Appendix G: Health and Safety Report

APPENDIX G
PUBLIC HEALTH AND SAFETY

Riverbend Wind, LLC retained Dr. Christopher Ollson, Ph.D., of Ollson Environmental Health Management (OEHM) to review the Riverbend Wind Energy Center (Riverbend Wind, the Project) design and layout and its compliance with the Speaker Township Wind Energy Conversion Systems (WECS) Zoning Ordinance to evaluate its adequacy to protect the public health and safety of Township residents. Dr. Ollson is recognized as an expert in the proper siting of wind turbines to ensure the protection of public health and safety in jurisdictions across the United States. Details of his qualifications are found attached to this report (Attachment 3).

Over the past fifteen years 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 (Attachment 1 and 2). There are now over 100 scientific articles that allow us to understand the proper siting of wind turbines.

As with any energy facility, it is important that proper setbacks, sound and shadow flicker guidelines are in place for wind turbines to ensure public health and safety. During the preparation of this report OEHM has reviewed the following project-specific documents:

- Speaker Township *Zoning Ordinance, Article XIA, Wind Energy Overlay District (WEOL), 11A.01.00 Energy Facilities, Amended 8/23/21*
- Riverbend Wind Energy Center Special Land Use Permit (SLUP) Application to Speaker Township.
- Sound Report
- Shadow Flicker Report
- Setback distances and Figures provided in the SLUP

This report provides review and comment on the Riverbend Wind project design and layout and how it will ensure the protection of public health and safety. The three main areas covered in this report deal with sound (audible, low frequency noise and infrasound), shadow flicker and setback distances for public safety. Overall, it was found that the Speaker Township Ordinance and the design of the Riverbend Wind Project will ensure the protection of public health and safety of the local population.

Riverbend Wind Project Design Compliance with Speaker Township WECF Zoning Ordinance

As with any energy facility, it is important that proper setbacks and guidelines are in place for wind turbines to ensure public health and safety. The Wind Energy Conversion Facility (WECF) siting regulations are provided in the Speaker Township *Zoning Ordinance, Section 11A.01.00 Energy Facilities (amended 8/23/21)*. OEHM has been asked to review the Riverbend Wind project design and layout, specifically in relation to the Ordinance and available published scientific information.

Table 1 provides a list of setbacks and restrictions provided in the ordinance. It also includes statements from OEHM as to their adequacy to protect public health and safety and how the Project complies with these standards. Table 2 provides the requirements of how project emissions will comply with the Ordinance and supporting scientific information.

In general, the Speaker Township Ordinance is consistent with those of other Michigan townships, and with the requirements of other US States and Counties that have operating wind projects. Attachments 1 and 2 of this document provide further scientific justification for the appropriateness of the Riverbend Wind project design.

Table 1. Riverbend Wind Project Layout and Compliance with Setback Requirements

Section	Setback	Existing Speaker WECF Ordinance	Riverbend Wind Meets This Requirement?	Protects Public Health & Safety?
11A.06.03(A)	Inhabited Structures	Each wind turbine shall be set back from the nearest dwelling, school, hospital, church, public library, or municipal limit a distance no less than the greater of either one thousand (1,000) feet or one hundred sixty (160%) percent of the total height [1,050 ft]. A lesser setback may be permitted only with written approval from the owner of the dwelling, school, hospital, church, public library within the lesser setback.	As demonstrated in Appendix C, the minimum distance to an inhabited structure is 1,071 ft. Wind turbine OPB-10 is located 144 ft from a municipal limit. Riverbend Wind is applying for a variance for this specific turbine.	A minimum setback distance to homes of 1,071 will ensure protection against ice throw, blade failure, and tower collapse. It ensures that homes are outside the zone of influence of these rare occurrences if they were to occur. See Attachment 1 for further details. Although Turbine OPB-10 requires a variance to the municipal limit setback it meets all other setback distances of the Ordinance.
11A.06.03(B)	Non-Participating Property Lines	Along the border of the Wind Energy Overlay District, there shall be a setback distance not less than the total wind turbine height plus fifty (50) feet [706 ft].	As demonstrated in Appendix C, the minimum distance to a non-participating property line is 721 ft.	Typical setback to non-participating property lines, as applied in other jurisdictions, is a minimum of 1.1x tip height. For a 656 ft tall wind turbine this would mean a 721 ft setback to non-participating property lines. See Attachment 1 for further details.
11A.06.03(C)	Public Road and Railways	Each wind turbine shall be set back from the nearest public road and/or railroad a distance no less than the total height of the wind turbine plus fifty (50) feet [706 ft], determined at the nearest boundary of the right-of-way easement and/or railroad easement.	As demonstrated in Appendix C, the minimum distance to a public road is 752 ft and 1,559 ft to a Railway.	Typical setback to roads, as applied in other jurisdictions, is a minimum of 1.1x tip height. For a 656 ft tall wind turbine this would mean a 721 ft setback to roadways. The use of a 752 ft setback is greater than this minimum setback to a roadway will ensure protection against ice throw, blade failure and tower collapse. This equally applies to railways. See Attachment 1 for further details.
11A.06.03(D)	Communication and Power Lines	Each wind turbine shall be set back from the nearest above-ground public utility transmission line a distance no less than the total wind turbine height plus fifty (50) feet [706 ft], determined from the existing above-ground power line or telephone line.	As demonstrated in Appendix C, the minimum distance to a utility line is 801 ft.	Typical setback to utilities is a minimum of 1.1x tip height. For a 656 ft tall wind turbine this would mean a 721 ft setback to utilities. The use of an 801 ft setback is greater than this minimum setback to a utility line will ensure protection against ice throw, blade failure and tower collapse. See Attachment 1 for further details.

