COUNTY BOARD SUMMARY REPORT

TO : County Clerk: Attn: Monet McCullen

FROM : David R. Cary, Director of Planning

RE : **County Text Amendment 18011**
(Amend Section 13.048 of the Lancaster County Zoning Regulations – Wind Energy)

DATE : December 3, 2018

1. On November 28, 2018, the Planning Commission held a public hearing on County Text Amendment 18011, as requested by Blue Prairie Wind, LLC.

2. Attached is the Planning staff report and related exhibits for **County Text Amendment 18011,** requested by the Blue Prairie Wind, LLC, to amend the Lancaster County Zoning regulations to add a noise limit for landowners who choose to participate in a wind energy project. The proposed legislative changes to the County Zoning Regulations will be provided by the County Attorney's Office separately. The minutes of the Planning Commission will be provided upon completion under separate cover.

3. The staff recommendation of approval is based upon the Analysis as set forth on pp.2-3, concluding that the proposed change would only apply to participating properties and will still protect the public health. Non-participating properties will continue to be protected from wind turbine noise with the existing restrictions on noise and setbacks. The key justification for this recommendation lies with the Lincoln-Lancaster County Health Department (LLCHD) recognizing the scientific peer-reviewed evidence relative to wind turbine noise and reported annoyance for participating properties. The scientific research and papers reviewed by the LLCHD indicate that participating property owners report much less annoyance relative to non-participating property owners that are exposed to wind turbine noise. Annoyance is the primary health concern related to wind turbine noise as this sensation can lead to sleep deprivation, stress, and potentially other negative health outcomes.

4. There was significant testimony both in support and in opposition to this proposed change.

5. On November 28, 2018, the Planning Commission agreed with the staff recommendation and voted 8-1 (Joy dissenting) to recommend approval of Text Amendment 18011.

6. To access all public comments and information on this application, click on the following link www.lincoln.ne.gov and (Keyword = PATS). Click on the "Selection Screen" under "Featured Links", type in the application number (i.e. TX18011); click on "Search", then "Select". Go to "Related Documents".

The Planning staff is scheduled to brief the County Board on this amendment at their regular staff meeting on Thursday, December 6, 2018, at 9:30 a.m., in Room 113 of the County-City Building, 555 South 10th Street, Lincoln, Nebraska. The public hearing before the County Board has been scheduled for **Tuesday, December 18, 2018, at 9:00 a.m.**, in Room 112 of the County-City Building, 555 South 10th Street, Lincoln, Nebraska.

If you need any further information, please let me know (402-441-6365).

cc: County Board
Jenifer Holloway, County Attorney's Office
Tom Cajka
Ann Ames, County Commissioners
Kerry Eagan, County Commissioners

CITY OF LINCOLN NEBRASKA

LANCASTER COUNTY NEBRASKA

LINCOLN/LANCASTER COUNTY PLANNING COMMISSION STAFF REPORT

FROM THE LINCOLN/LANCASTER COUNTY PLANNING DEPARTMENT, 555 S. 10TH STREET, SUITE 213, LINCOLN, NE 68508

APPLICATION NUMBER Text Amendment #18011	FINAL ACTION? No
PLANNING COMMISSION HEARING DATE November 28, 2018	RELATED APPLICATIONS None

RECOMMENDATION: APPROVAL

BRIEF SUMMARY OF REQUEST

This request is to amend the County zoning regulations, Section 13.048 Commercial Wind Energy Conversion Systems to add a condition to allow participating properties to have a higher noise level than non-participating properties.

JUSTIFICATION FOR RECOMMENDATION

The proposed change would only apply to participating properties. Non-participating properties will continue to be protected from wind turbine noise with the existing restrictions on noise and setbacks.

The key justification for this recommendation lies with the Lincoln-Lancaster County Health Department (LLCHD) recognizing the scientific peer-reviewed evidence relative to wind turbine noise and reported annoyance for participating properties. The scientific research and papers reviewed by the LLCHD indicate that participating property owners report much less annoyance relative to non-participating property owners that are exposed to wind turbine noise. Annoyance is the primary health concern related to wind turbine noise as this sensation can lead to sleep deprivation, stress, and potentially other negative health outcomes.

APPLICATION CONTACT

Blue Prairie Wind, LLC 561-691-7122

STAFF CONTACT

Tom Cajka, (402) 441-5662or
tcajka@lincoln.ne.gov

COMPATIBILITY WITH THE COMPREHENSIVE PLAN

The requested amendment would permit commercial wind turbines in Lancaster County and help meet a goal of the Comprehensive Plan for renewable energy sources, while protecting the public health. All of the previous protections for non-participating properties would be maintained.

KEY QUOTES FROM THE 2040 COMPREHENSIVE PLAN

The importance of building sustainable communities — communities that conserve and efficiently utilize our economic, social, and environmental resources so that the welfare of future generations is not compromised - has long been recognized. This concept has grown in importance with increased understanding of the limits to energy supplies and community resources, the likelihood that energy costs will continue to increase in the future, the climatic impacts of energy consumption, and the impacts on the physical and economic health of the community. LPlan 2040 describes a community that values natural and human resources, supports advances in technology, and encourages development that improves the health and quality of life of all citizens. (P.1.4)

Efforts are made to attract new and expanding industries that serve the emerging markets for more sustainable products and services. (P. 1.5)

LPlan 2040 supports the preservation of land in the bulk of the County for agricultural and natural resource purposes. (p.7.12)

Promote renewable energy sources. (P. 11.2)

Lincoln must develop a comprehensive strategy of fuel diversity and encourage conservation, alternative forms of energy and modern energy technologies. (P. 11.3)

Energy from renewable resources such as solar, geothermal, and wind technologies generally does not contribute to climate change or local air pollution and generally conserves nonrenewable resources. (P. 11.4)

Continue to encourage and expand wind and solar access to buildings and other land uses. (P. 11.7)

ANALYSIS

1. This request is to amend Section 13.048 Commercial Wind Energy Conversion Systems to add text that would allow a participating property to have a higher noise level. Noise levels for non-participating properties will remain unchanged. Initially the applicant had requested a change to the setbacks. They have subsequently withdrawn any changes to the setbacks.
2. The applicant is requesting a noise level of 50dBA maximum 10 minutes Leq for all hours of the day and night. This means that in any 10 consecutive minutes throughout the day and night the noise level cannot exceed 50 decibels on average.
3. In 2015 a Working Group was formed to revise the text that permits commercial wind energy projects with adequate protection of property owners and residents. Six public meetings were held between March and May of 2015. The outcome of the meetings was a draft text that was presented to Planning Commission at their public hearing on August 19, 2015.
4. The current regulations provides protection to non-participating property owners. These regulations include:

   a. Shadow flicker—shadow flicker shall not fall upon any non-participating dwelling for more than a total of 30 hours per any calendar year.

   b. Setbacks- the setback shall be 2 times the turbine height measured to the property line, or 3 1/2 times the turbine heights measured to the closest exterior wall of the dwelling, whichever is greater. The turbine must be a minimum of 1,000 feet from the property line.

   c. Noise- No turbine shall exceed 40 dBA maximum 10 minute Leq between the hours of 7:00 a.m. to 10:00 p.m. and 37 dBA maximum 10 minute Leq from the hours of 10:00 p.m. to 7"00 a.m. Leq is the average noise level over a specified period of time.

   d. There shall be a minimum 3 acre area within a lot that is not affected by setbacks or noise levels of a turbine. (see Exhibit 3 for the entire regulations)
5. The Lincoln-Lancaster County Health Department (LLCHD) is recommending approval for the proposed text change that establishes a fifty (50) dBA maximum 10 minute Leq for all hours of the day and night for participating properties. The key justification for this recommendation lies with the LLCHD recognizing the scientific peer-reviewed evidence relative to wind turbine noise and reported annoyance for participating properties. The scientific research and papers reviewed by the LLCHD indicate that participating property owners report much less annoyance relative to non-participating property owners that are exposed to wind turbine noise. Annoyance is the primary health concern related to wind turbine noise as this sensation can lead to sleep deprivation, stress, and potentially other negative health outcomes. In addition, LLCHD's review of the most recent scientific research on wind turbine noise and health continues to validate that the current regulations of 37 dBA at night and 40 dBA during the day for NON-participating property owners is necessary to prevent annoyance and protect the health of those people who choose not to participate in the wind energy

project.

6. Further analysis and conclusions from LLCHD can be found in the attached memo, See Exhibit 1. The memo references LLCHD Recommendations for Noise Levels from Commercial Wind Energy Conversion Systems from the original study done in May 2015. See Exhibit 2 for the study.

7. NextEra submitted an analysis of noise impacts conducted by Olsson Environmental Health Management, See Exhibit 4. The conclusion of the analysis is that there is scientific justification to allow commercial wind energy conversion systems to have a noise limit of 50dBA maximum 10 minutes Leq for participating properties.

8. NextEra had Epsilon Associates conduct a sound level modeling analysis on a hypothetical, but realistic layout that involved 54 wind turbines. See Exhibit 5. The turbines had a total blade tip height of 500 feet. A total of 157 homes were used in the analysis. The analysis found that to maintain the 37 dba required for non-participating dwellings the turbines would need to be a minimum of one mile from the dwelling. See attached, "Additional Wind Energy Information Requested" Page 2, Table 1.

9. This request does not change any of the protections given to non-participating properties. Based on the analysis performed by Epsilon Associates all property owners within a one mile radius would have to participate for a wind turbine to be allowed.

Prepared by

____
Tom Cajka, Planner

Date: November 14, 2018

Applicant: Blue Prairie Wind, LLC
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561-691-7122

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Proposed text amendment to Lancaster County Zoning Regulations:

13.048(A)(i). Noise: No CWECS or combination of CWECS turbine(s) shall be located as to cause an exceedance of the following as measured at the closest exterior wall of any dwelling located on the property. If a turbine violates a noise standard on a dwelling unit, constructed after the turbine is approved, then the turbine becomes a non-conforming use. For ~~both participating and~~ nonparticipating properties:

1. From the hours of 7 am to 10 pm:
i. Forty (40) dBA maximum 10 minute Leq or;
ii. Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 15 hour period.

2. From the hours of 10 pm to 7 am:
i. Thirty-seven (37) dBA maximum 10 minute Leq or;
ii. Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 9 hour period.

For participating properties:

1. Fifty (50) dBA maximum 10 minute Leq for all hours of the day and night.

Exhibit 1

MEMORANDUM

TO: Lincoln-Lancaster County Planning Commission

FROM: Chris Schroeder, MCRP, Environmental Health Supervisor
Scott E. Holmes, MS, REHS, Environmental Public Health Division Manager

DATE: November 19, 2018

RE: Text Amendment #18011 – Basis for Approval Recommendation

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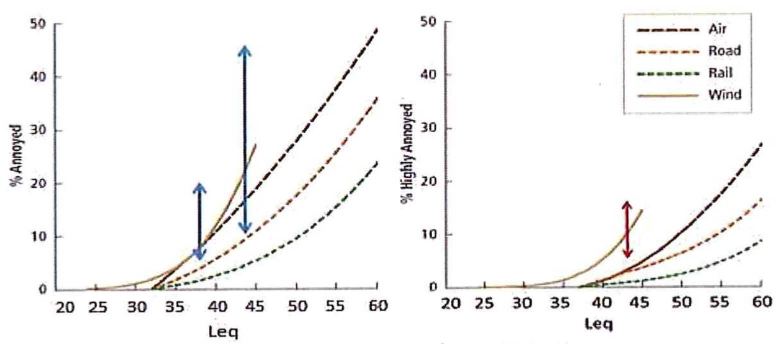
The purpose of this memo is to provide information on the basis for the Lincoln-Lancaster County Health Department's (LLCHD) approval recommendation for text amendment #18011. This text amendment proposes to amend County Zoning Regulation 13.048. Commercial Wind Energy Conversion System (CWECS) by establishing a fifty (50) dBA maximum 10 minute Leq for all hours of the day and night for participating properties.

In order to provide context for LLCHD recommending approval of this proposed text amendment, it is important to review the extensive work that was done circa 2015 in setting the public health, science-based wind turbine noise limits for participating and nonparticipating properties. Several recently published studies/reports and dozens of peer-reviewed science-based research papers were reviewed relative wind turbine noise exposure and potential negative health outcomes. The key negative health outcome identified and supported in the scientific literature was annoyance in relation to wind turbines noise exposure. In establishing the current wind turbine noise limits, the LLCHD relied strongly on studies that were completed in 2014 and 2015. These studies provided knowledge and guidance on the potential negative public health outcomes for people exposed to wind turbine noise. Of particular importance, these studies provided information about the percentage of people that were annoyed or extremely annoyed and that annoyance this was statically associated with sleep disturbance, stress levels and increased blood pressure.

Data from multiple studies, including the Health Canada Wind Turbine Noise and Health Study, advised that the percentage of people that will be "very" or "extremely annoyed increased significantly when wind turbine noise exposure levels exceed 40 dBA. In addition, Schmidt and Klokker indicated that 35 dBA appears to be a "tolerable level". Based upon this and other studies, the LLCHD estimated annoyance levels relative to wind turbine noise exposure levels to establish the current wind turbine noise limits.



LLCHD estimates of Annoyance with Leq in dB(A) based on Canadian Academies study Figure 6.1 using a 5dB conversion factor for Lden to Leq
- Range estimates ⇕ from Pedersen (2011)
- Range estimate ⇕ from Health Canada (2015) of very or extremely annoyed

For more detailed information regarding the basis for the establishment of the current wind turbine noise limits for both participating and nonparticipating property owners, please refer to the included document titled "Lincoln-Lancaster County Health Department Recommendations for Noise Levels from Commercial Wind Energy Conversion Systems (May 2015)".

The important distinction for this proposed text amendment relates to the words of participating and non-participating properties. The proposed change will only impact participating property owners and the existing noise limits and setbacks will still provide protection from annoyance for non-participating property owners. In the context of these terms used in County Zoning Regulation 13.048, participating properties means that the land owner is agreeable to the wind turbine project. For example, this could mean the property owner has a legally binding contract with the wind energy company. Relative to this proposed text amendment, the LLCHD evaluated the assertion that recently published peer-reviewed science-based articles revealed that participating property owners report much less annoyance in response to wind turbine noise exposure and therefore should not experience negative health outcomes. It was also very important to determine if the proposed wind turbine noise limit of fifty (50) dBA maximum 10 minute Leq for all hours of the day and night for participating properties was supported in wind turbine noise study data reviewed by the LLCHD. LLCHD's review of scientifically peer reviewed research articles and wind turbine noise study data confirmed that participating property owners report much less annoyance in response to wind turbine noise exposure and that the proposed wind turbine noise limit for participating property owners is supported by wind turbine noise data reported in several peer-reviewed research papers. Following is a discussion of three studies which the LLCHD relied upon to aid in the review of this proposed text amendment.

Health Canada Wind Turbine Noise and Health Study –

This was a large epidemiological study that was commissioned to investigate the impacts of wind turbine noise on health and well-being.[1] The study was performed in southwestern Ontario and Prince Edward Island on a final total of 1238 randomly selected participants.[1] Notably, this study achieved a 78.9% response rate with approximately a fifty/fifty split between male and female, ages 18-79 years and living between 0.25 and 11.22 km from wind turbines.[1]

LLCHD reviewed specific information for participants that received personal benefit from having wind turbines in the area in a 2018 research paper using this study's data.[2] Personal benefits includes benefit through rent, payments, or other indirect benefits such as a hall or community center for having wind turbines in their area. The most compelling finding that was presented in this paper stated that aggregate annoyance was effectively zero (0) for the 110 participants who reported that they receive personal benefit from having wind turbines in their area.[2] In this context, aggregate annoyance is for the entire spectrum of annoyance from "not at all annoyed" to "extremely annoyed".[2]

[1] Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, McGuire D, Bower T, Lavigne E, Murray BJ, Weiss SK, van den Berg F. 2016. Exposure to wind turbine noise: Perceptual responses and reported health effects. J Acoust Soc Am. 2016 Mar;139(3):1443-54.

[2] Michaud DS, Marro L, McNamee J. The association between self-reported and objective measures of health and aggregate annoyance scores toward wind turbine installation. Canadian Journal of Public Health (2018) 109:252-260.

The LLCHD also closely examined the wind turbine noise exposure data that was presented for the Health Canada Wind Turbine Noise and Study. Below is Table 1 from a 2018 Michaud paper that provides detailed information for the study participants' distance to the nearest wind turbine and their modeled wind turbine noise exposure level.[3]

Table 1 Sample exposure characteristics

Sample characteristics	Calculated distance between dwelling and nearest wind turbine (km)					
	≤0.550	(0.550, 1]	(1, 2]	(2, 5]	>5	Chi-square[a] *p* value
ON						
dBA mean [min, max]	41.13 [37.40, 44.60]	38.43 [31.80, 43.60]	33.21 [26.30, 40.40]	27.36 [22.60, 30.90]	8.69 [0.00, 18.20]	
dBC mean [min, max]	58.35 [55.00, 63.00]	56.49 [52.00, 61.00]	53.58 [47.00, 58.00]	50.21 [47.00, 54.00]	32.41 [0.00, 45.00]	
SFm mean [min, max]	33.76 [0.00, 79.00]	15.73 [0.00, 68.00]	5.78 [0.00, 23.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	
Response rate *n* (%)	34 (72.3)	488 (80.1)	396 (78.7)	42 (82.4)	51 (77.3)	0.7009
Personal benefits[b] *n* (%)	15 (44.1)	55 (11.5)	16 (4.3)	1 (2.6)	0 (0.0)	< 0.0001
Visible[c] *n* (%)	34 (100.0)	474 (97.1)	348 (88.3)	32 (78.0)	6 (11.8)	< 0.0001
Audible[d] *n* (%)	26 (76.5)	325 (66.6)	111 (28.0)	5 (11.9)	1 (2.0)	< 0.0001
PEI						
dBA mean [min, max]	42.87 [39.40, 46.10]	38.95 [34.30, 43.20]	32.47 [29.10, 37.20]	22.26 [14.60, 29.90]	11.10 [0.00, 18.20]	
dBC mean [min, max]	60.92 [58.00, 63.00]	58.20 [55.00, 62.00]	53.19 [51.00, 57.00]	45.44 [36.00, 54.00]	32.08 [0.00, 43.00]	
SFm mean [min, max]	40.11 [0.00, 78.00]	18.08 [0.00, 47.00]	1.69 [0.00, 20.00]	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	
Response rate *n* (%)	37 (77.1)	95 (79.2)	67 (75.3)	16 (64.0)	12 (100.0)	0.1666
Personal benefits[b] *n* (%)	8 (21.6)	6 (6.4)	5 (8.5)	3 (23.1)	1 (10.0)	0.0651
Visible[c] *n* (%)	34 (94.4)	94 (98.9)	59 (88.1)	2 (12.5)	2 (16.7)	< 0.0001
Audible[d] *n* (%)	30 (83.3)	73 (76.8)	15 (22.4)	0 (0.0)	0 (0.0)	< 0.0001

dBA calculated outdoor A-weighted wind turbine noise levels, *dBC* calculated outdoor C-weighted wind turbine noise levels, *SFm* calculated maximum shadow flicker at dwellings (min/day)

[a] Chi square test of independence, testing the independence between the sample characteristic and distance groups

[b] Participants reported to receive personal benefit through rent, payments, or other indirect benefits such as a hall or community centre for having wind turbines in their area

[c] Participants reported that wind turbines were visible from anywhere on their property when at home

[d] Participants reported that wind turbines were audible when inside or outside their home

What is important to note is that the wind turbine noise levels presented above, represent a long-term yearlong average for the study participants wind turbine noise exposure levels.[4] For the purpose of reviewing the proposed wind turbine noise limit for participating properties, the LLCHD focused on examining the number of participants in the highest wind turbine noise exposure category.

