dashed line: WHO 2009 threshold for sleep disturbance.
- Green dashed line: ANSI S12.9 threshold for incompatibility for an unfamiliar intrusive noise in a quiet rural area.

8.2 Wind turbine Lmax maximum levels have been measured using ANSI standards and are readily available from field studies, example the MassCEC Study [10].

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10 RSG et al, “Massachusetts Study on Wind Turbine Acoustics,” Massachusetts Clean Energy Center and Massachusetts (MassCEC) Department of Environmental Protection, 2016.

8.3 Recent testimony from wind industry experts confirmed that wind turbine Lmax noise levels are as much as 11 dBA above the long term average (Leq, the "equivalent" noise level is considered an "average" for a noise measurement period). In a court case (United States District Court, Eastern District of Michigan Northern Division, Case No. 17-cv-10497) evidence was submitted by consultants for the wind industry (RSG, Inc. and Epsilon Associates to Tuscola Wind III, LLC) documenting the MassCEC Study having determined ranges of Lmax values from 6 to 11 dB greater than the Leq and stating "*For this study, to be conservative, we are using an additional 11 dB adjustment above the +2.0 dB already modeled.*" [11] (Lmax = Leq + 11, dBA).

8.4 Recent testing in a quiet rural area in Vermont [12] confirmed that the A-weighted outdoor-to-indoor wind turbine noise level reduction (OILR) can be very poor, on the order of 1-3 dBA with windows fully open, and only 6 dBA with windows partially open. Most people keep one or more house windows at least partially open during much of the year to let fresh air indoors as part of their normal use of their property. From experience, this is true for many households even in winter, especially if a wood stove is used for heat.

8.5 Standard ISO 9613-2 provides the basis algorithm in modeling software used for noise prediction including for wind turbines. The standard provides a long term *average noise level* subject to inherent variability (estimate of accuracy) of +/- 3 dBA to 1000 meters (3280 feet); an estimate of accuracy beyond 1000 meters is not provided.

8.6 Wind industry noise research beyond 1000 meters [13] found "*Averaged far-field noise levels of a 2 MW wind turbine vary up to 7 dBA over a diurnal cycle. Enhanced far-field amplitude modulation depths are observed during evening and night.*"

8.7 Thus a predicted sound level of 40 dBA within 1000 meters of a wind turbine could result in a long term *average* noise level ranging as loud as 43 dBA (ISO 9613-2 uncertainty of +/- 3 dBA), and an associated potential maximum noise level as loud as 52 dBA (Leq+11). Similarly, beyond 1000 meters, a predicted average noise level of 35 dBA could be as loud as an average of 38 dBA, with potential maximum noise levels of 49 dBA.

8.8 There is no support in ISO 9613-2 for asserting that the actual facility noise levels will never exceed predicted levels. As stated in the ISO 9613-2 model standard, the estimates of accuracy in ISO 9613-2 Table 5 "*should not necessarily be expected to agree with the variation in measurements made at a given site on a given day. The latter can be expected to*

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11 Memo, from Ken Kaliski, P.E., INCE Bd. Cert., RSG Richard Lampeter, Epsilon Associates to Ryan Rumford, NextEra Energy Resources, December 22, 2016.

12 "Acentech measurements in July 2014 under similar test conditions did generally agree with this value; and depending on the measurement location within the room, yielded an OILR value of about 1 to 3 dBA with the windows fully open.", Acentech Report to Vermont Public Service Department, Vermont Public Service Board Docket 7156, Acentech Project 624219, 25 September 2015.

13 Barlas et al, Variability of wind turbine noise over a diurnal cycle, Renewable Energy Volume 126, October 2018, Pages 791-800. https://doi.org/10.1016/j.renene.2018.03.086. Renewable Energy is the "Official Journal of the World Renewable Energy Network".

be considerably larger..."