Table 2. Riverbend Wind Project Layout and Compliance with Emission Requirements

Section	Setback	Existing Speaker WECF Ordinance	Riverbend Wind Meets This Requirement?	Protects Public Health & Safety?
11A.06.05(A)	Sound	Audible noise or the sound pressure level from the operation of the Wind Energy Facility shall not exceed fifty (50) dBA, or the ambient sound pressure level plus five (5) dBA, which ever is greater for more than ten percent (10%) of any sixty (60) minute interval, measured at any residence, school, hospital, church, or public library existing on the date of approval of any Wind Energy Facility Special Land Use permit.	The sound report provided in Appendix D details that all sound levels will meet the 50 dBA L_{10} requirement for inhabited structures.	Yes. A common sound standard across the US is 50 dBA Leq 10-min to 1-hour at non-participating inhabited structure (home). Sound levels at 50 dBA L_{10} to homes has been demonstrated to be protective of health, sleep and medical concerns of residents. In addition, the use of a 50 dBA L_{10} standard also ensures protection for infrasound and low frequency noise. Attachment 3 provides details of the scientific studies that support the use of a 50 dBA L_{10} sound standard.
11A.06.06	Shadow Flicker	Shadow flicker shall not exceed thirty (30) hours per year. Applicant/developer shall mitigate the effects of any period of shadow flicker that exceeds thirty (30) minutes in duration by shutting down the offending turbine or other appropriate measures as the Township may approve.	Appendix E contains the Shadow Flicker report. Although there are a number of non-participating inhabitable structures that had over 30 hours of shadow flicker or over 30 min duration at a time Riverbend Wind has committed to mitigation measures, including curtailment, to ensure this measure is met.	The no more than 30 hours a year standard is a common limit used almost universally by townships, counties, and states across the US to limit nuisance to non-participating landowners. Shadow flicker does not pose a potential health threat. Modern turbines spin at a rate that is below that which could trigger photo-sensitive epileptics. However, the addition of no more than 30 minutes of shadow flicker duration at a time is not commonly employed in other jurisdictions. See Attachment 3 for further details on shadow flicker health concerns.

Conclusion

There is no question that appropriate wind turbine siting guidelines for sound and distance setback to homes and non-participating property lines is a key requirement for approving SLUP Applications.

During this SLUP Application review OEHM would encourage Speaker Township Planning Commission to make its decisions based on sound scientific evidence. In addition, other states and counties that have years of experience with wind projects, and have weighed the scientific evidence of health protection to enact their legislation, can be reviewed.

For example, The Ohio Department of Health recently published their review *Wind Turbines and Wind Farms Summary and Assessment (Ohio DOH, 2022; Attachment 4)*. This has been attached for your consideration. They concluded:

> *There is no significant body of peer-reviewed, scientific evidence that clearly demonstrates a direct link between adverse physical health effects and exposures to noise (audible, LFN, or infrasound), visual phenomena (shadow flicker), or EMF associated with wind turbine projects.*

OEHM has reviewed the Riverbend Wind project design and layout and believes that it is compliant with the Speaker Township Zoning Ordinance for WECFs. Based on scientific principles, and the collective findings of over 100 scientific articles, OEHM believes that the Riverbend Wind is properly sited to ensure the protection of public, health and safety of Speaker Township residents. Further information on other jurisdictions' zoning regulations and scientific support for these sound, shadow flicker and setback distances can be found in the attached.