[3] Michaud DS, Marro L, McNamee J. Derivation and application of a composite annoyance reaction construct based upon multiple wind turbine features. Canadian Journal of Public Health (2018) 109:242-251.

[4] Keith SE, Feder K, Voicescu SA, Victor S. Wind turbine sound pressure level calculations at dwellings. J Acoust Soc Am 39, 1436 (2016)

There were 234 participants in the 40-45 dBA wind turbine noise exposure category.[5] The applicant is requesting a wind turbine noise limit of 50 dBA with a short term average of 10 minutes. This is an important distinction because when comparing yearlong averages to short term averages for wind turbine noise, it should be noted that wind turbines do not operate all the time and not always at the same power output. Also for the calculated year-long noise average at dwellings, the wind direction is not constant throughout the year which influences the wind turbine noise exposures at dwellings. Therefore, it is reasonable to extrapolate that the yearlong average wind turbine noise exposure levels found in the Health Canada study should equate to a short term average of around 50 dBA 10 minute Leq as proposed by the applicant. In addition, this same difference between a long term average wind turbine noise exposure levels and short term averages is somewhat apparent in the wind turbine noise modeling provided by Epsilon Associates, Inc.[6] Epsilon Associates provided a hypothetical, but realistic analysis, of 54 wind turbines with a total of 167 receptors (homes) with three different scenarios of a short-term Leq, annual average Leq, and annual average Lden.[6] This wind turbine noise modeling data is provided below showing the short-term Leq and the annual average Leq. The important data to examine is comparing the number and percentage of receptors in the highest and lowest sound level categories. This modeling data shows that annual average noise levels are lower than short term average noise levels (10 min Leq). This is because wind turbines do not operate all the time or operate at the same power levels.

Short Term L_{eq} Broadband Sound Level (dBA)	Minimum Distance (ft)	Minimum Distance (mi)	Maximum Distance (ft)	Maximum Distance (mi)	Average Distance (ft)	Average Distance (mi)	Number of Receptors	% of Project Receptors
46 - 50	1,479	0.28	3,243	0.61	1,966	0.37	40	24%
41 - 45	1,934	0.37	4,861	0.92	3,308	0.63	46	28%
36 - 40	3,615	0.68	8,431	1.60	6,072	1.15	61	37%
<35	6,547	1.24	15,583	2.95	11,093	2.10	20	12%
37	5,326	1.01	7,656	1.45	6,552	1.24	12	

	Annual (L_{eq}, dBA)	
Sound Level Bin	**Number of Receptors**	**% of Project Receptors**
<= 35	79	47.3%
36 to 40	42	25.1%
41 to 45	46	27.5%
46 to 50	0	0.0%

5 Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, McGuire D, Bower T, Lavigne E, Murray BJ, Weiss SK, van den Berg F. 2016a. Exposure to wind turbine noise: Perceptual responses and reported health effects. J Acoust Soc Am. 2016 Mar;139(3):1443-54.

6 Epsilon Associates. Additional Wind Energy Information Requested Lincoln-Lancaster County Health Department. November 6 (2018).

The LLCHD also contacted Dr. Michaud, who is employed by Health Canada and is the author of several scientific papers discussing the results of the Health Canada Wind Turbine Noise and Health Study to schedule a conference call. Dr. Michaud graciously accepted our request and also invited Dr. Keith who conducted the wind turbine noise modeling for the Health Canada Wind Turbine Noise and Health Study. Prior to the conference call, LLCHD sent a list of questions for discussion. During the conference call that lasted over an hour, the LLCHD was able to gain additional insights on how to interpret the wind turbine noise data and results from the Health Canada Wind Turbine Noise and Health Study. Part of the conversation focused on the difference between long-term and short term wind turbine noise averages with Dr. Michaud indicating that the long term average would be lower than a short term average, mentioning that wind turbines do not operate all the time and that the sound power output varies during the year. We also discussed the subject of reported wind turbine annoyance with Dr. Michaud stating that no annoyance was reported in the Health Canada Wind Turbine Noise and Health study by participants that received personal benefit. He went on to state that he was unware of any study that showed annoyance for those who receive personal benefit.

Bakker Paper –

This peer-reviewed science based paper examined a research study conducted in the Netherlands that evaluated the relationship between wind turbine noise exposure and annoyance, self-reported sleep disturbance and psychological distress of individuals living in the vicinity of wind turbines.[7] This study focused on answering five main questions: (1) Are residents annoyed and if so, does the extent of exposure have a proportional impact on the level of annoyance: i.e. the more one is exposed (in terms of decibels) the more one gets annoyed? (2) Does annoyance lead to (self-reported) impaired sleep? (3) Does annoyance lead to psychological distress? (4) Does exposure to wind turbine sound (in terms of decibels) lead to (self-reported) impaired sleep and/or psychological distress? (5) If such a (direct) relation does not exist, can annoyance and/or sleep quality be regarded as intermediate states?[7] In addition, crucial to the review of this proposed text amendment to allow higher wind turbine noise limits for participating property owners, this study also looked at the influence of economic interests in wind turbines when answering the previously mentioned questions.[7]

Below is Table 1 from this study showing the total number and percentage of respondents in the various sound level categories in dBA relative to different area types.[7] For the purposes of this review, it is important to note the total number of respondents in the 41-45 and >45 dB(A) categories. There were total of 159 respondents in these two categories. Also, it was important for the statistical validity of this study to have at least 50 respondents in each of the noise exposure categories.[7] Additional demographic information for the respondents were a mean age of 51 years and nearly a fifty/fifty split between men and women. [7]

[7] Bakker RH, et al, Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress, Sci Total Environ (2012), doi:10.1016/j.scitotenv.2012.03.005

Table 1
Percentage of respondents in three area types and different immission levels.

	Sound pressure level, in dB(A)											
	<30		30–35		36–40		41–45		>45		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
Built-up area	68	37	84	38	28	17	18	19	1	2	199	23
Rural with main road	50	27	70	32	59	38	36	38	30	46	245	36
Rural without main road	67	36	65	30	75	47	40	43	34	52	281	41
Total	185	38	219	37	162	38	94	38	65	33	725	100

As previously mentioned, for the review of this proposed text amendment, the LLCHD sought to evaluate the assertion that participating property owners report or experience much less annoyance versus nonparticipating properties. Table 3 for outdoor wind turbine sound and Table 4 for indoor wind turbine sound below provide additional compelling evidence that participating property owners report much less annoyance and therefore should not have negative health outcomes from wind turbine noise exposure. This is apparent in the data below when examining the number of respondents in the rather annoyed and very annoyed categories relative to no economic benefit and those receiving economic benefit.

Table 3
Response to outdoor wind turbine sound among economically benefitting and non-benefitting respondents.

	Response											
	Do not notice		Notice, not annoyed		Slightly annoyed		Rather annoyed		Very annoyed		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
No economical benefit	255	44	184	31	78	13	41	7	28	5	586	100
Economical benefit	15	15	68	69	13	13	2	2	1	1	99	100

Table 4
Response to indoor wind turbine sound among economically benefitting and non-benefitting respondents.

	Response											
	Do not notice		Notice, not annoyed		Slightly annoyed		Rather annoyed		Very annoyed		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
No economical benefit	394	68	98	17	46	8	21	4	20	4	579	100
Economical benefit	53	54	39	39	7	7	0	0	0	0	99	100

In addition, as discussed above in the analysis of the Health Canada Wind Turbine Noise and Health Study's wind turbine noise exposure data, the same approach was used for the Bakker Study's wind turbine noise exposure data provided in Table 1 above.[7] The sound pressure levels presented in Table 1 in the Bakker paper are long term average wind turbine noise exposures. Therefore, the same conclusion can be drawn for this wind turbine noise data as for the Health Canada Wind Turbine Noise and Health Study data that found at least a 5 dBA conversion factor can be added to these long term noise averages to approximate a short term (10 minute Leq) noise average. Also, what is not seen in Table 1's data is that respondents for this study were exposed to wind turbines noise levels up to 54 dBA.[7]

Janssen Paper –

This paper analyzed data from a 2000 study in Sweden with 341 respondents, a 2005 study in Sweden with 754 respondents and a 2007 study in the Netherlands with 725 respondents to determine the exposure-response relationship between wind turbine noise exposure and annoyance.[8] The previously discussed Bakker study used the data from the Netherlands study.[7] Table 1 below provides a summary of the data for the studies used in this paper.

TABLE I. Individual and situational characteristics, plus percentages for each annoyance category indoors and outdoors, per study and in total.

	Sweden 2000		Sweden 2005		Netherlands 2007		Total	
	$n=341$		$n=754$		$n=725$		$n=1820$	
	Mean or %	SD	Mean or %	SD	Mean or %	SD	Mean or %	SD
L_{den}	39.3	3.2	38.1	3.1	39.8	6.4	39.0	4.8
Age	47.2	14.0	50.9	15.0	54.3	15.0	51.5	15.0
Noise sensitivity	51.0	20.9	50.7	22.3	46.1	23.8	48.9	22.7
Female (%)	58.5		55.6		49.2		53.6	
Economic benefit (%)	3.0		2.7		14.3		7.6	
Visible (%)	94.4		70.6		67.8		74.0	
Rural (%)	40.2		24.5		70.5		45.8	
Flat terrain (%)	100.0		50.3		100.0		79.4	
Annoyance 0–100	Indoors	Outdoors	Indoors	Outdoors	Indoors	Outdoors	Indoors	Outdoors
0–25 (%)	88.5	66.9	96.4	88.6	86.4	76.7	91.0	79.8
25–50 (%)	4.1	17.6	2.4	7.3	7.7	13.0	4.8	11.5
50–75 (%)	4.1	6.5	1.1	2.3	3.0	6.2	2.4	4.6
75–100 (%)	3.2	9.1	0.1	1.9	2.9	4.1	1.8	4.1

This paper reports that notwithstanding noise exposure, there were other individual and situational characteristics that influenced the level of annoyance such as having economic benefit from the use of wind turbines.[8] Further, in the data set that was analyzed, they found that even though the respondents with economic benefit lived in areas with the highest wind turbine noise exposures, they hardly reported any annoyance which resulted in a decrease in the annoyance reported at the highest noise exposures.[8] Therefore, this study supported the assertion that participating property owners in wind energy projects report much less annoyance.

Conclusion

The LLCHD has reviewed current science-based peer reviewed research relative to the proposed request to establish a higher noise limit for participating property owners. The most compelling evidence was from studies published after 2015 by Health Canada (Michaud and Keith) based on the data collected in the Health Canada Wind Turbine Noise and Health Study. In addition, studies published by Bakker and Janssen provided valuable information. Based on our evaluation, the LLCHD believes that peer-reviewed scientific studies support that participating property owners can be exposed to levels of noise up to 50 dBA (10 minute Leq) and not experience significant levels of annoyance. Therefore, LLCHD recommends approval of text amendment TX19011. However, the LLCHD remains firm in our past recommendation that wind turbine noise levels of 37 dBA at night and 40 dBA during the day for NON-participating property owners is necessary to prevent significant levels of annoyance and protect the health of people who choose not to participate in the wind energy project.

[8] Janssen SA, Vos H, Pedersen E. A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. J Acoust Soc Am (2011) 130:3746-53.

Exhibit 2

Lincoln-Lancaster County Health Department
Recommendations for Noise Levels from
Commercial Wind Energy Conversion Systems

UPDATED May 2015

The Lincoln-Lancaster County Health Department (LLCHD) recommends the following language for an updated text amendment to the County Resolution addressing noise levels from Commercial Wind Energy Conversion Systems.

No CWECS or combination of CWECS machine(s) shall be located as to cause an exceedance of the following as measured at the closest exterior wall of any dwelling located on the property:

- From the hours of 7 am to 10 pm:
    - Forty (40) dBA Leq measured during any ten minute period or;
    - Three (3) dBA above pre-construction/operational background levels as determined by the pre-construction noise level measured as an Leq during the 15 hour period of 7 am to 10 pm;
- From the hours of 10 pm to 7 am:
    - Thirty-seven (37) dBA or;
    - Three (3) dBA above pre-construction/operational background levels as determined by the nighttime pre-construction noise level measured as an Leq during the 9 hour period of 10 pm to 7 am

Background noise measurements shall be not be conducted when common seasonal agricultural activities, such as harvesting and irrigation, are being conducted.

LLCHD has modified the recommended allowable levels previously suggested for the Lancaster County Resolution text amendment in January 2015. The main changes to our recommendation are:

- using the more common noise metric of Leq,
- reducing the level of noise allowed above existing background noise from 5 dBA to 3 dBa, and
- establishing the same noise levels for both participating and non-participating households, assuring equal public health protection for all persons.

These recommendations are based on the most recent research and review reports cited on the next pages. Of particular importance to the updated recommendation were findings in studies completed in 2014 and 2015. These studies improved the knowledge on the potential health risk posed by wind turbine noise, the percentage of people exposed to wind turbine noise that will be annoyed or extremely annoyed, and found that self-reported annoyance was statistically significantly associated with sleep disturbance, stress levels (as measured by cortisol) and increased blood pressure (as measured in exposed individuals).

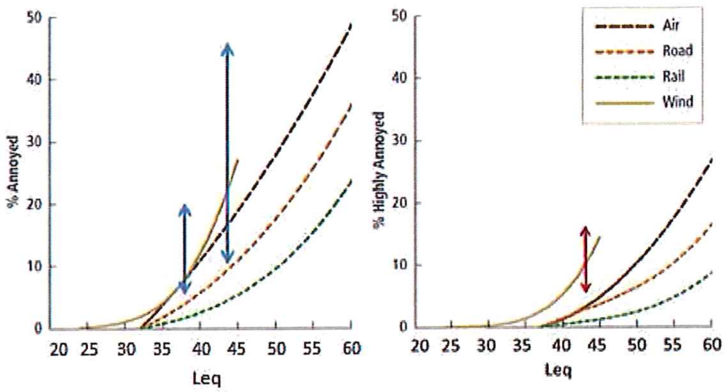
Other factors that influenced LLCHD's recommendation included:

1) Wind turbine noise is more annoying to people than other comparable noise, such as noise from traffic or airports. The primary reason appears to be that wind turbine noise has unique characteristics (amplitude modulation). No matter what the source of noise, if it includes significant and frequent amplitude modulation, persons exposed to it will respond as if it were a higher level of noise and indicate that it is more annoying than a noise of the same sound pressure which does not have amplitude modulation.

2) The 2015 Canadian Academies Expert Panel included this statement in their report: "The Panel stresses that, given the nature of the sound produced by wind turbines and the limited quality of available evidence (small sample sizes, small number of studies available, lack of comprehensive exposure measurement), the health impacts of wind turbine noise cannot be comprehensively assessed at this time."

   This means that there is still considerable uncertainty in potential health impacts with the research that has been conducted to date. In addition, the data on chronic health outcomes is significantly limited by the short period of time (last 7 to 10 years) that wind energy systems have grown substantially across the U.S.

3) Data on annoyance from multiple studies, including the 2015 Health Canada study indicated that the percentage of people that will be "very" or "extremely" annoyed increases considerable when they are exposed to noise levels above 40 dBA. In late 2014, Schmidt and Klokker indicated that 35 dBA appears to be a "tolerable level". The somewhat older Massachusetts expert panel review (2012) recommended Denmarks nighttime noise limit for residential areas of 37 dBA when wind speeds were 6 m/sec (about 13 mph) and 39 dBA when wind speeds are 8 m/sec (about 18 mph) as a "Promising Practice".



LLCHD estimates of Annoyance with Leq in dB(A)
based on Canadian Academies study Figure 6.1
using a 5dB conversion factor for Lden to Leq
- Range estimates ↕ from Pedersen (2011)
- Range estimate ↕ from Health Canada (2015) of very
or extremely annoyed

5) There appears evidence that a small percentage of the population is more senstive to wind turbine noise than the population as a whole.

Staff reviewed many studies, papers, news reports, websites, etc. on wind turbines and potential health impacts. Staff considered the following comprehensive literature review studies and large epidemiological study to be the most valuable and scientifically sound.

1) Wind Turbine Health Impact Study: Report of Independent Expert Panel; January 2012; Prepared for: Massachusetts Department of Environmental Protection & Massachusetts Department of Public Health

2) Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review. This article was written by Jesper Hvass Schmidt and Mads Klokker. (Refernce: Schmidt JH, Klokker M (2014) Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review. PLoS ONE 9(12): e114183.)

3) World Health Organization, Nighttime Noise in Europe, 2009. ISBN 978 92 890 41737

4) ***Understanding the Evidence: Wind Turbine Noise; The Expert Panel on Wind Turbine Noise and Human Health*** by the Council of Canadian Academies (2015), http://www.scienceadvice.ca/en/assessments/completed/wind-turbine-noise.aspx

5) Health Canada Wind Turbine Noise and Health Study (2015), http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php
This was a very well designed epidemiological study of people residing in 1,238 dwelling units exposed to wind turbine noise.

The following pages include:

- excerpted sections from the Massachusetts study's executive summary;
- the abstract from the Schmidt/Klokker article;
- the abstract from the WHO Nighttime Noise in Europe study;
- the executive summary of the Canadian Academies study; and
- the website summary of the Health Canada Study.

Wind Turbine Health Impact Study: Report of Independent Expert Panel; January 2012; Prepared for: Massachusetts Department of Environmental Protection & Massachusetts Department of Public Health

The Massachusetts Department of Environmental Protection (MassDEP) in collaboration with the Massachusetts Department of Public Health (MDPH) convened a panel of independent experts to identify any documented or potential health impacts of risks that may be associated with exposure to wind turbines, and, specifically, to facilitate discussion of wind turbines and public health based on scientific findings.

Expert Independent Panel Members:

Jeffrey M. Ellenbogen, MD; MMSc; Assistant Professor of Neurology, Harvard Medical School; Division Chief, Sleep Medicine, Massachusetts General Hospital

Sheryl Grace, PhD; MS Aerospace & Mechanical Engineering; Associate Professor of Mechanical Engineering, Boston University

Wendy J Heiger-Bernays, PhD; Associate Professor of Environmental Health, Department of Environmental Health; Boston University School of Public Health; Chair, Lexington Board of Health

James F. Manwell, PhD Mechanical Engineering; MS Electrical & Computer Engineering; BA Biophysics; Professor and Director of the Wind Energy Center, Department of Mechanical & Industrial Engineering University of Massachusetts, Amherst

Dora Anne Mills, MD, MPH, FAAP; State Health Officer, Maine 1996–2011; Vice President for Clinical Affairs, University of New England

Kimberly A. Sullivan, PhD; Research Assistant Professor of Environmental Health, Department of Environmental Health; Boston University School of Public Health

Marc G. Weisskopf, ScD Epidemiology; PhD Neuroscience; Associate Professor of Environmental Health and Epidemiology; Department of Environmental Health & Epidemiology, Harvard School of Public Health; Facilitative Support provided by Susan L. Santos, PhD, FOCUS GROUP Risk Communication and Environmental Management Consultants

Extensive literature searches and reviews were conducted to identify studies that specifically evaluate human population responses to turbines, as well as population and individual responses to the three primary characteristics or attributes of wind turbine operation: noise, vibration, and flicker. Beyond traditional forms of scientific publications, the Panel also took great care to review other non-peer reviewed materials regarding the potential for health effects including information related to "Wind Turbine Syndrome" and provided a rigorous analysis as to whether there is scientific basis for it. Since the most commonly reported complaint by people living near turbines is sleep disruption, the Panel provided a robust review of the relationship between noise, vibration, and annoyance as well as sleep disturbance from noises and the potential impacts of the resulting sleep deprivation.