8.9 Based on wind industry data [11], average wind turbine noise levels of 40 dBA (Leq) outside at a home have a potential maximum noise level (Lmax) as loud as 51 dBA. Assuming a 6 dBA noise reduction outdoors to indoors, the Lmax noise level indoors can range up to 45 dBA; by WHO guidelines based on less annoying transportation noise [14], more than loud enough to disturb sleep.

8.10 Periodic wind turbine noise (such as "whumps" or "thumps" as often reported by neighbors) with a long term average of 35 dBA outdoors could result in outdoors Lmax noise levels as loud as 46 dBA, with resulting sudden intrusive noise levels indoors as loud as 40 dBA, well above the Lmax sleep disturbance thresholds for EEG awakening and motility established by WHO sufficient evidence.

8.11 Wind turbines with pitch control such as the GE 2.82-127 can be modified to run at slower speeds and lower power on demand, ostensibly reducing noise levels. This method of control is sometimes referred to as "Noise Reduced Operation" or NRO. Some wind turbine manufacturers offer 1-dB to 4-dB NRO settings which can be engaged or freed with SCADA controls, which they market as a 1 to 4 dBA noise reduction for the wind turbine when operated within turbine design specifications. Does NRO work reliably? It is generally accepted that it takes a 3-dBA change for people to notice a difference.

8.12 No Guarantees: NRO operations are *not guaranteed* to reduce loudness at the installed location under real-world conditions. NRO controls were tested extensively with GE's technical assistance at a 3x1.5MW-turbine wind facility in Vinalhaven, Maine. No significant reduction in loudness was obtained [15] in real-world operation. I have seen no news reports or technical reports in the last nine years confirming that NRO works *reliably* in all atmospheric conditions in the real world outside test facilities. Whereas the County law is unbending; average noise levels must not exceed the noise limit anytime.

8.13 The application did not assess for perceptible vibration at nearby homes. It is well known from basic field research that noise can produce vibrations in homes that are humanly perceptible, as outlined by Hubbard [16]. Hubbard's Figure 8 provides a composite guideline for whole body vibration perception.

8.14 There is no evidence to date that wind turbine noise is somehow *less* annoying, *lower* in apparent loudness, or that an Leq-outdoors or Lmax-indoors sound level from a wind turbine modulation is *less* capable of provoking sleep disturbance or high noise annoyance or

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14 Pedersen et al.: Response to wind farm noise, J. Acoust. Soc. Am., Vol. 126, No. 2, August 2009.
15 Ben Hoen et al, "Assessing the Impacts of Reduced Noise Operations of Wind Turbines on Neighbor Annoyance: A Preliminary Analysis in Vinalhaven, Maine", Lawrence Berkeley National Laboratory, LBNL-3562E, June 2010. https://emp.lbl.gov/sites/all/files/lbnl-3562e.pdf
16 Hubbard, H., "Noise Induced House Vibration and Human Perception", Noise Control Engineering Journal, Volume 9 No.2, pp. 49-55, September-October 1982.

community response than noise levels from transportation noise on which the WHO sufficient evidence for sleep disturbance is based. Thus the WHO guidelines provide working baseline criteria for assessing wind turbine A-weighted noise levels. While the A-weighted noise level that filters out low frequency noise, unfiltered noise and vibration levels either predicted or measured can be compared to known criteria from Hubbard.