Sincerely,

OLLSON ENVIRONMENTAL HEALTH MANAGEMENT

Christopher Ollson, PhD

Attachment 1

Physical Health and Safety Considerations for Determining Appropriate Setback Distances

1 Physical Health and Safety Considerations for Determining Appropriate Setback Distances

Public health and safety with respect to wind projects are governed by setback and safety distances set by local, state and federal authorities. In addition, equipment manufacturers have developed similar recommendations based on their experience with projects around the world.

The following describes the suitability of use of a turbine height multiplier for protection from ice throw and blade failure. Overall, these setback distances are not meant to be protective of the fact that these issues can occur, rather the infrequent events under which they happen and the odds that an individual would be harmed.

Ice Throw

In 2007, Garrad Hassan Canada Inc. was commissioned by the Canadian Wind Energy Association (CanWEA) to undertake a probabilistic risk evaluation of the likelihood of ice fragment throw from wind turbines would strike a member of the public. They used hypothetical wind turbines, similar to those commonly in operation. They examined meteorological conditions in Ontario, Canada, which are similar to winter environment in Michigan. Three scenarios were examined – Scenario A House, Scenario B Road and Scenario C Individual. The setback distances they used were consistent or less than in the Speaker Township Ordinance. Their findings are provided in Table 3.

Table 3. Ice Throw Strike Probabilities (Garrad Hassan, 2007)

Scenario A House	Scenario B Road	Scenario C Individual
• 1000 ft^2 house • 1000 ft from turbine • 1 ice strike per 62,500 years	• north-south road is situated directly west of a turbine at 650 ft • 100 vehicles at 40 mph • 1 vehicle strike per 100,000 years	• ever-present individual between 65 ft to 1000 ft from turbine • 1 strike in 500 years

More recent studies on the potential for vehicles or individuals to be struck by ice throw from larger wind turbines support the Garrad Hassan findings. What is seen is that ice throw pieces that would be capable of harming people or vehicles typically fall within a distance of the turbine height.

The results indicate an extremely low probability that an individual or vehicle would ever be struck. They are far less than risks that people face in everyday life (e.g., driving a car, being struck by lightening, or being in an airplane crash). Therefore, setback distances in the Speaker Township Ordinance are more than sufficient to protect public health and safety from risk of ice throw to roads and non-participating residences.

Blade Failure

There have been a number of probabilistic studies that have been conducted examining the potential for blade failure to harm people or strike vehicles. In a recent U.S. study by Rogers and Costello (2022) of the School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA, titled *Methodology to assess wind turbine blade throw risk to vehicles on nearby roads*, they found:

> *For example, using the one fatality per impact assumption, the fatality risk for the 5.5 MW turbine at a 1.1x tip height setback is 1 fatality per 12 million years for 1 vehicle/mile traffic*

density, and 1 fatality per 1.1 million years for 10 vehicles/mile. Similarly, the results for the 1.5 MW and 3.4 MW turbines at a 1.1x tip height setback are well below 1 fatality per 100,000 years for 1 vehicle/mile and 10 vehicles/mile traffic densities. This indicates that, from an engineering safety perspective, the 1.1x tip height setback produces a satisfactory level of risk mitigation for rural roadways.

Results for these example turbines show that the typical setback of 1.1x tip height is generally sufficient at reducing risk to extremely low levels (between 1 impact in 1 million years and 1 impact in 10 million years) for roads in rural areas which tend to be lightly traveled.

In 2013, MMI Engineering Ltd undertook a study titled "*Study and development of a methodology for the estimation of the risk and harm to persons from wind turbines*" for the United Kingdom government. Through their probabilistic assessment they determined that risk of fatality from wind turbine blade fragment throw is low in comparison to other societal risks. It was roughly equivalent to the risk of fatality from taking two aircraft flights a year or being struck by lightning.

Given the very low probability of risk of fatality or injury from blade failure the setback distances of Speaker Township and those adopted by Riverbend Wind would be protective of public safety.

Attachment 2

Health Research on Living in Proximity to Wind Turbines

2 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 counties in Michigan achieving high levels of wind power capacity.