In assessing the state of the evidence for health effects of wind turbines, the Panel followed accepted scientific principles and relied on several different types of studies. The non-peer reviewed material was considered part of the weight of evidence. In all cases, data quality was considered; at times, some studies were rejected because of lack of rigor or the interpretations were inconsistent with the scientific evidence. The report cited about 100 specific references and provided a Bibliography containing about 115 reports, papers, regulations, etc. that were considered by the panel.

The Panel came to the following conclusions on health impacts of noise and vibration:

1. Most epidemiologic literature on human response to wind turbines relates to self-reported "annoyance," and this response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project.

a. There is limited epidemiologic evidence suggesting an association between exposure to wind turbines and annoyance.

b. There is insufficient epidemiologic evidence to determine whether there is an association between noise from wind turbines and annoyance independent from the effects of seeing a wind turbine and vice versa.

2. There is limited evidence from epidemiologic studies suggesting an association between noise from wind turbines and sleep disruption. In other words, it is possible that noise from some wind turbines can cause sleep disruption.

3. A very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest of sleepers at that same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. Further study would provide these levels.

4. Whether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified. While not based on evidence of wind turbines, there is evidence that sleep disruption can adversely affect mood, cognitive functioning, and overall sense of health and well-being.

5. There is insufficient evidence that the noise from wind turbines is *directly (i.e., independent from an effect on annoyance or sleep)* causing health problems or disease.

6. Claims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system.

7. There is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a "Wind Turbine Syndrome."

8. The strongest epidemiological study suggests that there is not an association between noise from wind turbines and measures of psychological distress or mental health problems. There were two smaller, weaker, studies: one did note an association, one did not. Therefore, we conclude the weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.

9. None of the limited epidemiological evidence reviewed suggests an association between noise from wind turbines and pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine.

Health Impacts of Shadow Flicker

1. Scientific evidence suggests that shadow flicker does not pose a risk for eliciting seizures as a result of photic stimulation.

2. There is limited scientific evidence of an association between annoyance from prolonged shadow flicker (exceeding 30 minutes per day) and potential transitory cognitive and physical health effects.

Ice Throw

Production of Ice Throw

Ice can fall or be thrown from a wind turbine during or after an event when ice forms or accumulates on the blades.

1. The distance that a piece of ice may travel from the turbine is a function of the wind speed, the operating conditions, and the shape of the ice.
2. In most cases, ice falls within a distance from the turbine equal to the tower height, and in any case, very seldom does the distance exceed twice the total height of the turbine (tower height plus blade length).

Health Impacts of Ice Throw

1. There is sufficient evidence that falling ice is physically harmful and measures should be taken to ensure that the public is not likely to encounter such ice.

Other Considerations

In addition to the specific findings stated above for noise and vibration, shadow flicker and ice throw, the Panel concludes the following:

1. Effective public participation in and direct benefits from wind energy projects (such as receiving electricity from the neighboring wind turbines) have been shown to result in less annoyance in general and better public acceptance overall.

The Panel developed "Best Practices" Recommendations Regarding Human Health Effects of Wind Turbines

Noise

Evidence regarding wind turbine noise and human health is limited. There is limited evidence of an association between wind turbine noise and both annoyance and sleep disruption, depending on the sound pressure level at the location of concern. However, there are no research-based sound pressure levels that correspond to human responses to noise. A number of countries that have more experience with wind energy and are protective of public health have developed guidelines to minimize the possible adverse effects of noise. These guidelines consider time of day, land use, and ambient wind speed. The table below summarizes the guidelines of Germany (in the categories of industrial, commercial and villages) and Denmark (in the categories of sparsely populated and residential). The sound levels shown in the table are for nighttime and are assumed to be taken immediately outside of the residence or building of concern. In addition, the World Health Organization recommends a maximum nighttime sound pressure level of 40 dB(A) in residential areas. Recommended setbacks corresponding to these values may be calculated by software such as WindPro or similar software. Such calculations are normally to be done as part of feasibility studies. The Panel considered the guidelines shown below to be Promising Practices (Category 3) but to embody some aspects of Field Tested Best Practices (Category 2) as well.

Promising Practices for Nighttime Sound Pressure Levels by Land Use Type

Land Use	**Sound Pressure Level dB(A) Nighttime Limits**
Industrial	70
Commercial	50
Villages, mixed usage	45
Sparsely populated areas, 8 m/s wind*	44
Sparsely populated areas, 6 m/s wind*	42
Residential areas, 8 m/s wind*	39
Residential areas, 6 m/s wind*	37

**measured at 10 m above ground, outside of residence or location of concern*

The time period over which these noise limits are measured or calculated also makes a difference. For instance, the often-cited World Health Organization recommended nighttime noise cap of 40 dB(A) is averaged over one year (and does not refer specifically to wind turbine noise). Denmark's noise limits in the table above are calculated over a 10-minute period. These limits are in line with the noise levels that the epidemiological studies connect with insignificant reports of annoyance.

The Panel recommends that noise limits such as those presented in the table above be included as part of a statewide policy *(in Massachusetts)* regarding new wind turbine installations. In addition, suitable ranges and procedures for cases when the noise levels may be greater than those values should also be considered. The considerations should take into account trade-offs between environmental and health impacts of different energy sources, national and state goals for energy independence, potential extent of impacts, etc.

Shadow Flicker

Based on the scientific evidence and field experience related to shadow flicker, Germany has adopted guidelines that specify the following:

1. Shadow flicker should be calculated based on the astronomical maximum values (i.e., not considering the effect of cloud cover, etc.).
2. Commercial software such as WindPro or similar software may be used for these calculations. Such calculations should be done as part of feasibility studies for new wind turbines.
3. Shadow flicker should not occur more than 30 minutes per day and not more than 30 hours per year at the point of concern (e.g., residences).
4. Shadow flicker can be kept to acceptable levels either by setback or by control of the wind turbine. In the latter case, the wind turbine manufacturer must be able to demonstrate that such control is possible.

Ice Throw

Ice falling from a wind turbine could pose a danger to human health. It is also clear that the danger is limited to those times when icing occurs and is limited to relatively close proximity to the wind turbine. Accordingly, the following should be considered Category 1 Best Practices.

1. In areas where icing events are possible, warnings should be posted so that no one passes underneath a wind turbine during an icing event and until the ice has been shed.
2. Activities in the vicinity of a wind turbine should be restricted during and immediately after icing events in consideration of the following two limits (in meters).

For a turbine that may not have ice control measures, it may be assumed that ice could fall within the following limit:

$x\,(\,R\,H\,)_{throw} = 1.5\ 2 + {}_{max,}$

Where: R = rotor radius (m), H = hub height (m)

For ice falling from a stationary turbine, the following limit should be used:

$(\,)/15\ {}_{max,}x\ U\,R\,H_{fall} = +$

Where: U = maximum likely wind speed (m/s)

The choice of maximum likely wind speed should be the expected one-year return maximum, found in accordance to the International Electrotechnical Commission's design standard for wind turbines, IEC 61400-1. Danger from falling ice may also be limited by ice control measures. If ice control measures are to be considered, the wind turbine manufacturer must be able to demonstrate that such control is possible.

Public Participation/Annoyance

There is some evidence of an association between participation, economic or otherwise, in a wind turbine project and the annoyance (or lack thereof) that affected individuals may express. Accordingly, measures taken to directly involve residents who live in close proximity to a wind turbine project may also serve to reduce the level of annoyance. Such measures may be considered to be a Promising Practice (Category 3).

The following is the Abstract for the December of 2014 PLOS One published an article titled Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review. This article was written by Jesper Hvass Schmidt1,2,3*, Mads Klokker4,5 1. Institute of Clinical Research, University of Southern Denmark, Odense, Denmark, 2. Department of Audiology, Odense University Hospital, Odense, Denmark, 3. Department of ENT Head and Neck Surgery, Odense University Hospital, Odense, Denmark, 4. Department of ENT Head and Neck Surgery & Audiology, Copenhagen University Hospital, Copenhagen, Denmark, 5. Faculty of Health and Medical Sciences, Copenhagen University, Copenhagen, Denmark (Refernce: Schmidt JH, Klokker M (2014) Health Effects Related to Wind Turbine Noise Exposure: A Systematic Review. PLoS ONE 9(12): e114183.

Background: Wind turbine noise exposure and suspected health-related effects thereof have attracted substantial attention. Various symptoms such as sleep related problems, headache, tinnitus and vertigo have been described by subjects suspected of having been exposed to wind turbine noise.

Objective: This review was conducted systematically with the purpose of identifying any reported associations between wind turbine noise exposure and suspected health-related effects.

Data Sources: A search of the scientific literature concerning the health-related effects of wind turbine noise was conducted on PubMed, Web of Science, Google Scholar and various other Internet sources. Study Eligibility Criteria: All studies investigating suspected health-related outcomes associated with wind turbine noise exposure were included.

Results: Wind turbines emit noise, including low-frequency noise, which decreases incrementally with increases in distance from the wind turbines. Likewise, evidence of a dose-response relationship between wind turbine noise linked to noise annoyance, sleep disturbance and possibly even psychological distress was present in the literature. Currently, there is no further existing statistically-significant evidence indicating any association between wind turbine noise exposure and tinnitus, hearing loss, vertigo or headache.

Limitations: Selection bias and information bias of differing magnitudes were found to be present in all current studies investigating wind turbine noise exposure and adverse health effects. Only articles published in English, German or Scandinavian languages were reviewed.

Conclusions: Exposure to wind turbines does seem to increase the risk of annoyance and self-reported sleep disturbance in a dose-response relationship. There appears, though, to be a tolerable level of around LAeq of 35 dB. Of the many other claimed health effects of wind turbine noise exposure reported in the literature, however, no conclusive evidence could be found. Future studies should focus on investigations aimed at objectively demonstrating whether or not measureable health-related outcomes can be proven to fluctuate depending on exposure to wind turbines.

In 2009, the World Health Organization – Europe published a report titled: Night Noise Guidelines for Europe. The following is an abstract from that report:

The WHO Regional Office for Europe set up a working group of experts to provide scientific advice to the Member States for the development of future legislation and policy action in the area of assessment and control of night noise exposure. The working group reviewed available scientific evidence on the health effects of night noise, and derived health-based guideline values. In December 2006, the working group and stakeholders from industry, government and nongovernmental organizations reviewed and reached general agreement on the guideline values and key texts for the final document of the *Night noise guidelines for Europe.*

Considering the scientific evidence on the thresholds of night noise exposure indicated by Lnight,outside as defined in the Environmental Noise Directive (2002/49/EC), an Lnight,outside of 40 dB should be the target of the night noise guideline (NNG) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. Lnight,outside value of 55 dB is recommended as an interim target for the countries where the NNG cannot be achieved in the short term for various reasons, and where policy-makers choose to adopt a stepwise approach. These guidelines are applicable to the Member States of the European Region, and may be considered as an extension to, as well as an update of, the previous WHO *Guidelines for community noise* (1999).

Below is a chart from the Executive Summary. This study was NOT specific to wind turbine noise, but did consider noise from all sources, such as traffic, industry, and airplanes.

Table 3
Effects of different levels of night noise on the population's health

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 no observed effect level (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 lowest observed adverse effect level (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.

Council of Canadian Academies, 2015. *Understanding the Evidence: Wind Turbine Noise.* Ottawa (ON): The Expert Panel on Wind Turbine Noise and Human Health, Council of Canadian Academies.
Executive Summary

Demand for renewable energy, including wind power, is expected to continue to grow both in Canada and globally for the foreseeable future. The wind energy sector in Canada has grown at an ever-increasing pace since the 1990s, and Canada is now the fifth-largest market in the world for the installation of new wind turbines. As the sector grows, the wind turbines being installed are getting more powerful. The first megawatt-scale turbines were installed in Canada in 2004, with 3 megawatt models arriving in 2008; larger models up to 7.5 megawatt are currently being tested internationally. To produce this power, turbines have also increased in size. As wind turbines become a more common feature of the Canadian landscape, this new source of environmental sound has raised concerns about potential health effects on nearby residents.

Determining whether wind power causes adverse health effects in people is therefore important so that all Canadians can equitably share in the benefits of this technology.

THE CHARGE TO THE PANEL

In response to growing public concern about the potential health effects of wind turbine noise, the Government of Canada, through the Minister of Health (the Sponsor), asked the Council of Canadian Academies (the Council) to conduct an assessment of the question:

Is there evidence to support a causal association between exposure to wind turbine noise and the development of adverse health effects?

The Charge also includes the following sub-questions:

Are there knowledge gaps in the scientific and technological areas that need to be addressed in order to fully assess possible health impacts from wind turbine noise?

Is the potential risk to human health sufficiently plausible to justify further research into the association between wind turbine noise exposure and the development of adverse health effects?

How does Canada compare internationally with respect to prevalence and nature of reported adverse health effects among populations living in the vicinity of commercial wind turbine establishments?

Are there engineering technologies and/or other best practices in other jurisdictions that might be contemplated in Canada as measures that may minimize adverse community response towards wind turbine noise?

The Panel defined *health* in a way that is consistent with the World Health Organization's concept of health: "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1946). The Panel interpreted *noise* to include both objective measures of acoustic signals in the environment (*sound*), as well as subjective perceptions of sound sensations that are unwanted by the listener (*noise*). As there are a variety of wind turbines available worldwide, with differing sound characteristics, the Panel focused specifically on the type that constitutes almost all of the installed turbines in Canada: modern, three-bladed, tower-mounted, utility-scale (500 kilowatt capacity or more), upwind, horizontal-axis wind turbines that were land-based.

THE PANEL'S APPROACH

To respond to the Charge, the Panel used an evidence-based approach to identify and review relevant research. First, the Panel identified more than 30 symptoms and health outcomes that have been attributed to exposure to wind turbine noise, based on a broad survey of peer-reviewed and grey literature, web pages, and legal decisions.

Empirical evidence related to any associations between these health outcomes and exposure to wind turbine noise was then collected from several sources, including peer-reviewed journal articles, conference papers, and grey literature. More than 300 publications were found through a comprehensive search, and these were narrowed down to 38 relevant studies related to the health effects of wind turbine noise. The body of evidence concerning each health outcome was appraised and assessed according to Bradford Hill's guidelines for causation, and summarized using standard terms adopted from the International Agency for Research on Cancer (IARC). The major steps of the Panel's approach are illustrated in Figure 1.

KEY FINDINGS

Based on its expertise and review of empirical research, the Panel made findings in the following areas:

Acoustic characteristics of wind turbine noise;
Evidence of causal relationships between exposure to wind turbine noise and adverse health effects;
Knowledge gaps and further research; and
Promising practices to reduce adverse community response.

Other aspects of the Charge, such as the prevalence of adverse health outcomes in Canada, could not be answered because of a lack of data.

ACOUSTIC CHARACTERISTICS OF WIND TURBINE NOISE

1. Sound from wind turbines is complex and variable

Like sound from any source, wind turbine noise can be described by frequency components (which determine pitch), sound pressure levels (which determine *loudness*), and the way both of these change over time. Sound from wind turbines is highly complex and variable, but has some characteristics that are similar to other sources of community noise, such as road and airport traffic noise:

Sound from wind turbines is *broadband*, composed of sound over a broad range of frequencies.

The overall sound pressure levels outdoors vary greatly depending on distance, wind speed, and transmission from the source to the receiver.

However, higher frequencies tend to be reduced indoors and with increasing distance, leading to an emphasis on lower frequencies.

It is amplitude modulated, with sound levels changing over time.

Wind turbines also emit sound with the following characteristics, which are less common than other sources of community noise:

Sounds from wind turbines may extend down to the infrasonic range and, in some cases, may include peaks or tonal components at low frequencies.

Sound emissions from a wind turbine increase with greater wind speed at the height of the blades, up to the turbine's *rated wind speed* (speed at which it generates maximum power), above which sound does not increase.

Sound from wind turbines can exhibit periodic *amplitude modulation*, often described as a "swishing" or "thumping" sound. The causes and consequences of this periodic amplitude modulation are areas of ongoing research, as wind turbine designers and manufacturers seek ways to reduce or mitigate it.

Most sound from wind turbines is produced by interactions between the surface of the blade and the air flowing over it (aerodynamic processes), which is strongest near — but not at — the blade tips. Mechanical noise from the physical movements of the gearbox, generator, and other components produces low-frequency tones in some cases.

2. Standard methods of measuring sound may not capture the low-frequency sound and amplitude modulation characteristic of wind turbine noise

Measurement of sound for health surveillance and research uses standard methods. The most commonly used methods include A-weighting, which emphasizes the frequencies according to human hearing sensitivity, and de-emphasizes low and very high frequencies. Although A-weighted measurement is an essential method, it may fail to capture the low-frequency components of wind turbine sound. In addition, measurement is often averaged over time (L_{eq}), which does not convey changes in sound pressure levels occurring in short periods (for example, within a second). Time-averaged measurement may thus fail to capture amplitude modulation.

A-weighted measurements are an important first step in determining people's exposure to audible sound in most cases, but more detailed measurements may be necessary in order for researchers to fully investigate the potential health impact of specific sources of wind turbine noise. The metrics of sound exposure most relevant to potential health outcomes are not completely understood, however, and remain an important area for further research.

WIND TURBINE NOISE AND ADVERSE HEALTH EFFECTS

The relevant empirical evidence was reviewed and weighted in order to determine the strength of evidence for a causal link between wind turbine noise and each potential adverse health effect.

3. The evidence is sufficient to establish a causal relationship between exposure to wind turbine noise and *annoyance*

The evidence consistently shows a positive relationship between outdoor wind turbine noise levels and the proportion of people who report high levels of annoyance. However, many factors can modify the strength of this relationship, such as a person's attitudes toward wind turbines and any economic benefits the person derives from them. As well, visual and noise effects of wind turbines are difficult to isolate from each other. The current state of the evidence does not allow for a definite conclusion about whether annoyance is caused by exposure to wind turbine noise alone, or whether factors such as visual impacts and personal attitudes modify the noise-annoyance relation — and to what extent, since the studies completed to date do not measure these factors independently of each other. It is also unclear which sound characteristics contribute to long-term chronic annoyance, although low-frequency components and periodic amplitude modulation have been investigated as likely candidates.

4. There is limited evidence to establish a causal relationship between exposure to wind turbine noise and *sleep disturbance*

The available evidence suggests that a direct causal relationship or an indirect (via annoyance) relationship between exposure to wind turbine noise and sleep disturbance might exist. While sleep disruption has been investigated in several studies, the resulting evidence base is smaller than that which examines the relationship between wind turbine noise and annoyance.