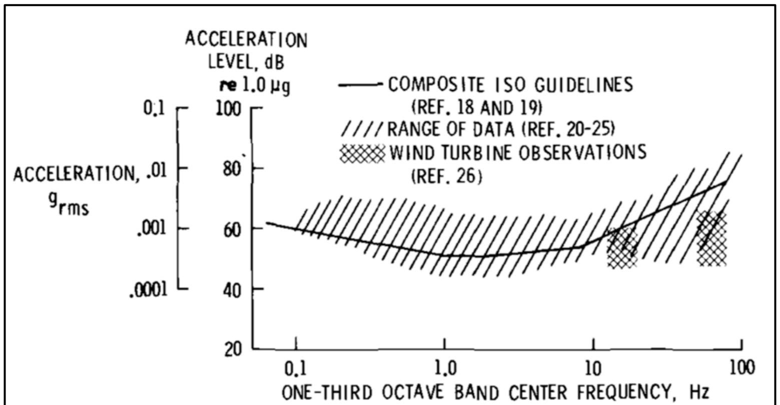

Figure 8—Most sensitive threshold of perception of vibratory motion by humans

Figure 8.5 Hubbard 1982, Figure 8; curve represents the combined responses of a person in either the up and down, fore and aft, or sideways directions whichever is the most sensitive. The composite guidelines curve of Fig. 8 is judged to be the best representation of the available whole body (most sensitive axis) vibration perception data (Hubbard).

8.14 Hubbard's Figure 9 outline "perceptible vibrations" thresholds spanning the low-frequency range from 0.1 to 100 Hz in one-third octave bands.

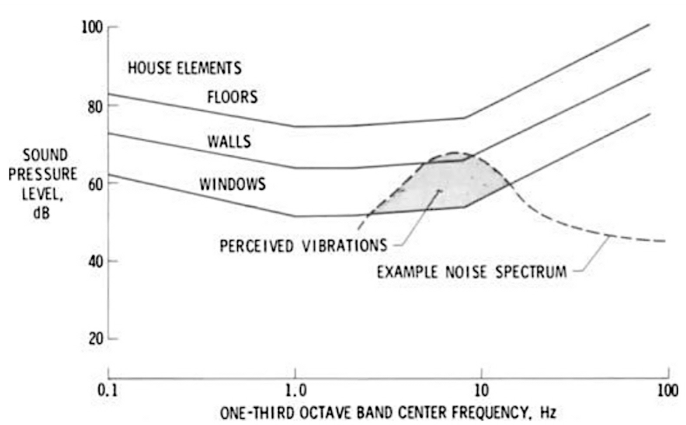

Figure 9—Sound pressure levels sufficient to cause perceptible vibrations of house structure elements over a range of frequencies

Figure 8.6 Hubbard 1982, Figure 9; indicates the outside sound pressure levels in given one-third octave bands causing perceptible vibration inside a house structure.

8.15 One-third-octave band sound levels acquired outdoors during partial power operation, for the widely spaced wind facility comprised of eight, Nordex 2.5-100 2.5MW turbines at Shirley, were superimposed on the Hubbard data in Figure 1 below.