5. The evidence suggests a lack of causality between exposure to wind turbine noise and *hearing loss*

There is convincing evidence that exposure to wind turbine noise at typical levels associated with regulated noise limits and setbacks (distance from structures) does not cause loss of hearing, even over a lifetime of exposure.

6. The Panel found inadequate evidence of a direct causal relationship between exposure to wind turbine noise and *stress*, although stress has been linked to other sources of community noise

Available evidence suggests that a direct or indirect mechanism between exposure to wind turbine noise and stress might exist, similar to the finding for sleep disturbance, but the evidence lacks methodological and statistical strength. *Stress* has been identified as a risk factor for a number of other diseases, such as cardiovascular diseases, in the context of long-term exposure to community noise from other sources, such as road, rail, and air traffic. The current evidence related to exposure to wind turbine noise and stress is inconsistent, however.

7. For *all other health effects* considered (fatigue, tinnitus, vertigo, nausea, dizziness, cardiovascular diseases, diabetes, etc.), the evidence was inadequate to come to any conclusion about the presence or absence of a causal relationship with exposure to wind turbine noise

Hypertension and other cardiovascular diseases, diabetes, tinnitus, cognitive or task performance, psychological health, and health-related quality of life have all been the subject of empirical, population-based, wind-turbine noise studies. The evidence, however, was inconsistent or the studies had methodological limitations preventing the determination of a causal relationship between these effects and exposure to wind turbine noise. None of the other health effects considered have been the subject of a population-level study or experiments in the context of wind turbine noise. Therefore, the evidence for a causal association is largely lacking for these other effects. Conclusions about causal relationships are therefore lacking for most of the health effects postulated in a wide variety of sources reviewed by the Panel, mainly as a result of lack of evidence or problems with the quality of evidence. However, research on environmental noise has shown that annoyance can be a contributing factor or precursor to adverse health effects such as sleep disturbance, stress and cardiovascular diseases. The Panel thus developed a conceptual framework of pathways through which sound from wind turbines could plausibly result in health outcomes. Figure 2 shows this framework and summarizes the Panel's findings on the potential causal pathways between exposure to wind turbine noise and the development of adverse health effects, or the exacerbation of existing health conditions.

KNOWLEDGE GAPS AND FURTHER RESEARCH

8. Knowledge gaps prevent a full assessment of public health effects of wind turbine noise

The Panel identified specific knowledge gaps for each health condition studied, where specific types of evidence would help clarify the strength of associations, minimize bias, or eliminate possible confounding factors with respect to exposure to wind turbine noise. For example, it is unclear whether the possible pathway that could lead to sleep disturbance or stress is the direct result of exposure to wind turbine noise or of annoyance as a mediating factor.

Most existing epidemiological studies of wind turbine noise lack sufficient power to detect small changes in the risk of adverse health effects, or were designed in a way that could not rule out bias in responses or adequately control confounding factors. The Panel also identified an absence of longitudinal studies. The Panel stresses that there is a paucity of research on sensitive populations, such as children and infants and people affected by clinical conditions that may lead to an increased sensitivity to sound.

The use of adequate methods and procedures for measuring and modelling sound exposure from wind turbines, particularly indoors, would improve the quality of future studies on adverse health effects (see Key Finding 2).

9. Research on long-term exposure to wind turbine noise would provide a better understanding of the causal associations between wind turbine noise exposure and certain adverse health effects

Chronic annoyance and sleep disturbance have been linked to stress responses in studies of long-term exposure to other sources of noise, such as air and road traffic. Furthermore, these health effects are themselves risk factors for other diseases, such as cardiovascular diseases, which have previously been associated with long-term exposure to other sources of community noise. Given the burden of cardiovascular diseases on society and Canada's health care system, further research on the long-term effects of exposure to wind turbine noise, in particular on stress and sleep disturbance, would provide more data to assess the health effects of wind turbine noise. Finally, the Panel stresses that the available evidence does not allow conclusions with regard to the prevalence of annoyance or other health effects within the population exposed to sound from wind turbines in Canada. Further research and surveillance would provide a better understanding of this prevalence, both in those exposed to wind turbine noise and in the general population.

PROMISING PRACTICES AND TECHNOLOGIES TO REDUCE ADVERSE COMMUNITY RESPONSE TO WIND TURBINE NOISE

10. Technological development is unlikely to resolve, in the short term, the current issues related to perceived adverse health effects of wind turbine noise

Wind turbine designs, modifications, and technology that could reduce sound emissions are currently being explored by wind turbine manufacturers. Ongoing technological development has contributed to lower sound emissions for turbines of a given size over the previous generation of turbines, with further improvements expected. Other factors such as power output favour larger turbines, however, which can offset overall reductions in sound emissions per kilowatt of electricity produced.

11. Impact assessments and community engagement provide communities with greater knowledge and control over wind energy projects and therefore help limit annoyance

Equity and fairness have been crucial for the acceptance of wind turbines in many communities, with perceived loss of social justice and disempowerment being significant barriers to acceptance in some cases. One important regulatory approach is to conduct a noise impact assessment of any proposed project; several Canadian provinces and other countries require such an assessment. In some of the international practices reviewed by the Panel, wind energy developers engaged in consultation and communication with local authorities and residents beginning at an early stage of project development, through all stages of implementation, and even after installation. Community engagement helps to inform and educate local residents, as well as involve them in a wind energy project with the goal of fostering social acceptance.

Wind turbines are a progressively familiar sight in Canada and contribute an increasing share of the electricity consumed in Canada. Concerns over the health effects of wind turbine noise have been expressed in many ways but rarely with detailed, reproducible, and rigorous data sufficient to support a conclusion on either causation or magnitude of any potential health effect. The Panel's final report is an attempt to objectively and rigorously review empirical research on the causal link between wind turbine noise and adverse health effects, as well as potential solutions to noise-related issues contemplated elsewhere, all of which may help in addressing concerns about wind turbine noise in Canada. The report is intended not only as a tool to inform decision-making and academic research on the subject, but also to inform the continuing dialogue across Canada and internationally, and across many sectors, about wind turbine noise and adverse human health effects.

Health Canada Wind Turbine Noise and Health Study: Summary of Results

http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php#share

Background and Rationale

The Government of Canada is committed to protecting the health and well-being of Canadians. Jurisdiction for the regulation of noise is shared across many levels of government in Canada. Health Canada's mandate with respect to wind power includes providing science-based advice, upon request, to federal departments, provinces, territories and other stakeholders on the potential impacts of wind turbine noise (WTN) on community health and well-being. Provinces and territories, through the legislation they have enacted, make decisions in relation to areas including installation, placement, sound levels and mitigation measures for wind turbines.

Globally, wind energy is relied upon as an alternative source of renewable energy. In Canada wind energy capacity has grown from approximately 137 Megawatts (MW) in 2000 to just over 8.5 Gigawatts (GW) in 2014 (CANWEA, 2014). At the same time, there has been concern from some Canadians living within the vicinity of wind turbine installations that their health and well-being are negatively affected from exposure to WTN.

The scientific evidence base in relation to WTN exposure and health is limited, which includes uncertainty as to whether or not low frequency noise (LFN) and infrasound from wind turbines contributes to the observed community response and potential health impacts. Studies that are available differ in many important areas including methodological design, the evaluated health effects, and strength of the conclusions offered.

In July 2012, Health Canada announced its intention to undertake a large scale epidemiology study in collaboration with Statistics Canada (*Statistics Canada Official Title: Community Noise and Health Study*). The study was launched to support a broader evidence base on which to provide federal advice and in acknowledgement of the community health concerns expressed in relation to wind turbines.

Research Objectives and Methodology

The objectives of the study were to:

- Investigate the prevalence of health effects or health indicators among a sample of Canadians exposed to WTN using both self-reported and objectively measured health outcomes;
- Apply statistical modeling in order to derive exposure response relationships between WTN levels and self-reported and objectively measured health outcomes; and,
- Investigate the contribution of LFN and infrasound from wind turbines as a potential contributing factor towards adverse community reaction.

The study was undertaken in two Canadian provinces, Ontario (ON) and Prince Edward Island (PEI), where there were a sufficient number of homes within the vicinity of wind turbine installations. The study consisted of three primary components: an in-person questionnaire, administered by Statistics Canada to randomly selected participants living at varying distances from wind turbine installations; collection of objectively measured outcomes that assess hair cortisol, blood pressure and sleep quality; and, more than 4000 hours of WTN measurements conducted by Health Canada to support the calculation of WTN levels at residences captured in the study scope. To support the assessment and reporting of data, and permit comparisons to other studies, residences were grouped into different categories of calculated outdoor A-weighted

WTN levels as follows: less than 25 dB; 25-<30dB; 30-<35dB; 35-<40dB; and greater than or equal to 40 dB[Footnote1].

Detailed information on Health Canada's *Wind Turbine Noise and Health Study*methodology, including the 60-day public consultation and peer review process is available on the Health Canada website. The detailed methodology for the study is also available in the peer reviewed literature (*Michaud et al., Noise News International, 21(4): 14-23, 2013*).

Preliminary Research Findings[Footnote2]

Health Canada has completed its preliminary analysis of the data obtained. Research findings are presented below in accordance with the study component in which they were obtained i.e. in-person, self-report questionnaire findings, objectively measured responses, and noise measurements and calculations. As with other studies of this nature, a number of limitations and considerations apply to the study findings including:

- results may not be generalized to areas beyond the sample as the wind turbine locations in this study were not randomly selected from all possible sites operating in Canada;
- results do not permit any conclusions about causality; and,
- results should be considered in the context of all published peer-reviewed literature on the subject.

A. *Study Population and Participation*

The study locations were drawn from areas in ON and PEI where there were a sufficient number of homes within the vicinity of wind turbine installations. Twelve (12) and six wind turbine developments were sampled in ON and PEI, representing 315 and 84 wind turbines respectively. All potential homes within approximately 600 m of a wind turbine were selected, as well as a random selection of homes between 600 m and 10 km. From these, one person between the ages of 18 and 79 years from each household was randomly selected to participate.

The final sample size consisted of 2004 potential households. Of the 2004 locations sampled, 1570 were found to be valid dwellings[Footnote3] of which a total of 1238 households with similar demographics[Footnote4] participated, resulting in an overall participation rate of 78.9%. Participation rate was similar regardless of one's proximity to wind turbines and equally high in both provinces. The high response rates in this study help to reduce, but not eliminate, non-response bias[Footnote5].

B. *Self-Reported Questionnaire Results*

Results are presented in relation to WTN levels. For findings related to WTN annoyance, results are also provided in relation to distance to allow for comparisons with other studies. WTN is a more sensitive measure of exposure level and allows for consideration of topography, wind turbine characteristics and the number of wind turbines at any given distance. To illustrate, two similar homes may exist in similar environments located at the same distance from the nearest turbine operating in areas with 1 small and 75 large wind turbines respectively. These homes would be treated the same if the analysis was conducted using only distance to the nearest wind turbine, however they would be completely different in terms of their WTN exposure levels.

The following were not found to be associated with WTN exposure:

- self-reported sleep (e.g., general disturbance, use of sleep medication, diagnosed sleep disorders);
- self-reported illnesses (e.g., dizziness, tinnitus, prevalence of frequent migraines and headaches) and chronic health conditions (e.g., heart disease, high blood pressure and diabetes); and
- self-reported perceived stress and quality of life.

While some individuals reported some of the health conditions above, the prevalence was not found to change in relation to WTN levels.

1. Self-reported Sleep

Long-term sleep disturbance can have adverse impacts on health and disturbed sleep is one of the more commonly reported complaints documented in the community noise literature. Self-reported sleep disturbance has been shown in some, but not all, studies to be related to exposure to wind turbines.

The Pittsburgh Sleep Quality Index (PSQI) is a frequently used questionnaire for providing a validated measure of reported sleep pathology where scores can range from 0-21 and a global score of greater than 5 is considered to reflect poor sleep quality. The PSQI was administered as part of the overall questionnaire, which was supplemented with questions about the use of sleep medication, prevalence of sleep disorders diagnosed by a healthcare professional and how sleep disturbed people were in general over the last year.

Results of self-reported measures of sleep, that relate to aspects including, but not limited to general disturbance, use of sleep medication, diagnosed sleep disorders and scores on the PSQI, did not support an association between sleep quality and WTN levels.

2. Self-reported Illnesses and Chronic Diseases

Self-reports of having been diagnosed with a number of health conditions were not found to be associated with exposure to WTN levels. These conditions included, but were not limited to chronic pain, high blood pressure, diabetes, heart disease, dizziness, migraines, ringing, buzzing or whistling sounds in the ear (i.e., tinnitus).

3. Self-reported Stress

Exposure to stressors and how people cope with these stressors has long been considered by health professionals to represent a potential risk factor to health, particularly to cardiovascular health and mental well-being. The Perceived Stress Scale is a validated questionnaire that provides an assessment of the degree to which situations in one's life are appraised as stressful.

Self-reported stress, as measured by scores on the Perceived Stress Scale, was not found to be related to exposure to WTN levels.

4. Quality of Life

Impact on quality of life was assessed through the abbreviated version of the World Health Organization's Quality of Life scale; a validated questionnaire that has been used extensively in social studies to assess quality of life across the following four domains: Physical; Environmental; Social and Psychological.

Exposure to WTN was not found to be associated with any significant changes in reported quality of life for any of the four domains, nor with overall quality of life and satisfaction with health.

The following was found to be statistically associated with increasing levels of WTN:

- annoyance towards several wind turbine features (i.e. noise, shadow flicker, blinking lights, vibrations, and visual impacts).

5 Annoyance

5.1 Community Annoyance as a Measure of Well-being

The questionnaire, administered by Statistics Canada, included themes that were intended to capture both the participants' perceptions of wind turbines and reported prevalence of effects related to health and well-being. In this regard, one of the most widely studied responses to environmental noise is community annoyance. There has been more than 50 years of social and socio-acoustical research related to the impact that noise has on community annoyance. Studies have consistently shown that an increase in noise level was associated with an increase in the percentage of the community indicating that they are "highly annoyed" on social surveys. The literature shows that in comparison to the scientific literature on noise annoyance to transportation noise sources such as rail or road traffic, community annoyance with WTN begins at a lower sound level and increases more rapidly with increasing WTN.

Annoyance is defined as a long-term response (approximately 12 months) of being "very or extremely annoyed" as determined by means of surveys. Reference to the last year or so is intended to distinguish a long term response from one's annoyance on any given day. The relationship between noise and community annoyance is stronger than any other self-reported measure, including complaints and reported sleep disturbance.

5.2 Community Annoyance Findings

Statistically significant exposure-response relationships were found between increasing WTN levels and the prevalence of reporting high annoyance. These associations were found with annoyance due to noise, vibrations, blinking lights, shadow and visual impacts from wind turbines. In all cases, annoyance increased with increasing exposure to WTN levels.

The following additional findings in relation to WTN annoyance were obtained:

- At the highest WTN levels (≥ 40 dBA in both provinces), the following percentages of respondents were highly annoyed by wind turbine noise: ON-16.5%; PEI-6.3%. While overall a similar pattern of response was observed, the prevalence of WTN annoyance was 3.29 times higher in ON versus PEI (95% confidence interval, 1.47 - 8.68).
- A statistically significant increase in annoyance was found when WTN levels exceeded 35 dBA.
- Reported WTN annoyance was statistically higher in the summer, outdoors and during evening and night time.
- Community annoyance was observed to drop at distances between 1-2km in ON, compared to PEI where almost all of the participants who were highly annoyed by WTN lived within 550m of a wind turbine. Investigating the reasons for provincial differences is outside the scope of the current study.
- WTN annoyance significantly dropped in areas where calculated nighttime background noise exceeded WTN by 10dB or more.

- Annoyance was significantly lower among the 110 participants who received personal benefit, which could include rent, payments or other indirect benefits of having wind turbines in the area e.g., community improvements. However, there were other factors that were found to be more strongly associated with annoyance, such as the visual appearance, concern for physical safety due to the presence of wind turbines and reporting to be sensitive to noise in general.

5.3 Annoyance and Health

- WTN annoyance was found to be statistically related to several self-reported health effects including, but not limited to, blood pressure, migraines, tinnitus, dizziness, scores on the PSQI, and perceived stress.
- WTN annoyance was found to be statistically related to measured hair cortisol, systolic and diastolic blood pressure.
- The above associations for self-reported and measured health endpoints were not dependent on the particular levels of noise, or particular distances from the turbines, and were also observed in many cases for road traffic noise annoyance.
- Although Health Canada has no way of knowing whether these conditions may have either pre-dated, and/or are possibly exacerbated by, exposure to wind turbines, the findings support a potential link between long term high annoyance and health.
- Findings suggest that health and well-being effects may be partially related to activities that influence community annoyance, over and above exposure to wind turbines.

C. *Objectively Measured Results*

Objectively measured health outcomes were found to be consistent and statistically related to corresponding self-reported results. WTN was not observed to be related to hair cortisol concentrations, blood pressure, resting heart rate or measured sleep (e.g., sleep latency, awakenings, sleep efficiency) following the application of multiple regression models[Footnote 6].

1. Measures Associated with Stress

Hair cortisol, blood pressure and resting heart rate measures were applied in addition to the Perceived Stress Scale to provide a more complete assessment of the possibility that exposure to WTN may be associated with physiological changes that are known to be related to stress.

Cortisol is a well-establish biomarker of stress, which is traditionally measured from blood and/or saliva. However, measures from blood and saliva reflect short term fluctuations in cortisol and are influenced by many variables including time of day, food consumption, body position, brief stress, etc., that are very difficult to control for in an epidemiology study. To a large extent, such concerns are eliminated through measurement of cortisol in hair samples as cortisol incorporates into hair as it grows. With a predictable average growth rate of 1 cm per month, measurement of cortisol in hair makes it possible to retrospectively examine months of stressor exposure. Therefore cortisol is particularly useful in evaluating the potential impact that long term exposure to WTN has on one of the primary biomarkers linked to stress.

The results from multiple linear regression analysis reveal consistency between hair cortisol concentrations and scores on the Perceived Stress Scale (i.e., higher scores on this scale were associated with higher concentrations of hair cortisol) with neither measure found to be significantly affected by exposure to WTN. Similarly, while self-reported high blood pressure (hypertension) was associated with higher measured blood pressure, no statistically significant association was observed between measured blood pressure, or resting heart rate, and WTN exposure.

2. Sleep Quality

Sleep was measured using the Actiwatch2™, which is a compact wrist-worn activity monitor that resembles a watch. This device has advanced sensing capabilities to accurately and objectively measure activity and sleep information over a period of several days. This device is considered to be a reliable and valid method of assessing sleep in non-clinical situations. The following measured sleep impacts were considered: sleep latency (how long it took to fall asleep); wake time after sleep onset (the total duration of awakenings); total sleep time; the rate of awakening bouts (calculates how many awakenings occur as a function of time spent in bed); and sleep efficiency (total sleep time divided by time in bed).

Sleep efficiency is especially important because it provides a good indication of overall sleep quality. Sleep efficiency was found to very high at 85% and statistically influenced by gender, body mass index (BMI), education and caffeine consumption.

The rates of awakening bouts, total sleep time or sleep latency were further found in some cases to be related to: age, marital status, closing bedroom windows, BMI, physical pain, having a stand-alone air conditioner in the bedroom, self-reports of restless leg syndrome and being highly annoyed by the blinking lights on wind turbines.

While it can be seen that many variables had a significant impact on measured sleep, calculated outdoor WTN levels near the participants' home was not found to be associated with sleep efficiency, the rate of awakenings, duration of awakenings, total sleep time, or how long it took to fall asleep.

D. *Wind Turbine Noise Measures Results*

Note - To support a greater understanding of the concepts included in this section, Health Canada has developed a short Primer on Noise.

Scientists that study the community response to noise typically measure different sounds levels with a unit called the A-weighted decibel (dBA). The A-weighting reflects how people respond to the loudness of common sounds; that is, it places less importance on the frequencies to which the ear is less sensitive. For most community noise sources this is an acceptable practice. However, when a source contains a significant amount of low frequencies, an A-weighted filter may not fully reflect the intrusiveness or the effect that the sound may have (e.g. annoyance). In these cases, the use of a C-weighted filter (dBC) may be more appropriate because it is similar to the A-weighting except that it includes more of the contribution from the lower frequencies than the A-weighted filter.

1. A- Weighted

More than 4000 hours of WTN measurements conducted by Health Canada supported the calculations of A-weighted WTN levels at all 1238 homes captured in the study sample.

- Calculated outdoor A-weighted WTN levels for the homes participating in the study reached 46 dBA for wind speeds of 8m/s. This approach is the most appropriate to quantify the potential adverse effects of WTN. The calculated WTN levels are likely to be representative of yearly averages with an uncertainty of about +/- 5dB and therefore can be compared to World Health Organization (WHO) guidelines. The WHO identifies an annual outdoor night time average of 40 dBA as the level below which no health effects associated with sleep disturbance are expected to occur even among the most vulnerable people (WHO (2009) *Night Noise Guidelines for Europe*).

2. Low Frequency Noise

Wind turbines emit LFN, which can enter the home with little or no reduction in energy potentially resulting in rattles in light weight structures and annoyance. Although the limits of LFN are not fixed, it generally includes frequencies from between 20Hz and 200Hz. C-weighted sound levels can be a better indicator of LFN in comparison to A-weighted levels, and were calculated in order to assess the potential LFN impacts.

- Calculated outdoor dBC levels for homes ranged from 24 dBC and reached 63 dBC.
- Three (3)% of the homes were found to exceed 60 dBC[Footnote 7].
- No additional benefit was observed in assessing LFN because C- and A-weighted levels were so highly correlated (r=0.94) that they essentially provided the same information. It was therefore not surprising that the relationship between annoyance and WTN levels was predicted with equal strength using dBC or dBA and that there was no association found between dBC levels and any of the self-reported illnesses or chronic health conditions assessed (e.g., migraines, tinnitus, high blood pressure, etc.)
- Sound pressure levels were found to be below the recommended thresholds for reducing perceptible rattle and the annoyance that rattle may cause.

As LFN is generally considered to be an indoor noise problem, it was of interest to better understand how much outdoor LFN makes its way into the home.

- At a selection of representative homes, Health Canada measurements showed an average of 14dB of outdoor WTN is blocked from entering a home at low frequencies (16 Hz - 100 Hz) with closed windows compared to an average reduction of 10dB with windows partially open.

3. Infrasound

Long-term measurements over a period of 1 year were also conducted in relation to infrasound levels.

- Infrasound from wind turbines could sometimes be measured at distances up to 10km from the wind turbines, but was in many cases below background infrasound levels.
- The levels were found to decrease with increasing distance from the wind turbine at a rate of 3dB per doubling of distance beyond 1km, downwind from a wind turbine.
- The levels of infrasound measured near the base of the turbine were around the threshold of audibility that has been reported for about 1% of people that have the most sensitive hearing.

Due to the large volume of acoustical data, including that related to infrasound, analysis will continue over subsequent months with additional results being released at the earliest opportunity throughout 2015.

Data Availability and Application

Detailed descriptions of the above results will be submitted for peer review with open access in scientific journals and should only be considered final following publication. All publications by Health Canada related to the study will be identified on the Health Canada website.

Raw data originating from the study is available to Canadians, other jurisdictions and interested parties through a number of sources: Statistics Canada Federal Research Data Centres, the Health Canada website (noise data), open access to publications in scientific journals and conference presentations. Plain language abstracts outlining the research and identifying the scientific journals where papers can be found will further be published to the Departmental website.

Health Canada's Wind Turbine Noise and Health Study included both self-reported and physically measured health effects as together they provide a more complete overall assessment of the potential impact that exposure to wind turbines may have on health and well-being.

Study results will support decision makers by strengthening the peer-reviewed scientific evidence base that supports decisions, advice and policies regarding wind turbine development proposals, installations and operations. The data obtained will also contribute to the global knowledge of the relationship between WTN and health.

Exhibit 3

COUNTY ZONING REGULATIONS

ARTICLE 13 SPECIAL PERMIT

13.048. Commercial Wind Energy Conversion System (CWECS)

A Commercial Wind Energy Conversion System (CWECS) may be allowed in the AG District by special permit under the conditions listed below:

a. In cases where CWECS wind turbines are part of a unified plan, parcels which are separated from one another only by the presence of public right-of-way may be combined into one special permit application. When a special permit covers multiple premises, the lease or easement holder may sign the application rather than the lot owner.

b. Turbines shall meet all FAA requirements, including but not limited to lighting and radar interference issues. Strobe lighting shall be avoided if alternative lighting is allowed. Color and finish shall be white, gray or another non-obtrusive, non-reflective finish. There shall be no advertising, logo, or other symbols painted on the turbine other than those required by the FAA or other governing body. Each turbine shall have onsite a name plate which is clearly legible from the public right-of-way and contains contact information of the operator of the wind facility.

c. Each application shall have a decommissioning plan outlining the means, procedures and cost of removing the turbine(s) and all related supporting infrastructure and a bond or equivalent enforceable resource to guarantee removal and restoration upon discontinuance, decommissioning or abandonment. Each tower shall be removed within one year of decommissioning or revocation of the special permit. Upon removal of the tower, there shall be

d. Any proposed turbine which is within half mile of any non-participating dwelling shall provide shadow flicker modeling data showing the expected effect of shadow flicker on non-participating properties. Shadow flicker shall not fall upon any non-participating dwelling, or other building which is occupied by humans, for more than a total of 30 hours per any calendar year. If shadow flicker exceeds these limits, measures shall be taken to reduce the effects of shadow flicker on buildings, which may include shutting the turbine down during periods of shadow flicker. If a turbine violates this standard on a non-participating dwelling unit, constructed after the turbine is approved, then the turbine becomes a non-conforming use.

e. Construction and operation shall not adversely impact identified State or Federal threatened or endangered species such as saline wetlands, or rare natural resources such as native prairie and grasslands.

f. No turbine shall obstruct or impair an identified view corridor or scenic vista of public value, as mapped on the Capitol View Corridors map in the Lincoln/ Lancaster County Comprehensive Plan. The views from prominent environmental areas, such as Nine Mile Prairie and Spring Creek Prairie, shall also be protected from adverse visual or noise impacts. Any application which, upon initial review, poses a possible impact to these views will be required to be relocated or provide view shed mapping, and visual simulations from key observation points for review.

g. Setbacks to the turbine base:

   2. For a non-participating lot, the setback shall be 2 times the turbine height measured to the property line, or 3 ½ times the turbine height, measured to the closest exterior wall of the dwelling unit, whichever is greater, but at a minimum 1,000 feet to the property line.
   3. For participating dwelling units, the setback shall be 2 times the turbine height measured to the closest exterior wall of the dwelling.
   4. The setback to any public right-of-way or private roadway shall be no less than the turbine height.

5. Setbacks to the external boundary of the special permit area shall be no less than as stated above, except that the owner of the adjacent property may sign an agreement allowing that setback to be reduced to the rotor radius plus the setback of the zoning district.

h. The turbine(s) shall not impact a non-participating lot, (vacant or occupied; of any size), to the extent that, because of the location of turbine(s), the lot owner is left with less than 3 acres of land outside of the CWECS setbacks and the noise impact area in Section (i) below, unless they are part of an agreement with the CWECS owner/operator.

i. Noise: No CWECS or combination of CWECS turbine(s) shall be located as to cause an exceedance of the following as measured at the closest exterior wall of any dwelling located on the property. If a turbine violates a noise standard on a dwelling unit, constructed after the turbine is approved, then the turbine becomes a non-conforming use. For both participating and nonparticipating properties:

   1. From the hours of 7 am to 10 pm:
      i. Forty (40) dBA maximum 10 minute Leq or;
      ii. Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 15 hour period.
   2. From the hours of 10 pm to 7 am:
      i. Thirty-seven (37) dBA maximum 10 minute Leq or;
      ii. Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 9 hour period.

j. A professional pre-construction noise study shall be conducted which includes all property within one mile of a tower support base. The protocol and methodology for such studies shall be submitted to the Lincoln-Lancaster County Health Department for review and approval. Such studies shall include noise modeling for all four seasons and include typical and worst case scenarios for noise propagation. The complete results and full study report shall be submitted to the Lincoln-Lancaster County Health Department for review.

k. Prior to the commencement of construction of any turbine, pre-construction noise monitoring may be conducted to determine ambient sound levels in accordance with procedures acceptable to the Lincoln-Lancaster County Health Department.

l. Prior to the commencement of construction of any turbine, the applicant shall enter into an agreement with the County Engineer regarding use of County roads during construction.

m. At the discretion of the County Board, post-construction noise level measurements may be required to be performed in accordance with procedures acceptable to the Lincoln-Lancaster County Health Department.

n. All noise complaints regarding the operation of any CWECS shall be referred to the County Board. The County Board shall determine if noise monitoring shall be required to determine whether a violation has occurred. (Resolution No. R-15-0061, November 24, 2015; Resolution No. R-11-0022, March 29, 2011)

Blue Prairie Wind, LLC

November 16, 2018

Lancaster County Planning Department
555 South Tenth Street
Lincoln, Nebraska 68508

RE: Application for Text Amendment

Lancaster County Planning and Zoning Board:

Enclosed is a proposed text amendment to Lancaster County Zoning Regulations Chapter 13.048 that modifies a noise limit for landowners who choose to participate in a wind energy project. This change is designed to provide needed flexibility for citizens seeking to invest in wind energy development while protecting disinterested third parties from disturbance. In addition, this proposed change would align Lancaster County more closely with surrounding counties, thus making Lancaster County competitive for wind energy development, without sacrificing any of the protections that Lancaster County citizens currently enjoy under the regulations the County Commission adopted in 2015. We look forward to the opportunity to review the details of this proposal at your earliest convenience.

~~Warmest~~ Regards,

David Kuhn
Project Manager
Renewable Development

Blue Prairie Wind, LLC
700 Universe Boulevard, Juno Beach, FL 33408

Exhibit 4

OLLSON
Environmental Health Management

September 21, 2018

Proposed Noise Levels at Participating Landowners Dwelling in a Commercial Wind Energy Conversion System (CWECS) in Lancaster County, Nebraska

Over the past decade there has been considerable research conducted around the world evaluating health concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government medical agencies has taken place in many different countries on a variety of models of turbines that have been in communities for numerous years. Based on scientific principles, and the collective findings of over 80 scientific articles, there is scientific justification to allow CWECS project participating landowners to have a noise limit of fifty (50) dBA maximum 10 minute Leq level at the exterior wall of their dwellings. This limit will enable proper siting of wind turbines on participating land while still ensuring the protection of public health, safety and welfare of participating residents.

This report examines the key issues surrounding sound levels at participating landowner's homes and provides scientific support for allowing the standard to be increased, while still ensuring the protection of their health.

1 Proposed Noise Levels at Participating Landowner Dwellings in Lancaster County, NE

The Lancaster Board of County Commissioners adopted Resolution No. R-15-0061 on November 10th, 2015. This resolution resulted in the adoption of Section 13.048, Commercial Wind Energy Conversion Systems, that revised the special permit conditions for wind turbine projects regarding decommissioning, shadow flicker, impact on environmental resources and view corridors, setbacks, noise, noise studies and other conditions.

The focus of this report is on Subsection (i), which states:

> *(i) Noise: No CWECS or combination of CWECS turbine(s) shall be located as to cause an exceedance of the following as measured at the closest exterior wall of any dwelling located on the property. If a turbine violates a noise standard on a dwelling unit, constructed after the turbine is approved, then the turbine becomes a non-conforming use. For both participating and nonparticipating properties:*
>
> *(1) From the hours of 7 am to 10 pm:*
>
> - *Forty (40) dBA maximum 10 minute Leq or;*
> - *Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 15 hour period.*
>
> *(2) From the hours of 10 pm to 7 am:*
>
> - *Thirty-seven (37) dBA maximum 10 minute Leq or;*
> - *Three (3) dBA maximum 10 minute Leq above background level as determined by a pre-construction noise study. The background level shall be a Leq measured over a representative 9 hour period.*

Additionally, Subsection (j) provides details on pre-construction noise study to be completed:

(j) *A professional pre-construction noise study shall be conducted which includes all property within one mile of a tower support base. The protocol and methodology for such studies shall be submitted to the Lincoln-Lancaster County Health Department for review and approval. Such studies shall include noise modeling for all four seasons and include typical and worst case scenarios for noise propagation. The complete results and full study report shall be submitted to the Lincoln-Lancaster County Health Department for review.*

Subsection (j) is appropriate to ensure the protection of both participating and non-participating landowners. However, Subsection (i) should not be equally applied to participating and non-participating landowners. The amended Lancaster County ordinance is amongst the most restrictive sound levels in the Midwest for participating landowners.

Participating and non-participating landowners should be considered separately. In fact, there are numerous examples in the Lancaster County Section 13.048 where this is already the case. For example, the provisions for shadow flicker apply only to non-participating dwellings. In addition, setback distances from wind turbines to dwellings are more restrictive for non-participants than for participating landowners. Allowing a greater setback for non-participating landowners is consistent with general zoning principles for energy facilities and should equally apply to the noise requirements in the ordinance.

It is recommended that the Board of Commissioners should consider changing the language for participating land owners to:

Fifty (50) dBA maximum 10 minute Leq for all hours of the day.

The following sections provide the scientific basis for allowing for up to 50 dBA sound level at participating dwellings. OEHM has not provided any comment on the sound levels for nonparticipating landowners as it is my understanding that NEER intends to design their wind project to comply with these requirements.

2 Other Nebraska and State Jurisdiction Sound Levels

OEHM respects that each jurisdiction has the right to set noise limits that they believe to be appropriate to protect the public health and safety of their citizens. It is understood that a considerable amount of time was spent by the County Health Department and others aiding in developing the amendment to the CWECS siting guidelines. For this very reason OEHM has not commented on the appropriateness of the 37 dBA nighttime and 40 dBA daytime for protecting and reducing annoyance for non-participating landowners. However, there are many jurisdictions that allow participating landowners to voluntarily have different sound levels than their non-participating neighbors.

2.1 Nebraska Experience

By 2017 there were almost 800 wind turbines in Nebraska with an installed wind capacity of 1500 MW across the state and an additional 862 MW of wind projects under construction. In Nebraska there is no overarching state regulation on the sound level at homes resulting from wind turbines. However, numerous counties in Nebraska allow for a 50 dBA or greater noise limit at participating (and even non-participating) dwellings. NEER currently operates two wind farms in Nebraska – Cottonwood Wind (2017, 40 turbine, 90 MW) in Webster County and Steel Flats (2013, 44 turbine, 75 MW) in Gage County.

Webster County Zoning Regulations Section 609.E.G.3. provides the following for sound levels:

> *SOUND LEVEL: The utility grid WECS sound levels shall not exceed fifty-five (55) decibels using the A scale (dBA), as measured at any occupied building or noise sensitive receptor within the project boundary and on non-leased lands with the project boundary and on lands within one-half mile of the project boundary. In the event audible noise from the operation of the WCES contains a pure steady tone, the maximum sound level shall be reduced by five (5) dBA. The applicant shall provide modeling and analysis that will confirm that the utility grid WECS project will not exceed the maximum permitted sound pressure levels. Modeling and analysis shall conform to IEC 61400 and ISO 9613.*

Gage County Zoning Regulations Article 6.6 (updated March 2016) Section 6.70 provides the following for noise:

6.70 Noise

> *A. No CWECS shall exceed 60 dBA 10 minute Leq at the nearest structure occupied by humans. In the event of periods of severe weather, as defined by the United States Weather Service, a CWECS may exceed 60 dBA. Except that a participating landowner may waive a noise limitation by written agreement, which shall be submitted at the time of the application.*
>
> *1. No CWECS shall exceed 45 dBA during the day time and 40 dBA at night (night hours are 10:00 pm to 7:00 am) at the nearest residence of a non-participating property; or*
>
> > *a. Five (5) dBA maximum 10 minute Leq allowed above ambient noise level.*
> >
> > *b. In the event of periods of severe weather, as defined by the United States Weather Service, a CWECS may exceed 60 dBA.*
>
> *2. A non-participating landowner can waive a noise requirement by written agreement. A written waiver shall be submitted at the time of the application. Such an agreement must be filed with the Register of Deeds and proof of that filing shall be provided to the Gage County Planning & Zoning Administrator prior to approval of the permit.*

The NEER projects in both of these counties were designed such that the maximum sound level at participating residents does not exceed 50 dBA. It is OEHM's understanding that NEER has an excellent working relationship with their participating landowners and has not received any complaints about the noise levels associated with the wind turbines.

The Gage County Zoning Ordinance provides similar language to what is being proposed by OEHM to Lancaster County for consideration. Specifically they also have a lower noise level for non-participating landowners and allow participating landowners a greater noise at the nearest occupied dwelling. Therefore, this precedent has already been established in Nebraska and it has been proven to work.

2.2 Oregon Administrative Rule 340-035-0035 Noise Control Regulations for Industry and Commerce

There are a number of jurisdictions, both at the county and state level, that allow for higher noise levels at participating homes than those for non-participants. Oregon provides the best example of a comparable rule to Gage County, NE and that being requested by NEER for Lancaster County. The following is an excerpt from the rules governing noise levels from wind turbines at participating and non-participating:

> *(iii) For noise levels generated or caused by a wind energy facility:*

(I) The increase in ambient statistical noise levels is based on an assumed background L50 ambient noise level of 26 dBA or the actual ambient background level. The person owning the wind energy facility may conduct measurements to determine the actual ambient L10 and L50 background level.

(II) The "actual ambient background level" is the measured noise level at the appropriate measurement point as specified in subsection (3)(b) of this rule using generally accepted noise engineering measurement practices. Background noise measurements shall be obtained at the appropriate measurement point, synchronized with wind speed measurements of hub height conditions at the nearest wind turbine location. "Actual ambient background level" does not include noise generated or caused by the wind energy facility.

(III) The noise levels from a wind energy facility may increase the ambient statistical noise levels L10 and L50 by more than 10 dBA (but not above the limits specified in Table 8 [50 dBA]), if the person who owns the noise sensitive property executes a legally effective easement or real covenant that benefits the property on which the wind energy facility is located. The easement or covenant must authorize the wind energy facility to increase the ambient statistical noise levels, L10 or L50 on the sensitive property by more than 10 dBA at the appropriate measurement point.