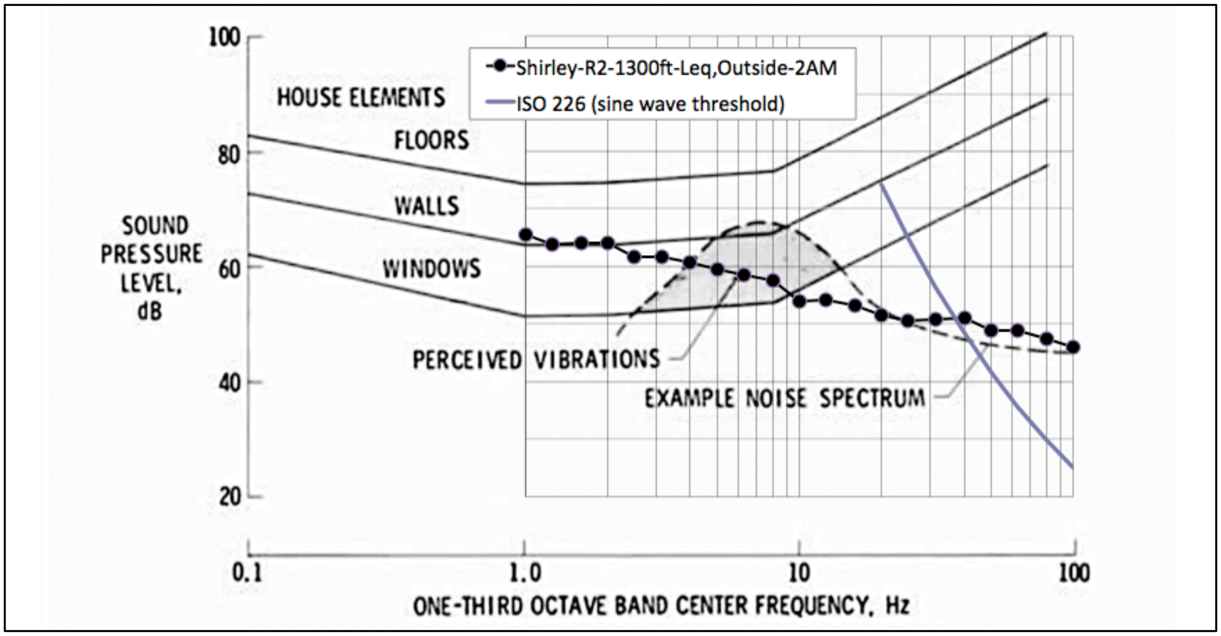

Figure 8.7 Perceptible Vibration. From outdoors noise levels acquired at a comparable wind turbine facility, appears certain for the Application. Note: Hubbard's Figure 9 indicates the outside sound pressure levels in given one-third octave bands that will cause perceptible vibration inside a house structure. To this, outdoors 1/3 octave band sound levels acquired at Shirley, WI 2012 during partial power operation were superimposed (), along with the median audibility threshold listed in ISO 226 (range +/-12dB). The figure shows that vibration is possible from wind turbine noise and perceivable indoors as sensation well below the median audible threshold (which has a standard deviation of 6+ dB at low frequencies).

8.16 How do these low frequency noise levels at Shirley relate to probable low frequency noise levels at the distances for neighbors in Deuel County? It appears they may be roughly equivalent, based on analysis below.

- The Application's proposed 2.82-127MW turbines are louder (A-weighted) than the Shirley 2.5MW turbines. The Application turbine blades are longer, and with more turbines the likelihood of inflow turbulence from other turbines is increased, with resulting increased low frequency noise levels by at least 1 or more decibels [17,18].
- The data shown in Figure 1 is for partial power conditions; during Shirley testing, Duke Energy did not supply full power operations despite apparent suitable wind

17 Møller, H.; Pedersen, C.S. Low-frequency noise from large wind turbines. J. Acoust. Soc. Am. 129 (6), 3727–3744.
18 Shepherd, D.; Hanning, C.; Thorne, R. Noise: Windfarms. Encyclopedia of Environmental Management DOI: 10.108/E-EEM-120047802, 2012.

conditions. At full power the low frequency noise levels are expected to be higher.

- Unlike for higher frequency noise sources, wind turbine low frequency noise levels drop with cylindrical propagation beyond a kilometer with near and far turbines contributing to primarily low frequency immissions at residential properties. The charted levels are judged to approximate noise levels for distances to neighbors of about a 1/2 mile, remaining in the range of perception [19].
- Wind turbines are not steady noise sources; they exhibit amplitude modulation that increases noise levels well over the averages often quoted. Peak or maximum noise levels can range much higher [20], supporting greater perception in a wider range of frequencies. Barometric oscillations at blade pass frequencies may excite house structural resonances and increase sound levels indoors through sudden pressure pulsations impacting the house exterior [21]. The peak perception frequencies in Figure 1 are in the frequency range of house wall and window resonances.
- The use of so-called "LNTE" blades appears to provide no low frequency noise reduction in the range associated to perception by Hubbard. The figure below shows a comparison of standard and LNTE blade technologies for the GE 2.5-116 [22].