The Orgeon metric of L50 is the same as the Leq being used by Lancaster County. Essentially what the language says, and is done in practice, is that non-participating homes can not experience more than 36 dBA at the exterior of their homes (similar to the 37 dBA in Lancaster County at nighttime), while participating landowners with waiver may experience up to 50 dBA of noise at the exterior of their homes both during the day and at night. This practice was put in place to reduce the level of annoyance for non-participating landowners, while recognizing that those who economically benefit from the projects will unlikely be annoyed by the sound. According to a health impact assessment (HIA) completed by the Oregon Health Authority (2013):

> *"Further, landowners who waive Oregon's ambient degradation standard may perceive and respond differently (potentially more favorably) to the new noise levels, particularly if they benefit from the facility or have good relations with the developer."*

3 Health Research on Living in Proximity to Wind Turbines

Wind-based energy production has been identified as a clean and renewable resource that does not produce any known emissions or harmful wastes. As a result, wind power has become the fastest growing source of new electric power generation, with several countries achieving high levels of wind power capacity.

Over 80 studies have been published worldwide to examine the relationship between wind turbines and possible human health effects. Based on the findings and scientific merit of these studies they have led health and medical authorities to conclude that when sited properly (i.e., based on distance and/or noise guidelines and setbacks), wind turbines are not causally related to adverse effects.

This report serves to provide the scientific basis that allowing a different noise level at participating dwellings will still ensure the protection of their health and safety. The focus is on:

- Audible noise
- Low frequency noise and infrasound
- Annoyance

The past decade of rapid increase in wind power development in North America has been coupled with some who believe that wind turbines should be set miles back from residences, at very low noise levels, or else it will result in public health impacts. However, the weight of scientific evidence does not hold this to be true. The following section provides an overview of the most up to date peer-reviewed published evidence that provides the rationale that 50 dBA is protective of health, especially for participating landowners.

3.1 Peer-Reviewed Health Literature for Consideration

The Health Canada Wind Turbine Noise and Health Study – The Most Comprehensive Study 2012-2014

This study is the most comprehensive study of its kind to date and its results will be referenced a number of times in this report. The following provides a high-level overview of the study design. This study was initiated in 2012 and was a partnership between Health Canada and Statistics Canada to understand the potential impacts of wind turbine noise on health and wellbeing of communities in Southern Ontario and Prince Edward Island (PEI). A total of 1238 households participated in the study, with an almost 80% response rate of all households within 10 km (6 mi) of projects investigated, making it the largest and most comprehensive study ever undertaken around the world. Households were located as close as 250 m (820 ft) and out to 10 km (6 mi) from operational wind turbines. Their reported high response rate included 1238 randomly selected participants (606 males, 632 females) between the ages of 18-79 years old. In addition, the study included both self-reported and physical/objective measures of health in participants. The sound modeling conducted in relation to this study indicated wind turbine noise (WTN) as high as 46 dBA outside of people's homes. This does not mean that issues arise at levels of greater than 46 dBA, rather it is just the high end of sound that was predicted in this study. Note that modeling wind turbine noise is typically more conservative in the United States and would result in 46 dBA being modeled typically as 47-49 dBA at the exterior of the homes.

In 2014, Health Canada released a Summary of their findings on their website (Health Canada, 2014).

http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

Health Canada chose to release the summary of their findings to make the information available to the scientific community and the public in a timely manner. Subsequently, they have released eight (8) peer-reviewed scientific publications with their results.

Health Canada's public brochure contains the following statement:

> *The Wind Turbine Noise and Health Study is a landmark study and the most comprehensive of its kind. Both the methodology used and the results are significant contributions to the global knowledge base and examples of innovative; leading edge research.*

At the time that Lancaster County was reviewing the amendments in 2015 only a summary of the Health Canada findings was available on their website. Since 2016, Health Canada has published a number of their findings in scientific peer-reviewed journals. This provides considerably more information than what was available in 2015. Scientific papers with the first author "Michaud" that are provided below are those resulting from the Health Canada study.

3.2 Sleep and Audible Sound (Noise)

The critical effect from a health perspective in setting any sound source standard is to ensure that it is protective of sleep. Quality of sleep and sleep perception can be challenging to establish causation through self-reported surveys alone.

In 2006, the Institute of Medicine of the National Academies released the book "*Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*" (IOM, 2006). At that time they reported that: *"It is estimated that 50 to 70 million Americans suffer from a chronic disorder of sleep and wakefulness, hindering daily functioning and adversely affecting health."* In 2006 the population of the United States was 298 million, resulting in an approximately 23% of Americans with sleep disorders. This needs to be considered within any review of the sleep literature with respect to wind turbines.

Michaud et al., 2016. Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep. Sleep, Vol. 39, No. 1 (Health Canada)

The journal Sleep is a highly respected scientific publication in this area of research. This is reflected in its five-year Impact Factor score of 5.8. The paper presents the peer-reviewed published findings of the Health Canada study (2014) of wind turbine noise on sleep. The sample size was the entire 1,238 participants from the overall study for self-reported sleep quality over 30 days using the Pittsburgh Sleep Quality Index (PSQI) and additional questions assessing the prevalence of diagnosed sleep disorders and the magnitude of sleep disturbance over the previous year. For the first time for wind turbine sound and objective measures for sleep latency, sleep efficiency, total sleep time, rate of awakening bouts, and wake duration after sleep were recorded using the wrist worn Actiwatch2® for 654 participants, over a total of 3,772 sleep nights.

It is the largest and most comprehensive of its kind ever undertaken for wind turbine noise.

Table 1 in Michaud et al. (2016), provides an overview of the self-reported sleep magnitude and contribution of disturbance. They reported, "*The prevalence of reported sleep disturbance was unrelated to wind turbine noise levels.*"

From the conclusions of the paper:

> *However, in the current study it was demonstrated that the factors that influence sleep quality (e.g. age, body mass index, caffeine, health conditions) were related to one or more self-reported and objective measures of sleep. This demonstrated sensitivity, together with the observation that there was consistency between multiple measures of self-reported sleep disturbance and among some of the self reported and actigraphy measures, lends strength to the robustness of the conclusion that WTN levels up to 46 dB(A) [at homes as close as 820 ft] had no statistically significant effect on any measure of sleep quality.*

This is a critical study given the breadth of the study, the number of participants and consistency with past credible, peer-reviewed studies on whether living in proximity to wind turbines impacts sleep.. In addition, this study did not distinguish between participating and non-participating landowners. Therefore, there was no affect on sleep whether one was participating or not.

The Health Canada findings are consistent with credible previously published peer-reviewed literature in the field. In addition, given the variability in how Health Canada conducted wind turbine noise modeling and standard practice in the United States, the equivalent level in the US would be ~48-49 dBA at the exterior of homes.

Bakker et al. 2012. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Science of The Total Environment, Volume 425, 15 May 2012, Pages 42-51

The most compelling research into wind sound awakenings, prior to the Health Canada Study (2014), was conducted by Bakker et al. (2012). This research reported the number or percentage of awakenings with those non-participating residents living in proximity to wind turbines in a rural setting. This is because participating landowners did not report any sleep disturbance from living near wind turbines. Table 7 from the Bakker paper shows that more people in rural environments are awakened by people/animal sound and traffic/mechanical sounds, than by the proximate wind turbines. In this study, people living in close proximity to wind turbines reported being awoken more by people/animal noise (11.7%) and rural traffic/mechanical noise (12.5%), than by turbine noise (6.0%). Sound levels in this study were as high as 54 dBA.

Table 7
Sound sources of sleep disturbance in rural and urban area types, only respondents who did not benefit economically from wind turbines.

Sound source of sleep disturbance	Rural		Urban		Total	
	n	%	n	%	n	%
Not disturbed	196	69.8	288	64.9	484	66.8
Disturbed by people/ animals	33	11.7	64	14.4	97	13.4
Disturbed by traffic/ mechanical sounds	35	12.5	75	16.9	110	15.2
Disturbed by wind turbines	17	6.0	17	3.8	34	4.7
Total	281	100	444	100	725	100

The Health Canada study provides the following comment linking the two studies (Michaud et al., 2016):

> *"Study results [Health Canada] concur with those of Bakker et al. (2012), with outdoor WTN levels up to 54 dB(A), wherein it was concluded that there was no association between the levels of WTN and sleep disturbance when noise annoyance was taken into account".*

Again, the Bakker study was only for those non-participating landowners, given that participating landowners did not express concern about sleep disturbance at levels as high as 54 dBA at the exterior of their homes. So even at levels of >50 dBA people were less disturbed by wind turbine noise than other common rural sources of noise.

Jalali et al. 2016. Before–after field study of effects of wind turbine noise on polysomnographic sleep parameters. Noise Health; 18:194-205.

The first study to be published on before-after operation effect of wind turbine noise on objectively measured sleep was conducted in 16 participants living within 2 km to a five-wind turbine project in Ontario, Canada. For the first time authors used portable polysomnography (PSG), which is a comprehensive system that objectively monitors people's sleep in their homes.

The authors concluded:

> *The result of this study based on advanced sleep recording methodology together with extensive noise measurements in an ecologically valid setting cautiously suggests that there are no major changes in the sleep of participants who host new industrial WTs in their community.*

Note in this case 'participants' refer to the community as a whole and not only those being paid to host wind turbines. These findings are consistent with the previous reported studies that wind turbines did not disturb their sleep.

Conclusion on Wind Turbine Noise and Sleep

The recent published findings reveal that there is no association between exterior wind turbine sound levels and impact on sleep for residences as close as 820 ft and sound levels at 50 dBA. Therefore, allowing up to a maximum of 50 dBA at exterior of participating landowners dwellings is sufficient to protect residents and should not affect their sleep.

3.3 Low Frequency Noise (LFN) and Infrasound

Infrasound is a term used to describe sounds that are produced at frequencies too low to be heard by the human ear at frequencies of 0 to 20 Hz, at common everyday levels. It is typically measured and reported on the G-weighted scale (dBG). Low frequency noise (LFN), at frequencies between 20 to 200 Hz, can be audible. It is measured and reported on the C-weighted scale (dBC) to account for higher-level measurements and peak sound pressure levels. The A-weighted scale (dBA), covers the audible range 20 Hz to 20 kHz and is similar to the response of the human ear at lower levels.

Over the past couple of years some have speculated that wind turbine infrasound and LFN could potentially cause health impacts or sleep disturbance. The mere presence of measured LFN and infrasound does not indicate a potential threat to health or an inability for people to sleep. The fact that one can measure infrasound and LFN from wind turbines at either the exterior or interior of a home does mean that it is at a level that poses a potential health threat.

Although wind turbines are a source of LFN and infrasound during operation, these sound pressure levels are not unique to wind turbines. Common natural sources of infrasound and LFN and infrasound include ocean waves, thunder, and even the wind itself. Other sources include road traffic, refrigerators, air conditioners, machinery, and airplanes.

Berger, et al. 2014. Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines" Frontiers in Public Health

Given the growing attention being paid to this issue, an international team of acousticians and health scientists published a peer-reviewed article to investigate whether typical audible noise-based guidelines (dBA) for wind turbines account for the protection of human health given the levels of infrasound and LFN typically produced by wind turbines. The analysis showed that indoor infrasound levels were below auditory threshold levels while LFN levels at generally accepted setback distances were similar to background LFN levels.

From the abstract of Berger et al., 2015:

> *Over-all, the available data from this and other studies suggest that health-based audible noise wind turbine siting guidelines provide an effective means to evaluate, monitor, and protect potential receptors from audible noise as well as Infrasound and Low Frequency Noise.*

Simply put, the 50 dBA noise level at participating dwelling will ensure that levels of LFN and infrasound will also not impact health.

Ministry for the Environment, Climate and Energy of the Federal State of Bade Wuerttemberg in Germany. 2016. Low-frequency noise including infrasound from wind turbines and other sources.

The objective of the research was to collect field measurement of infrasound and low-frequency noise around six different turbines by different manufacturers from 1.8 to 3.2 MW. Measurements were taken at 150 m (492 feet), 300 m (984 feet) and 700 m (2296 feet) from wind turbines.

Measurements of other common sources of infrasound and low frequency noise were also collected for comparative purposes.

Figure 1 (from MECE, 2016) provides detail on the range of infrasound and low frequency noise measured at 300 m (984 feet). It can be seen that the levels of infrasound from wind turbines were similar to that of just the wind in an open field, while there was a slight increase in low frequency sound. The levels were considerably lower than either being in the interior of a car, near roadside traffic or in a home with oil heating. All infrasound levels (< 20 Hz) were below the perception threshold and international standards.

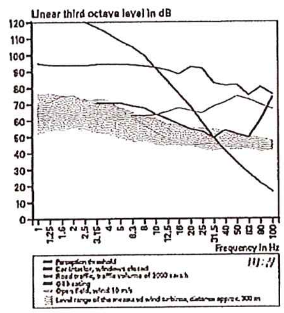


Figure 1. Measurements of infrasound and low frequency noise 300 m from wind turbines compared to other sources. [from MECE, 2016].

Overall, they concluded:

> *"Infrasound and low-frequency noise are an everyday part of our technical and natural environment. Compared with other technical and natural sources, the level of infrasound caused by wind turbines is low. Already at a distance of 150 m, it is well below the human limits of perception. Accordingly, it is even lower at the usual distances from residential areas. Effects on health caused by infrasound below the perception thresholds have not been scientifically proven. Together with the health authorities, we in Baden-Württemberg have come to the conclusion that adverse effects relating to infrasound from wind turbines cannot be expected on the basis of the evidence at hand.*
>
> *The measurement results of wind turbines also show no acoustic abnormalities for the frequency range of audible sound. Wind turbines can thus be assessed like other installations according to the specifications of the TA Lärm (noise prevention regulations).*
>
> *It can be concluded that, given the respective compliance with legal and professional technical requirements for planning and approval, harmful effects of noise from wind turbines cannot be deduced."*

Conclusion on Low Frequency Noise and Infrasound

Wind turbine sound standards are set using audible dBA levels and approved based on modeling. The levels of low frequency noise or infrasound from wind turbines are quite simply too low to cause health effects. Therefore, Lancaster County allowing an audible sound level at 50 dBA at participating landowners dwellings will ensure that infrasound and low frequency noise also do not pose a health threat.

3.4 Other Potential Health Concerns Living in Proximity to Wind Turbines

Much of the peer-reviewed literature on living in proximity to wind turbines has been focused on sleep and annoyance. This section is focused on the literature investigating both self-reported and physical measures of health for those living around wind turbines. Given that the extensive nature of the literature it is not possible to summarize it all in this document. Rather, preference has been given to key references and those most recent or extensive.

There are numerous peer-reviewed studies that have explicitly examined the relationship between levels of wind turbine noise and various self-reported indicators of human health and well-being (e.g., Health Canada 2014 and associated publications; Bakker et al. 2012; Janssen et al. 2011; Pedersen 2011; Pedersen and Persson Waye 2004; 2007). These studies have researched a wide range of wind turbine models, manufacturers, heights and noise levels. They were conducted over several years, in some cases over 10 years, after wind turbines became operational.

It is important to understand that from a health perspective it is not the height of the turbines, or the noise output at their hub, that is the important. Rather, it is the resulting sound level at people's homes that is critical to ensure the protection of public health. Simply put, whether a developer selects a 500-foot wind turbine, or smaller model, the requirement to meet the 50 dB sound level at participating landowner homes would remain the same.

In general, peer reviewed studies do not support a correlation between wind turbine noise exposure and any other response other than some annoyance (McCunney et al., 2014). For example, various studies based on the results of two surveys performed in Sweden and one in the Netherlands (1755 respondents overall), found that no measured variable (e.g., self-reported evaluations of high blood pressure, cardiovascular disease, tinnitus, headache, sleep interruption, diabetes, tiredness, and reports of feeling tense, stressed, or irritable) other than annoyance was directly related to wind turbine noise for all three datasets (Pedersen, 2011).

Michaud et al. 2016a. Exposure to wind turbine noise: Perceptual responses and reported health effects. (Health Canada)

This paper provides the results of Health Canada's investigation into perceptual responses (annoyance and quality of life) and those of self-reported health effects by participants. Only the self-reported health effects results are discussed here. Health Canada developed a final questionnaire (Michaud, 2013) that consistent of socio-demographics, modules on community noise and annoyance, self-reported health effects, lifestyle behaviours, and prevalent chronic illness.

Health Canada reported that:

> *"The results from the current study did not show any statistically significant increase in the self-reported prevalence of chronic pain, asthma, arthritis, high blood pressure, bronchitis, emphysema, chronic obstructive pulmonary disease (COPD), diabetes, heart disease, migraines/headaches, dizziness, or tinnitus in relation to WTN exposure up to 46 dBA [at homes as close as 820 ft]. In other words, individuals with these conditions were equally distributed among WTN exposure categories."*

This resulted in the overall conclusion of the paper that:

> *"Beyond annoyance, results do not support an association between exposure to WTN up to 46 dBA [at homes as close as 820 ft] and the evaluated health-related endpoints."*

Michaud et al. 2016c. Self-reported and measured stress related responses associated with exposure to wind turbine noise (Health Canada)

This is the only study reported in the literature that in addition to collecting self-reported measures of stress, includes biophysical and chemical objective measurements of health associated with living in proximity to wind turbines. Of the 1238 study participants 1077 (87%) agreed to have blood pressure measurements, 917 of 1043 (87.9%) participants with hair consented to sampling for cortisol analysis and all completed questionnaires.

In the Concluding Remarks the authors report:

> *The results provide no evidence that self-reported or objectively measured stress reactions are significantly influenced by exposure to increasing levels of WTN up to 46 dB [at homes as close as 820 ft]. There is an added level of confidence in the findings as this is the first study to date to investigate the potential stress impacts associated with WTN exposure using a combination of self-reported and objectively measured endpoints.*

Therefore, wind turbine noise annoyance should not be considered a health impact and the level of annoyance falls within levels that we accept in our daily lives.

Conclusions on Other Potential Health Effects of Living Near Wind Turbines

The Health Canada study clearly demonstrated that there were no measurable changes in either people's perceived health status or that of the objective measures of health and the distance and sound level that they experience from wind turbines. This is consistent with the credible peer-reviewed scientific studies published to date.

3.5 Annoyance from Living in Proximity to Wind Turbines

The reported correlation between wind turbine noise and annoyance is not unexpected. Noise-related annoyance has been extensively linked to a variety of common noise sources such as rail, road, and air traffic (Berglund and Lindvall 1995; Laszlo et al. 2012; WHO Europe 2011).

Dr. Robert McCunney of Massachusetts Institute of Technology (MIT) and colleagues concluded the following on annoyance in their 2014 review paper:

> *Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison with other factors in leading people to report annoyance in the context of wind turbines.*

This finding is supported by numerous papers published in the field that indicate that the reported annoyance levels of those living in proximity to wind turbines is more related to the subjective factors of visual cue, economic benefit and attitude towards the project.

Much of the annoyance literature is focused on those non-participating residents living in proximity to wind turbines. However, there are a number of studies that support the notion that participating landowners that are paid to host wind turbines on their properties do not find the sound or the visual aspects of wind turbines annoying.

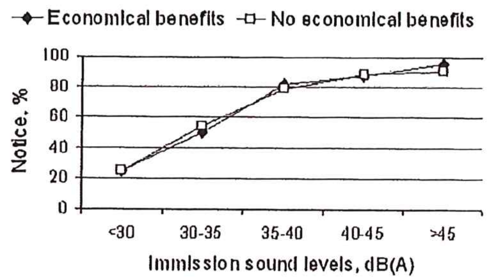
The following provides some examples that demonstrate that participating landowners do not report annoyance with living often much closer to wind turbines than non-participating neighbors.

Pederson et al. 2009. Response to noise from modern wind farms in The Netherlands. J. Acoust. Soc. Am., Vol. 126, No. 2, August 2009

Pederson and her colleagues provided some of the earliest evidence that participating landowners do not report annoyance with having the turbines, including sound levels as high as 50 dBA at their homes. The authors state:

As was expected, people benefiting economically from a noise source are less likely to be annoyed by it, though to the best of the authors' knowledge this has not previously been demonstrated as clearly as in this study.

This is clearly demonstrated in the graphs below. Those that economically benefit (participating landowners) notice the sound from wind turbines in the same way their non-participating neighbors do (Graph A). However, they report little to no annoyance at all from the noise, even at levels of >45 dBA.



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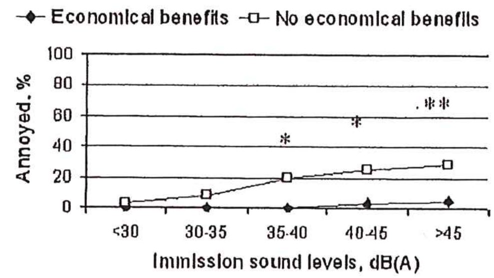

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<u>*Bakker et al. 2012. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Science of The Total Environment, Volume 425, 15 May 2012, Pages 42-51*</u>

Table 3 and 4 of the Bakker (2012) study that shows the clear difference between annoyance levels between participating and non-participating landowners. Although a very small percentage of participating landowners (1%) were very annoyed with outdoor noise levels, none (0%) were either rather or very annoyed with sound in the interior of their home. Again this is consistent with the evidence that participating landowners living in close proximity are also not experiencing sleep issues.

Table 3
Response to outdoor wind turbine sound among economically benefitting and non-benefitting respondents.

	Response											
	Do not notice		Notice, not annoyed		Slightly annoyed		Rather annoyed		Very annoyed		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
No economical benefit	255	44	184	31	78	13	41	7	28	5	586	100
Economical benefit	15	15	68	69	13	13	2	2	1	1	99	100

Table 4
Response to indoor wind turbine sound among economically benefitting and non-benefitting respondents.

	Response											
	Do not notice		Notice, not annoyed		Slightly annoyed		Rather annoyed		Very annoyed		Total	
	n	%	n	%	n	%	n	%	n	%	n	%
No economical benefit	394	68	98	17	46	8	21	4	20	4	579	100
Economical benefit	53	54	39	39	7	7	0	0	0	0	99	100

<u>*Michaud et al. 2016b. Personal and situational variables associated with wind turbine noise annoyance. (Health Canada)*</u>

This paper is a continuance of the work reported in Michaud et al. (2016a). They found that similar to previous studies wind turbine annoyance is not based solely on sound levels but that there are numerous visual and social factors that contribute to reported annoyance levels in relation to living in proximity to wind turbines.

They concluded (Michaud et al., 2016b):

> *"Variables associated with WTN annoyance included, but were not limited to, other wind turbine-related annoyances, personal benefit, noise sensitivity, physical safety concerns, property ownership, and province."*

Overall, annoyance levels associated with wind turbine sound are low and consistent with other levels of noise related annoyance. Regardless of the presence of some annoyance, the previous Health Canada research (Michaud et al. 2016a), demonstrated there was no association between self-reported health conditions and sound levels. It also demonstrates that "personal benefit" or participating landowners results in decreased annoyance with wind turbine noise.

Summary of Annoyance and Participating Landowners

Participating landowners that are paid to host wind turbines on their properties have not reported undue annoyance with the sound levels being requested by NEER of 50 dBA. The economic benefit and desire to participate in the project commonly results in a positive attitude towards hosting the turbines and the sound they make.

4 Conclusions

In summary, over the past decade there has been considerable research conducted around the world evaluating health concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government medical agencies has taken place in many different countries on a variety of models of turbines that have been in communities for numerous years. Based on scientific principles, and the collective findings of over 80 scientific articles, there is scientific justification to allow CWECS project participating landowners to have a noise limit of fifty (50) dBA maximum 10 minute Leq level at the exterior wall of their dwellings.

This limit will enable proper siting of wind turbines on participating land while still ensuring the protection of public health, safety and welfare of participating residents.

Sincerely,

OLLSON ENVIRONMENTAL HEALTH MANAGEMENT

Christopher Ollson, PhD
Senior Environmental Health Scientist

References

Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. *Sci Total Environ* (2012) **425**:42–51.

Berger R.G., Ashtiani P., **Ollson C.A.**, Whitfield Aslund M., McCallum L.C., Leventhall G., Knopper L.D. 2015. *Health-based audible noise guidelines account for infrasound and low frequency noise produced by Wind Turbines.* Front Public Health. Vol 3, Art. 31

Berglund B, Lindvall T. (Eds.) *Community Noise.* Center for Sensory Research, Stockholm University and Karolinska Institute (1995).

Gage County Zoning Regulations Article 6.6 Section 6.70

Health Canada. Wind Turbine Noise and Health. The Government of Canada. 2014. Available online: http://www.hc-sc.gc.ca/ewh-semt/noise-bruit/turbine-eoliennes/summary-resume-eng.php

Institute of Medicine (IOM). 2006. *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*

Jalali et al. 2016. Before–after field study of effects of wind turbine noise on polysomnographic sleep parameters. Noise Health; 18:194-205.

Janssen SA, Vos H, Pedersen E. A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. *J Acoust Soc Am* (2011) **130**:3746-53.

Knopper, L.D., **Ollson, C.A.,** McCallum, L.C., Aslund, M.L., Berger, R.G, Souweine, K., and McDaniel, M. 2014. *Wind turbines and Human Health.* Front. Public Health, Vol. 2, Art. 63

Knopper, L.D. and **Ollson, C.A.** 2011. *Health Effects and Wind Turbines: A Review of the Literature.* Environmental Health. 10:78. Open Access. Highly Accessed.

Lancaster County 1979 Zoning Resolution Section 13.048

Laszlo HE, McRobie ES, Stansfeld SA, Hansell AL. Annoyance and other reaction measures to changes in noise exposure - A review. *Sci Total Environ* (2012) **435**:551-562.

McCallum, L.C., Whitfield Aslund, M.L., Knopper, L.D., Ferguson, G.L., **Ollson, C.A.** 2014. *Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?* Environmental Health 13(9), doi:10.1186/1476-069X-13-9.

McCunney, R.J., Mundt, K.A., Colby, D., Dobie, R., Kaliski, K., Blais, M. 2014. Wind Turbines and Health A Critical Review of the Scientific Literature. JOEM Volume 56, Number 11

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Murray BJ, Weiss SK, Villeneuve PJ, van den Berg F, Bower T. 2016. Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep. Sleep. 2016 Jan 1;39(1):97-109. doi: 10.5665/sleep.5326.

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, McGuire D, Bower T, Lavigne E, Murray BJ, Weiss SK, van den Berg F. 2016a. Exposure to wind turbine noise: Perceptual responses and reported health effects. J Acoust Soc Am. 2016 Mar;139(3):1443-54.

Michaud DS, Keith SE, Feder K, Voicescu SA, Marro L, Than J, Guay M, Bower T, Denning A, Lavigne E, Whelan C, Janssen SA, Leroux T, van den Berg F. 2016b. Personal and situational variables associated with wind turbine noise annoyance. J Acoust Soc Am. 2016 Mar;139(3):1455-66.

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Bower T, Villeneuve PJ, Russell E, Koren G, van den Berg F. 2016c. Self-reported and measured stress related responses associated with exposure to wind turbine noise. J Acoust Soc Am. 2016 Mar;139(3):1467-79.

Michaud DS, Keith SE, McMurchy D. Noise annoyance in Canada. *Noise Health* (2005) **7**:39-47.

Ministry for the Environment, Climate and Energy of the Federal State of Bade Wuerttemberg in Germany. 2016. Low-frequency noise including infrasound from wind turbines and other sources.

Ollson, C.A., Knopper L.D. McCallum, L.C., Aslund-Whitfield, M.L. 2013. *Are the findings of 'Effects of industrial wind turbine noise on sleep and health' supported?* Noise & Health 15:63, 148-150.

Oregon Administrative Rule 340-035-0035 Noise Control Regulations for Industry and Commerce

Pedersen E. 2009. Health aspects associated with wind turbine noise-Results from three field studies. *Noise Control Eng J* (2011) **59**:47-53.

Pedersen E, Persson Waye K. Perception and annoyance due to wind turbine noise – a dose–response relationship. *J Acoust Soc Am* (2004) **116**:3460-70.

Pedersen E, Persson Waye K. Wind turbine noise, annoyance and self-reported health and well-being in different living environments. *Occup Environ Med* (2007) **64**:480-6.

Webster County Zoning Regulations Section 609.E.G.3

Whitfield Aslund, M.L., **Ollson, C.A.**, Knopper, L.D. 2013. *Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada.* Energy Policy. 62, 44-50

WHO (World Health Organization), Regional Office for Europe. *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe.* WHO Regional Office for Europe, Copenhagen, Denmark (2011).

OLLSON
Environmental Health Management

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Dr. Ollson is Owner and Senior Environmental Health Scientist at Ollson Environmental Health Management (OEHM). He has 20 years of international consulting experience in environmental health sciences and toxicology. Dr. Ollson has worked across the United States and is well versed in Federal and State environmental legislation. His Canadian experience spans from coast-to-coast-to-coast, having worked in all Provinces and Territories. Throughout his career, Chris has led some of North America's most high profile and controversial multi-disciplinary environmental health assessments.

Dr. Ollson is considered an expert in environmental health issues related to the energy sector. He has led risk assessments and provided risk communication support for wind turbine, solar, hydroelectric, energy-from-waste / waste-to-energy facilities, wind turbine projects, natural gas fired stations, oil sands environmental assessments, refineries, pipelines, and coal power plants. Dr. Ollson has conducted extensive research in potential health and environmental issues surrounding wind turbine facilities and has published numerous peer-reviewed articles and government white papers on the topic.

Chris has spent countless hours in community and stakeholder consultation on behalf of clients. Through proper risk communication they became part of the decision-making process on issues surrounding atmospheric, soil and water contaminant issues. Specific to the wind and solar sector Dr. Ollson has spent 1000s of hours in public consultation, stakeholder engagement, meetings with public health staff and local councils.

Dr. Ollson has testified at more than a dozen environmental review tribunals, commissions, hearings and court proceedings with respect to potential health concerns in living in proximity to wind turbines. With six peer-reviewed scientific journal articles, numerous invited conference presentations and invited university lectures he is considered one of the foremost experts in North America on renewable energy health issues. In recognition of these accomplishments he was the co-recipient of the 2015 Canadian Wind Energy Association R.J. Templin Award. The R.J. Templin Award recognizes an individual or organization that has undertaken scientific, technical, engineering or policy research and development work that has produced results that have served to significantly advance the wind energy industry in Canada.

In addition to his consulting practice, Dr. Ollson maintains an active research program through his Adjunct Assistant Professor appointment at the University of Toronto Scarborough. He teaches graduate level courses in Environmental Risk Assessment and has co-supervised a number of graduate students and Post-Doctoral Fellows. Dr. Ollson's primary research interests are in potential health issues related to the renewable energy sector, waste-to-energy sector and the emerging field of Health Impact Assessment of major projects.

EDUCATION

2003	Ph.D., Environmental Science (Specialization in Risk Assessment), Royal Military College of Canada
2000	M.Sc., Environmental Science, Royal Military College of Canada
1995	B.Sc., (Honours), Biology, Queen's University.
QP_{RA}	Qualified Person for Risk Assessment as defined by the Environmental Protection Act of Ontario (Brownfields Legislation)

AREAS OF SCIENTIFIC EXPERTISE

- Health Impact Assessment
- Environmental Health
- Air Quality Assessment
- Human Health Risk Assessment
- Major Infrastructure Health Assessment
- Energy Sector

EMPLOYMENT HISTORY

2015 – Present	**Ollson Environmental Health Management** Senior Environmental Health Scientist
2011-2015	Intrinsik Environmental Sciences Inc. Mississauga, Ontario Vice President, Strategic Development Senior Environmental Health Scientist
2002 – 2011	Stantec Consulting Ltd (formerly Jacques Whitford Limited) Practice Leader, Environmental Health Sciences
1997 - 2002	Royal Military College of Canada, Environmental Sciences Group (ESG) Senior Environmental Scientist / Risk Assessor
1990 – 2002	Naval Reserves, Department of National Defence Maritime Surface (MARS) Officer, Lt(N) Ret'd

PROFESSIONAL AFFILIATIONS

- Full Member of the International Association for Impact Assessment (IAIA)
- Full Member of the Society of Practitioners of Health Impact Assessment (SOPHIA)

ACADEMIC EXPERIENCE

2013 – PRESENT **University of Toronto Scarborough, Department of Physical and Environmental Sciences**
Adjunct Professor

2011 – PRESENT **University of Toronto, School of the Environment**
Graduate Course Lecturer

2013 - 2016 **University of Toronto Scarborough, Member Campus Governing Council, Vice-Chair of the Academic Affairs Committee**

2009-2011 **University of Toronto, Scarborough**
Adjunct Lecturer, Physical & Environmental Sciences,

2004 - PRESENT **Royal Military College of Canada**
Adjunct Assistant Professor

AWARDS

Co-recipient of the 2015 Canadian Wind Energy Association R.J. Templin Award. *First awarded in 1985, the R.J. Templin Award recognizes an individual or organization that has undertaken scientific, technical, engineering or policy research and development work that has produced results that have served to significantly advance the wind energy industry in Canada.*

Wind Turbine Peer Reviewed Scientific Publications

Primary Research

Berger, R.G., Ashtiani, P., **Ollson, C.A.**, Whitfield Aslund, M. McCallum, L.C., Leventhall, G. and Knopper, L.D. 2015 Health-based audible noise guidelines account for infrasound and low-frequency noise produced by wind turbines. Front. Public Health 3:31. Citations: 8

McCallum, L., Whitfield Aslund, M., Knopper, L.D., Ferguson, G.M. and **Ollson, C.A.** 2014. An investigation of wind energy and health: quantifying electromagnetic fields around wind turbines in Canada. *Environmental Health* 2014, **13**:9. Citations: 7

Whitfield Aslund, M.L., **Ollson, C.A.,** Knopper, L.D. 2013. Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada. Energy Policy 62, 44-50. Citations: 4

Systematic Literature Reviews

Knopper, L.D., **Ollson, C.A.**, McCallum, L.C., Aslund, M.L., Berger, R.G, Souweine, K., and McDaniel, M. 2014. Wind turbines and Human Health. Front. Public Health, 19 June 2014. Citations: 22

Knopper, L.D. and **Ollson, C.A.** 2011. Health Effects and Wind Turbines: A Review of the Literature. Environmental Health. 10:78. Open Access. Highly Accessed. Citations: 86

Published Critique

Ollson, C.A., Knopper L.D. McCallum, L.C., Aslund-Whitfield, M.L. 2013. Are the findings of 'Effects of industrial wind turbine noise on sleep and health' supported? Noise & Health 15:63, 148-150. Citations: 5

Hearings, Tribunals and Court Proceedings on Wind Turbines and Associated Transmission Lines

In the following proceedings I testified and formally qualified as an expert in wind turbines and human health

Ontario Environmental Review Tribunals – Appeal of Company Renewable Energy Approvals

Erickson v. MOE 2011	Suncor
Monture v. MOE [GREP] 2012;	Samsung
Moseley v. MOE 2014;	Capstone
Lambton County v. MOE 2015	Suncor
EOCA v MOE 2015	ProWind

Queen's Bench of Saskatchewan in McKinnon v. Martin (2010 – also referred to as the Red Lily case)

Alberta Utilities Commission (AUC) Proceeding No. 22563, Halkirk 2 Wind Project (November 2017)

Alberta Utilities Commission (AUC) Proceeding No. 3329, Grizzly Bear Creek Wind Project (March 2016)

Alberta Utilities Commission (AUC) Proceeding No. 1955, Bull Creek Wind Project (October 2013)

North Dakota Public Services Commission 2015

Brady Wind Energy Center NextEra
Brady II Wind Energy Center NextEra
Oliver III Wind Energy Center NextEra

Clinton County Planning and Zoning Commission, MO, County Ordinance Changes (2016)

Chowan County and Perquimins County Board of Commissioners hearings for the Timbermill Wind Project (2016)

Court Proceedings Unrelated to Wind Turbine Projects

John Chart vs. Town of Parma. W.D.N.Y Civil Action No. 6:10-CV-06179, Deposed 2013.

Lockridge and Plain v. Ministry of the Environment and Suncor Energy Products Ltd., 528/10, Ontario Superior Court of Justice, Deposed 2012

Appearances before Government Bodies

North Dakota State Senate and Representative Natural Resources Committee. Study on Wind Energy Conversion Facilities. December 2017.

Indiana State Senate Energy Committee Meeting on Wind Turbine Siting. October 2017.

North Dakota State Senate Energy and Natural Resources Committee. Senate Bill 2313. Exclusion Areas for Wind Energy Conversion Facilities. February 2017.

Vermont Public Services Board. Proposed Rule on Sound from Wind Generation Facilities. December 2016.

Example Appearances before US County Planning & Zoning Commissions and County Boards

Redfield Town Board, New York, Mad River Wind Farm, 2017

Parshville Town Board, New York, North Ridge Wind Farm, 2017

Grant and Dickinson County Planning and Zoning Commissions, Iowa, Upland Prairie Wind Farm, 2017

Codington and Grant County Planning Commissions, Dakota Range Wind, South Dakota, 2017

Deuel County Zoning Board, South Dakota, Crown Ridge Wind Project, 2017

Rush County Board of Zoning Appeals, Indiana, West Forks Wind Project, 2016

Hettinger County Planning and Zoning Commission and County Commission, North Dakota, Brady II Wind Energy Center, 2016

Kingman County Planning and Zoning Commission, Kansas, Kingman Wind Energy Center, 2016

Pratt County Planning and Zoning Commission, Kansas, Ninnesçah Wind Energy Center, 2016

Stark County Planning and Zoning Commission and County Commission, North Dakota, Dickinson Wind Energy Center, 2015, 2016

Stark County Planning and Zoning Commission and County Commission, North Dakota, Brady Wind Energy Center, 2015, 2016

Colfax Township Board, Dekalb County, Missouri, Osborn Wind Energy Center, 2016

WashingtonTownship Planning Board, Dekalb County, Missouri, Osborn Wind Energy Center, 2016

Niagara County Board of Health, New York, Lightstation Wind Energy Center, 2015

El Paso Planning Commission and County Commission, Colorado, Golden West Energy Center, 2015

Stony Creek Town Commission, New York, Proposed InvEnergy project, working for the Town Commission, 2011

Wind Project Developers- Worked as Project Health Consultant of Record (Alphabetical)

- APEX, Algonquin Power, Avangrid, BluEarth, Boralex, Capital Power, Capstone, EDF, EDPR, InvEnergy, Longyung Power, NextERA, Niagara Region Wind Corporation, Northland Power, Pattern Energy, Prowind, RES, Samsung, South Canoe Wind, Sprott, Suncor, Veresen, Vermont Public Services Department, WPD

Wind Turbine Conference Proceedings

Whitfield Aslund, M.L., Berger, R.G.; Ashtiani, P.; **Ollson, C.A.**; McCallum L.C.; Leventhall, G.; Knopper, L.D. 2015. Health-based audible noise guidelines account for infrasound and low frequency noise produced by wind turbines. *Proceedings of the 6th International Conference on Wind Turbine Noise, April 2015, Glasgow, Scotland.*

Whitfield Aslund, M.L., Ollson, C.A., Knopper, L.D. 2013. 'Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada', submitted for publication in *Proceedings of the 5th International Conference on Wind Turbine Noise, Denver Colorado 28-30 August 2013*

Knopper, L.D., Whitfield Aslund, M.L., McCallum, L.C., Ollson, C.A. 2013. 'Wind turbine noise: What has the Science Told Us?', submitted for publication in *Proceedings of the 5th International Conference on Wind Turbine Noise, Denver Colorado 28-30 August 2013*

Conference Presentations on Wind Turbines and Health

Ollson, C.A., 2015. Effective Communication Strategies for Addressing Health Concerns. CanWEA annual conference.