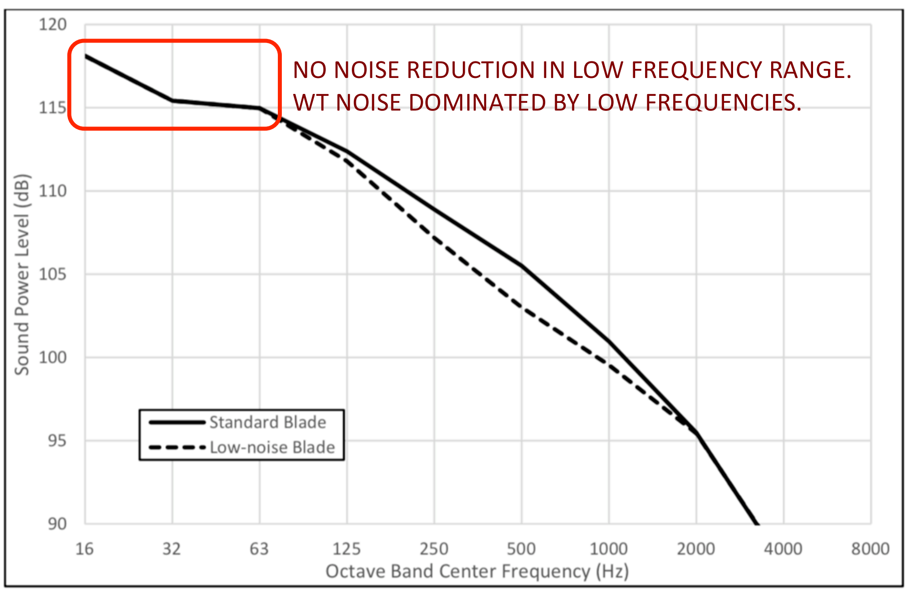

Figure 8.8 LNTE noise reduction limited to mid-frequency bands, shifts acoustic signature to low frequencies.

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19 Marcillo, O., S. Arrowsmith, P. Blom, and K. Jones (2015), On infrasound generated by wind farms and its propagation in low-altitude tropospheric wave-guides, J. Geophys. Res. Atmos., 120, 9855–9868, doi:10.1002/2014JD022821.
20 Memo, from Ken Kaliski, P.E., INCE Bd. Cert., RSG Richard Lampeter, Epsilon Associates to Ryan Rumford, NextEra Energy Resources, December 22, 2016.
21 Ambrose, S. E., Krogh, C. M., Rand, R.W., "Wind Turbine Acoustic Investigation: Infrasound and Low-Frequency Noise--A Case Study", SAGE Bulletin of Science Technology & Society 2012 32:128.
22 Source, Pre-Construction Noise Impact Assessment for the proposed Canisteo Wind Farm, NY State Board on Electric Generation Siting and the Environment Case 16-F-0205, October 23, 2018. Figure 3-3, GE 2.5-116.

8.17 Three things are evident from this comparison:

- LNTE provides no noise reduction below 100 Hz in the 16, 31.5 and 63 Hz octave bands,
- the bulk of the wind turbine noise output is low-frequency, below 200 Hz, and
- use of LNTE blades shifts the wind turbine acoustic signature into lower frequencies, thus an A-weighted predicted noise level consists more of low frequency noise than for a non-LNTE turbine.

8.18 Perception of noise from wind turbines was documented as occurring some 10 dB below ambient sound levels from wind in trees [23],"*From the experimental results it has been observed that the masking threshold occur when the wind turbine noise level is around 10 dB lower than the ambient sound levels.*" For example, wind noise would have to 55 dBA to start to mask wind turbine noise at 45 dBA, and does not assure masking of strong low frequency periodic whumping. Nor does ambient wind noise prevent wind turbine low-frequency noise and pressure pulsations from impinging on, penetrating and shaking homes.

23 Bolin, K., "Wind Turbine Noise and Natural Sounds- Masking, Propagation and Modeling", Doctoral Thesis, Royal Institute of Technology, Stockholm, Sweden, 2009.