Ollson, C.A. 2014. Responding to Health Concerns. CanWEA annual conference.

Ollson, C.A. 2014 Wind Turbines – Do They Cause Health Impacts? CPANs Air & Waste Management Association. Edmonton, Alberta

Ollson, C.A., McCallum, L.C., Whitfield Aslund, M.L., Knopper, L.D. 2014. Social Licence to Operate – Lessons From Canadian Wind Industry. International Association of Impact Assessment (IAIA) International Conference 2014. Chile.

Whitfield Aslund, M.L., **Ollson, C.A.**, Knopper, L.D. 2013. 'Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada', Wind Turbine Noise 2013, Denver, August 2013.

Ollson, C.A. ; Knopper, L.D., Whitfield Aslund, M.L., McCallum, L.C., 2013. 'Wind turbine noise: What has the Science Told Us?', Wind Turbine Noise 2013, Denver, August 2013.

Ollson, C.A., 2013 Health Effects and Renewable Energy: An Overview of the Issues. Association of Power Producers of Ontario Toronto, 2013

Ollson, C.A. and Knopper, L.D. Health Effects and Wind Turbines: A Review of the Issues. CANWEA Communications Summit , Vancouver, October, 2011

Additional Peer-Reviewed Scientific Publications

McCallum, LC, **Ollson, CA**, Stefanovic, IL. 2017. An adaptable Health Impact Assessment (HIA) framework for assessing health within Environmental Assessment (EA): Canadian Context, International Application. Impact Assessment and Project Appraisal. In Press.

McCallum, LC, **Ollson, CA**, Stefanovic, IL. 2016. Prioritizing Health: A Systematic Approach to Scoping Determinants in Health Impact Assessment. Frontiers in Public Health. Aug 22;4:170

McCallum, LC, **Ollson, CA**, Stefanovic, IL. 2016. Development of a Health Impact Assessment Screening Tool: A Value Versus Investment Approach. Journal of Environmental Assessment Policy and Management Vol. 18, No. 2

McAuley, C., Dersch, A., Kates, L. N., Sowan, D. R. and **Ollson, C. A.** 2016. Improving Risk Assessment Calculations for Traditional Foods Through Collaborative Research with First Nations Communities. Risk Analysis. Dec; 36(12):2195-2207

McAuley, C., Dersch, A., Kates, L. N., Sowan, D. R., Koppe, R and **Ollson, C. A.** 2016. Assessment of Exposure to Chlorinated Organics through the Ingestion of Moose Meat for a Canadian First Nation Community. Frontiers in Environmental Science. November 2016: Vol 4: Article 78

McCallum LC, Souweine K, McDaniel M, Koppe B, McFarland C, Butler K, **Ollson CA**. Health Impact Assessment of an oil drilling project in California. Int J Occup Med Environ Health. 2016;29(2):229-53.

McCallum, L.C., **Ollson, C.A.** and Stefanovic I.L. 2015. Advancing the practice of health impact assessment in Canada: obstacles and opportunities. Environmental Impact Assessment Review. Volume 55, November 2015, Pages 98–109

Ollson, C.A., Knopper, L.D., Whitfield Aslund, M., Jayasinghe, R. 2014. Site specific risk assessment of an energy-from-waste thermal treatment facility in Durham Region, Ontario, Canada. Part A: Human health risk assessment. Science of the Total Environment 466-467: 345-356.

Ollson, C.A., Knopper, L.D., Whitfield Aslund, M., Dan, T. 2014. Site specific risk assessment of an energy-from-waste/ thermal treatment facility in Durham Region, Ontario, Canada. Part B: Ecological risk assessment. Science of the Total Environment 466-467: 242-252.

Johnson KE, Knopper LD, Schneider DC, **Ollson CA**, Reimer KJ. 2009. Effects of local point source polychlorinated biphenyl (PCB) contamination on bone mineral density in deer mice (Peromyscus maniculatus). Sci Total Environ. 2009 Sep 1; 407(18):5050-5. Epub 2009 Jul 5

Ollson, C.A., Koch, I., Smith, P.; Knopper, L.D., Hough, C., Reimer, K, J. 2009. Addressing arsenic bioaccessibility in ecological risk assessment: A novel approach to avoid overestimating risk. Environmental Toxicology and Chemistry 28(3): 668-675.

Knopper, L.D., Smith, G.K., **Ollson, C.A.**, Stephenson, M. 2009. Use of Body Mass Scaling of Dose in Ecological Risk Assessments In Ecotoxicological Research Developments. Nova Publishers, pp. 23-29.

Gregor, D., Stow, J., Kennedy, D., Reimer, K., **Ollson, C**. 2003. Local Sources of Contaminants in the

Canadian Arctic. Canadian Arctic Contaminants Assessment Report /I(CACAR /I) Physical Environment 157-183

Reimer, K.J., **Ollson, C.A.**, Koch, I. 2002. An Approach for Characterizing Arsenic Sources and Risks at Contaminated Sites: The Consequences of 60 Years of Gold Mining in Yellowknife, NWT, Canada. 2003. Metals in the Environment. American Chemical Society.

Koch, I., Hough, C., Mousseau, S., Mir, K., Rutter, A., **Ollson, C.,** Lee, E., Andrewes, P., Granhchino, S,, Cullen, B., Reimer, K. 2002. Canadian Journal of Analytical Sciences And Spectroscopy 47(4):109-118.

Koch, I., **Ollson, C.A.**, Potten, J., and Reimer, K.J. 2002. Arsenic in Vegetables: An Evaluation of Risk from the Consumption of Produce from Residential and Mine Gardens in Yellowknife, Northwest Territories, Canada. I. in Annual Reviews in Food and Nutrition: Toxic and Pathological Aspects, Taylor & Francis, London.

Koch, I., Wang, L., **Ollson, C.A.,** Cullen, W.R., Reimer, K. J. 2000. The Predominance of Inorganic Arsenic Species in Plants from Yellowknife, Northwest Territories, Canada. Environmental Science and Technology 34:22 26.

Ollson, C. A. 2003. Arsenic Risk Assessments: The Importance of Bioavailability. PhD Thesis, Royal Military College of Canada.

Ollson, C. A. 1999. Arsenic Contamination of the Terrestrial and Freshwater Environment Impacted by Gold Mining Operations, Yellowknife, NWT. M,Sc, Thesis, Royal Military College of Canada.

Exhibit 5

Additional Wind Energy Information Requested

Lincoln-Lancaster County Health Department

November 6, 2018

The following provides answers to questions posed to NextEra Energy Resources by the Lincoln-Lancaster County Health Department on October 16, 2018.

Sound Modeling of Hypothetical Wind Project in Lancaster County

Epsilon Associates, Inc. conducted a sound level modeling analysis that was done on a hypothetical, but realistic layout, that involved 54 GE 2.52-127 wind turbines at an 89 meter hub height. The total tip height of these turbines is 500 ft (152.5 m). The purpose of this assessment is to predict hypothetical community sound levels in Lancaster County when the wind turbines are operational.

The sound impacts associated with the proposed wind turbines were predicted using the Cadna/A sound calculation software developed by DataKustik GmbH (Version 2018 MR 1). This software uses the ISO 9613-2, an international standard for sound propagation (Acoustics - Attenuation of sound during propagation outdoors - Part 2: General method of calculation). The benefits of this software are a more refined set of computations due to the inclusion of topography, ground attenuation, multiple building reflections, drop-off with distance, and atmospheric absorption. The Cadna/A software allows for octave band calculation of sound from multiple sources as well as computation of diffraction.

The model was run with a ground absorption factor of 0.5, and at a receptor height of 1.5 meters. A total of 167 receptors (homes) were included in this analysis with closest distance to a turbine ranging from 1479 ft (1/4 mile) to 3 miles. For the purpose of this analysis it was assumed that all homes with sound level >37 dBA short-term Leq were participants in the project. There were three scenarios requested by the Lincoln-Lancaster County Health Department – Short-term Leq, Annual Average Leq, and Annual Average L_{DEN}. Short-term sound level modeling included a +2 uncertainty (k factor) while the annual modeling (Leq and Lden) did not include uncertainty. A seven (7) decibel adjustment factor was added to the annual results to calculate an Lden sound level.

1) How many and what percent of participating residential dwelling units will be exposed to dBA levels of: <=35; 36 to 40; 41 to 45; and 46 to 50?

The table below presents the percentage of modeled residential homes exposed to short-term Leq sound levels of: <=35; 36 to 40; 41 to 45; and 46 to 50 dBA from the proposed wind turbines.

Short Term L_{eq} Broadband Sound Level (dBA)	Minimum Distance (ft)	Minimum Distance (mi)	Maximum Distance (ft)	Maximum Distance (mi)	Average Distance (ft)	Average Distance (mi)	Number of Receptors	% of Project Receptors
46 - 50	1,479	0.28	3,243	0.61	1,966	0.37	40	24%
41 - 45	1,934	0.37	4,861	0.92	3,308	0.63	46	28%
36 - 40	3,615	0.68	8,431	1.60	6,072	1.15	61	37%
<35	6,547	1.24	15,583	2.95	11,093	2.10	20	12%
37	5,326	1.01	7,656	1.45	6,552	1.24	12	

The sound levels presented above are cumulative levels (i.e., multiple wind turbines at different distances contributing to the modeled sound level); therefore, no specific distance corresponds to a given sound level. Receptors modeled at 37 dBA ranged from 5,326 ft (1 mile) to 7,656 ft (1.5 mi) from the closest wind turbine with an average setback distance of 1.24 mi.

2) Can you also provide the number and percent of participating residential dwelling units that will be exposed to Lden levels of: <=35; 36 to 40; 41 to 45; and 46 to 50?

The table below presents the percentage of modeled residential homes exposed to annual Lden levels of: <=35; 36 to 40; 41 to 45; 46 to 50; and >50 dBA.

	Day Evening Night (L_{den}, dBA)	
Sound Level Bin	Number of Receptors	% of Project Receptors
<= 35	10	6.0%
36 to 40	43	25.7%
41 to 45	57	34.1%
46 to 50	49	29.3%
51 +	8	4.8%

The Lden level was calculated by adding a 7 decibel correction factor to the modeled Annual Leq sound level at each receptor (see response to Question 3 for annual calculation details). This approach takes into account the 5 decibel evening penalty and 10 decibel nighttime penalty by assuming that the average annual wind speed does not differ between the daytime, evening, and the nighttime.

It is noted that Lden is typically used in Europe for continuous sound sources, which wind turbines are not. It is not a common metric applied in the United States, nor is the medical or annoyance literature for wind turbines typically provided in Lden. More commonly it is provided as a short-term Leq as provided in response to Question 1 and the same metric required for reporting in the County ordinance.

3) **What will be the long term average noise levels (in dBA) for participating residential dwelling units?**

The table below presents the percentage of modeled residential homes exposed to annual Leq sound levels of: <=35; 36 to 40; 41 to 45; and 46 to 50 dBA. As compared to the short-term sound level modeling a lower sound power level was assigned to each wind turbine based on the expected average annual hub height wind speed at the site. The annual Leq was approximately 5 dBA lower than the short-term Leq results.

	Annual (L_{eq}, dBA)	
Sound Level Bin	Number of Receptors	% of Project Receptors
<= 35	79	47.3%
36 to 40	42	25.1%
41 to 45	46	27.5%
46 to 50	0	0.0%

4) **Could you please provide a list of specific peer reviewed research papers (and copies of the research papers themselves) which you believe support the specific recommendation of allowing participating property dwelling units to be exposed to 50 dBA at all hours, night and day.**

*Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Sci Total Environ (2012) **425**:42–51.*

*Janssen SA, Vos H, Pedersen E. A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. J Acoust Soc Am (2011) **130**:3746-53.*

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Murray BJ, Weiss SK, Villeneuve PJ, van den Berg F, Bower T. 2016. Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep. Sleep. 2016 Jan 1;39(1):97-109. doi: 10.5665/sleep.5326.

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, McGuire D, Bower T, Lavigne E, Murray BJ, Weiss SK, van den Berg F. 2016a. Exposure to wind turbine noise: Perceptual responses and reported health effects. J Acoust Soc Am. 2016 Mar;139(3):1443-54.

Michaud DS, Keith SE, Feder K, Voicescu SA, Marro L, Than J, Guay M, Bower T, Denning A, Lavigne E, Whelan C, Janssen SA, Leroux T, van den Berg F. 2016b. Personal and situational variables associated with wind turbine noise annoyance. J Acoust Soc Am. 2016 Mar;139(3):1455-66.

Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Bower T, Villeneuve PJ, Russell E, Koren G, van den Berg F. 2016c. Self-reported and measured stress related responses associated with exposure to wind turbine noise. J Acoust Soc Am. 2016 Mar;139(3):1467-79.

Michaud DS, Feder K, Voicescu SA, Marro L, Than J, Guay M, Lavigne E, Denning A, Murray BJ, Weiss SK, Villeneuve P. 2018. Clarifications on the Design and Interpretation of Conclusions from Health Canada's Study on Wind Turbine Noise and Health. Acoustics Australia. https://doi.org/10.1007/s40857-017-0125-4

Ministry for the Environment, Climate and Energy of the Federal State of Bade Wuerttemberg in Germany. 2016. Low-frequency noise including infrasound from wind turbines and other sources.

The Lawrence Berkeley National Laboratory (LBNL Wind Study).

Although not yet peer reviewed Lawrence Berkeley Lead Researcher Ben Hoen and colleagues have hosted a number of webinars and presentations of their findings. They are available on the website. This is the largest and most comprehensive study of wind turbine in the US. As you will see from the Haac presentation there were numerous homes at 50 dBA or greater. Collectively the research indicates compensated landowners hosting wind turbines do not report annoyance or health issues related to turbine noise. (Ollson summary)

https://emp.lbl.gov/projects/wind-neighbor-survey

Haac, R., K. Kaliski, M. Landis, B. Hoen, J. Firestone, J. Rand, (2018) Predicting Audibility Of and Annoyance To Wind Power Project Sounds Using Modeled Sound. Lawrence Berkeley National Laboratory. Preliminary Results Webinar. February 27, 2018. – Especially slide 61

Hübner, G., J. Pohl, B. Hoen, J. Firestone, J. Rand, D. Elliott (2018) Comparing Strongly Annoyed Individuals with Symptoms Near U.S. Turbines To Those In Surveyed European Communities. Lawrence Berkeley National Laboratory. Preliminary Results Webinar. March 13, 2018.

Hoen, B., J. Firestone, J. Rand, D. Elliott, G. Hübner, J. Pohl, R. Wiser, E. Lantz (2018) Overall Analysis of Attitudes of 1,705 Wind Power Project Neighbors. Lawrence Berkeley National Laboratory. Preliminary Results Webinar. January 30, 2018.

5) Could you please provide a list of specific peer reviewed research papers (and copies of the research papers themselves) which you believe support the assertion that people that benefit from wind turbines (participating persons) report less noise annoyance than those that do not benefit from the wind turbine (non-participating persons) when exposed to the same level of wind turbine noise.

*Bakker RH, Pedersen E, van den Berg GP, Stewart RE, Lok W, Bouma J. Impact of wind turbine sound on annoyance, self-reported sleep disturbance and psychological distress. Sci Total Environ (2012) **425**:42–51.*

*Janssen SA, Vos H, Pedersen E. A comparison between exposure-response relationships for wind turbine annoyance and annoyance due to other noise sources. J Acoust Soc Am (2011) **130**:3746-53.*

Pedersen, E., F. van den Berg, R. Bakker, Bouma, J., (2009). Response to noise from modern wind farms in The Netherlands. J. Acoust. Soc. Am. 126 (2), 634-643.

6) In your white paper *Proposed Noise Levels at Participating Landowners Dwelling in a Commercial Wind Energy Conversion System (CWECS) in Lancaster County, NE*, dated September 21, 2018, on page 5 in section 3.1 you indicate that "modeling wind turbine noise is typically more conservative in the United States and would resulted in 46 dBA being modeled typically as 47-49 dBA at the exterior of the homes." A similar statement is made on the bottom of page 6 in section 3.2. Can you please explain this comment further? What are the differences in the modeling used in Canada versus the U.S. that would result in such a difference?

Sound level modeling for predicting wind turbine sound at homes in the United States, as in Canada, is done following the ISO 9613-2. Calculations performed according to this standard require multiple user inputs. Variations in these modeling input parameters can lead to significantly different predicted sound level results at homes. Although there is no absolute standard approach in the selection of all modeling inputs in the United States, The input parameters listed below were used in modeling short-term wind turbine sound levels provided to the Lincoln-Lancaster County Health Department.

A review of the Health Canada study results (Keith et al., 2016) reveals there are three main differences between their approach and those commonly used in the United States:ground absorption factor; an uncertainty factor; and receptor (home) height:

- Health Canada presents the modeled sound levels with a standard deviation value of approximately ± 4 dB at less than 1 km (3280 ft). In the United States the modeling approach includes a 2 dB manufacturer's uncertainty as a +2 dBA to the sound level. Health Canada makes no adjustment; therefore the modeled U.S. sound level is higher.
- United States modeling approach uses a ground absorption factor of 0.5 vs. 0.7 used by Health Canada. Using a lower ground absorption factor number is more conservative and results in a higher sound level predicted at homes.
- United States modeling is done either at 1.5 meter or 4 meter height at receptors. Health Canada uses 4 m that is more conservative than 1.5 m. It is due to the variation in receptor height used in United States modeling approaches that we have provided a range in results between approaches. The use of a 1.5 m receptor height would result in a less conservative sound level than Health Canada.

In our professional experience, differences in these input parameters result in a 1-3 dBA higher modeled sound level at receptors (homes) following the "United States modeling approach" than those reported in the Health Canada study.

Attached paper:

Keith SE, Feder K, Voicescu SA, Soukhovtsev V, Denning A, Tsang J, Broner N, Leroux, T, Richarz W, van den Berg F. 2016. Wind turbine sound pressure level calculations at dwellings. J. Acoust. Soc. Am. 139 (3), 1436-1442