ATTACHMENT 9: BACKGROUND: WIND TURBINE NOISE

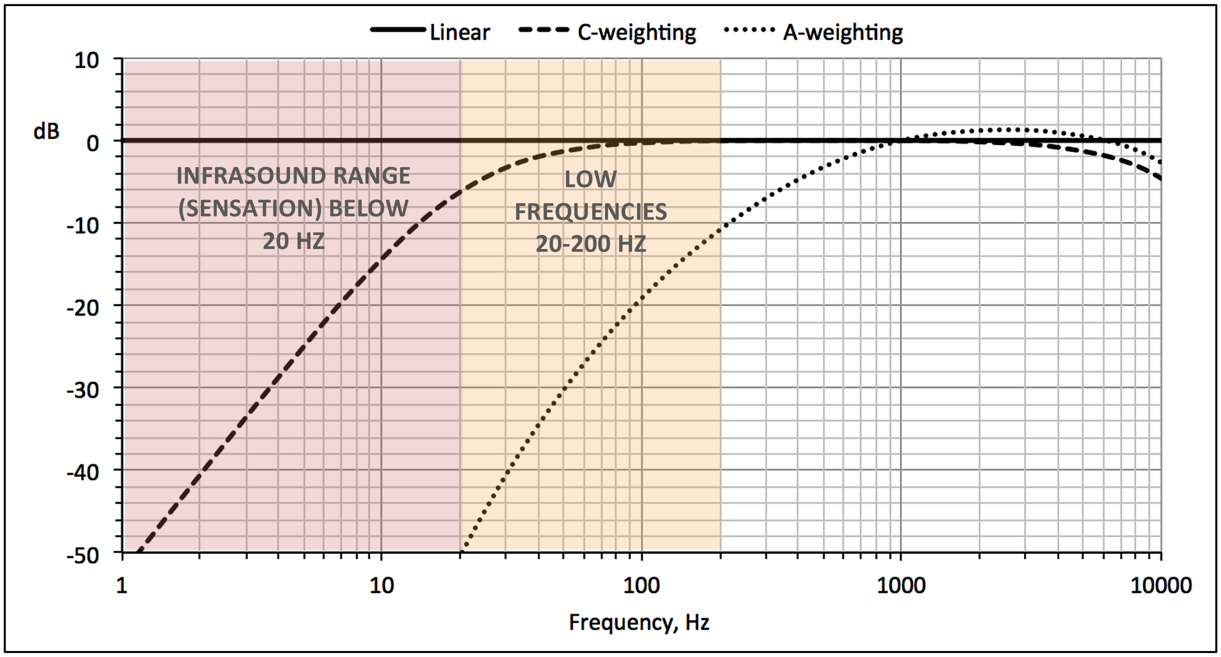
9.1 In the mid 1980s the US Department of Energy (Kelley et al) found that large wind turbine technology (2 MW) produced strong annoyance as far as several kilometers and presented these finding in papers and to the wind industry. Kelley et al identified impulse pressure pulsations at the blade pass frequency were connected to "transient stall" during the blade passage in front of the tower. Kelly et al also identified low-frequency noise as a dominant factor in annoyance at neighbors many thousands of feet away (similar to complaints of thumping and low frequency tones in neighborhoods near large rock concerts). The wind industry quickly changed reversed the blade design so that the blades were rotating in front of the tower rather than behind. However this did not eliminate the transient stall impulse pulsations, it only reduced them (and set up other problems including, how to keep the turbine faced into the wind and, preventing the bending blades from striking the tower). A more effective way of minimizing the acoustic pressure impulse pulsations and low frequency noise was needed.

9.2 In the mid 1990s a wind turbine noise measurement standard was developed (IEC 61400-11) which required A-weighting filtering on all measurements. A-weighting is used for assessing speech frequencies and hearing loss and filters out low frequency noise. At the wind turbine blade pass frequency of around 1 Hz, an A-weighted microphone signal is attenuated by -149 dB, rendering it invisible to testing or later assessment. Similarly low frequency noise at 10 and 20 Hertz (a range where house resonances occur) is attenuated by -70 and -50 dB, respectively, almost impossible to detect or assess. A comparison of the unweighted and A-weighted sound power levels for a modern wind turbine shows how much has been deliberately hidden by the wind industry standard: about 99 percent of total acoustic power output.

Vestas V90-3MW	Unweighted (dB)	A-weighted (dBA)
Sound Power Level, dB re 1pW	128.5 dB	109.4 dBA
Percentage total power	100 %	1 %

It is hard to imagine a cheaper and more effective way to prevent understanding or proper assessment of the low frequency output of wind turbines than to A-weight the data.

C-weighting has response within 6 dB at 20 Hz below which noise turns from audible sound to sensation. C-weighting covers about 1/4 of total wind turbine acoustic emissions. The bulk of large wind turbine acoustic power output is infrasonic (sensation range).



9.3 To date, distance has proved the only ***reliable*** noise control option available for wind turbines. Distance must be scaled sufficiently to turbine size and power output prior to permit. If complaints occur during operation, the only reliable noise control option available is shutdown. This has been confirmed at multiple sites including Falmouth, Fairhaven, and Kingston, Massachusetts, where municipal-owned turbines have been shut down at night or permanently shut down under court order. In an apparent nod to wind turbine noise control deficiencies, regulatory and oversight bodies have adopted minimum distance requirements for wind turbines, including Poland, Bavaria, the Cape Cod Commission, and many others.

9.4 It is worth noting that no one is putting a gun to an applicant's head and demanding they use wind turbines to generate electric power. All other electric power generation technologies have numerous noise control options: enclosing noisy equipment in buildings, insulating buildings, lagging piping and ductwork, installing air and gas-flow silencers, erecting barriers, and the list goes on. Whereas wind turbine facility applicants have voluntarily selected a deficient technology: the only reliable noise control option for wind turbines is sufficient setback distance set during permitting.

9.5 In contrast to all other forms of power generation, nuclear, gas, coal, oil, biomass, solar, and hydro as examples: wind turbine facilities are now elevated hundreds of feet into the air. Wind turbines operate more at aircraft height than ground height. Wind turbines must remain exposed to the wind: additional noise control at the source is not possible (confirmed by Vestas CEO, 2011). Similarly, due to the tremendous height of the wind turbine noise source, barrier walls are not feasible. And similarly, the predominantly low frequency noise emitted by wind turbines is not easily reduced by acoustic controls in homes; low frequency noise and "whump whump" pulsations from wind turbines penetrate and shake homes.

9.6 This single, inescapable noise control design deficiency of wind turbines seems to drive the entire contentious wind facility design and permitting process. Wind turbine hearings are dominated by attorneys. Disturbingly, wind sound consultants who are INCE members required by INCE Membership to "hold paramount the safety, health and welfare of the public" are noticeably *silent* about noise impacts on people. In the last nine years reviewing dozens of applications, I'm not sure I've seen a single wind turbine application assess for noise impact on people. During application hearings, wind turbine sound consultants provide sound level predictions; no noise impact assessment. Noise impacts on people are handled by paid health consultants who assert universally that there will be no problems.

9.7 Wind industry application noise sections that discuss regulatory noise limits only, and appear to imply that meeting a regulatory noise limit will prevent complaints and annoyance, mislead regulators.

9.8 Wind turbine testing for background sound levels has proved problematic where regulations specify a maximum increase over background. Rather than design with sufficient distance to meet regulatory limits, wind sound consultants have been observed obtaining sound measurements near streams, culverts, directly under trees, and on busy roads- anything to drive the numbers up. Many reports have listed background sound levels in the 40s dBA. Any tests done for background must be carefully scrutinized understanding that the primary task of the wind sound consultant is to obtain the highest reading possible and minimize apparent changes in noise level, rather than comply with ANSI standards such as S12.100.

SUPPLEMENT 10: NEUTRAL ANALYSIS

As a neutral party, my background is in power generation noise control, community noise impact assessment, and designing to meet regulations and prevent complaints. I worked for Stone & Webster for ten years in the Noise and Vibration Group and have designed or reviewed noise controls for most utility-scale power technologies and a number of commercial technologies. If someone who doesn't know me and what I do levels the charge "anti-wind", they also don't know that by the same logic they'd have to label me "anti-coal", "anti-oil", "anti-nuclear", "anti-transformer", even "anti-backup-generator".

In my firm's independent professional capacity, there is no particular "bias" or interest in the brand of power generation being investigated or designed. My firm's professional work is consultation for the best possible facility design ensuring that regulations are met, public safety, health and welfare are protected and complaints are prevented. These are professional ethics that utility, commercial and community clients have contracted for.

The recommendations and professional cautions my firm issues are carefully developed from years of power generation experience and professional investigations. My firm's services and opinions are useful for utilities, regulators and communities alike.

I approve the use of quiet technology and proper siting. With respect to wind turbines, due to materials and design limitations (distance the only reliable noise control option), noise levels suitable from rural to urban areas are constrained by turbine size and output.

My experience of power utility commitment to noise pollution controls: Power utility clients over the years have demonstrated their commitment to their shareholders and their operations by investing in noise controls to prevent complaints and legal action. The shift to "turnkey" systems since the mid 1990s has placed greater burden on proper specifications.

Emotionally charged, unprofessional labels could have undesired effects of cooling customer interest in professional services. Deliberate slander or libel could destroy future income. I am aware of work lost due to libel. I consider this a serious matter and expect it to be so for the Boards and customers who work cooperatively with noise impact assessment experts to determine the best actions that observe zoning objectives, assure compliance with regulatory limits, and most of all, protect the safety, health and welfare of the public.

SUPPLEMENT 11: QUALIFICATIONS

Mr. Rand is an independent acoustic investigator and a Member of the Institute of Noise Control Engineers (INCE) since 1993 and a Member of the Acoustical Society of America (ASA) with over thirty-eight years of experience providing environmental and technical consulting services to power generation, commerce, industry, and communities.
Mr. Rand's breadth of experience in general acoustics includes industrial noise control, environmental impact assessment, interior acoustics, and electro-acoustics, with ten years in the Noise Control Group at Stone & Webster Engineering Corporation. He has conducted environmental acoustic analyses; project engineering and cost analyses, permitting reviews, acoustic testing, noise control design and costing, and operations monitoring activities for power generation and commercial projects. He has provided a professional acoustic consultancy to industry, commercial, regulatory and community clients since 1996.

Mr. Rand's wind turbine experience spans the last ten years from 2009 to present day with investigations and testing of sound and infrasound pressure pulsations and community noise impact assessment for industrial wind turbines at multiple facilities. Significant testing reported in the literature includes independent peer-reviewed investigations in Falmouth, Massachusetts in April 2011, and the Cooperative Measurement Study in Shirley, Wisconsin in December 2012.

Mr. Rand is qualified to opine on the relationship of wind turbine acoustical emissions to health effects, having unexpectedly experienced adverse health effects including sleep disturbance during investigations in Falmouth, Massachusetts in April 2011, which took some time for recovery. Unusual acoustic characteristics identified during the survey included recurring barometric pressure oscillations occurring at the blade pass frequency of the nearby turbine, which were larger inside the home under investigation. Impacts were mitigated with distance. The barometric oscillations at the blade pass rate were found at Shirley as well in 2012. Mr. Rand is susceptible to motion sickness and experienced adverse health impacts during investigations at three other industrial wind turbine facilities: Hardscrabble Wind Facility, New York, July 2012; Vader Piet Wind Facility, Aruba, October 2012; and Shirley Wind Facility, Shirley Wisconsin, December 2012.

A copy of his biography, work history, cases where he has been accepted as an expert witness in the field of acoustics, and a list of papers published is available separately.