Over 100 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 lead health and medical authorities to state that when sited properly (i.e., based on distance and/or noise guidelines and setbacks), wind turbines are not causally related to adverse effects.

Issues that are commonly raised and need to be addressed to protect public health and safety are:

- Audible noise
- Low Frequency Noise (LFN) / Infrasound (IS)
- Shadow Flicker
- Ice Throw / Blade Throw

The Health Canada Wind Turbine Noise and Health Study

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. There have been a number of US based studies; however, the Health Canada results have been relied upon recently by numerous jurisdictions to reach conclusions on potential health effects of living near wind turbines during formal State-level hearings; including New York, South Dakota, and North Dakota.

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. It is also noted that the manner in which health Canada modeled wind turbine sound is more equivalent to approximately 50 dBA L_{10} as required in the Speaker Township Ordinance.

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

It is OEHM's understanding that 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 sixteen (16) 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.*

This research will be discussed as appropriate throughout this report.

2.1 Audible Sound (Noise)

The existing Speaker Township Ordinance requires that sound does not exceed 50 dBA L_{10} at the homes and other inhabited structures.

2.1.1 Sleep

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 the past 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.

The following excerpt from the paper discusses the study objective:

> *The current study was designed to objectively measure sleep in relation to WTN exposure using actigraphy, which has emerged as a widely accepted tool for tracking sleep and wake behavior. The objective measures of sleep, when considered together with self-report,*

> *provide a more comprehensive evaluation of the potential effect that WTN may have on sleep.*

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:

> *The potential association between WTN levels and sleep quality was assessed over the previous 30 days using the PSQI, the previous year using percentage highly sleep disturbed, together with an assessment of diagnosed sleep disorders. These self-reported measures were considered in addition to several objective measures including total sleep time, sleep onset latency, awakenings, and sleep efficiency. In all cases, in the final analysis there was no consistent pattern observed between any of the self-reported or actigraphy-measured endpoints and WTN levels up to 46 dB(A) [at homes as close as 820 ft]. Given the lack of an association between WTN levels and sleep, it should be considered that the study design may not have been sensitive enough to reveal effects on sleep. 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.*

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 OEHM believes that this is a critical study.

The Health Canada findings are consistent with credible previously published peer-reviewed literature in the field.

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

Prior to the Health Canada Study (2014), perhaps the most compelling research into wind sound awakenings was conducted by Bakker et al. (2012). This research reported the number or percentage of awakenings with those living in proximity to wind turbines in a rural setting. As can be seen from Table 7 from the Bakker paper, 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, 9 dBA greater than the Speaker Township Ordinance.

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

From Michaud et al., 2016:

> *"Study results concur with those of Bakker et al. (2002), 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".*

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. It should be noted that outdoor sound measurements ranged between 40 – 45 dBA before operation and 38-42 dBA after the turbines became operational. The average indoor sound level in the bedrooms was reported as 31 dBA. For the first time authors used portable polysomnography (PSG), which is a comprehensive system that objectively monitors people's sleep in their homes.

Although there are concerns about the small sample size and that exterior sound levels were higher pre-operation of wind turbines, 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.*

These findings are consistent with the previous reported studies.

Liebich et al. 2020. A systematic review and meta-analysis of wind turbine noise effects on sleep using validated objective and subjective sleep assessments. Journal of Sleep Research

Recently, researchers in Australia undertook a systematic review and meta-analysis of the published literature of how wind turbine noise may impact both objective and subjective sleep outcomes.

They retained nine studies for review, with five of them containing sufficient data that could be used in the meta-analysis of sleep outcomes. The systematic review includes the three publications already reviewed above in the OEHM report. They found:

> *The meta-analysis of five studies found no evidence to support that objectively measured sleep latency, sleep efficiency, time spent asleep and awake during the night are significantly different in the presence versus absence of WTN exposure.*

They could not conduct a meta-analysis on the self-reported sleep outcomes because the measurement outcomes were not consistent enough between studies. They concluded:

> *This systematic review and meta-analysis suggests that WTN does not significantly impact key indicators of objective sleep. Cautious interpretation remains warranted given variable measurement methodologies, WTN interventions, limited sample sizes, and cross-sectional study designs, where cause and- effect relationships are uncertain. Well-controlled experimental studies using ecologically valid WTN, objective and psychometrically validated sleep assessments are needed to provide conclusive evidence regarding WTN impacts on sleep.*

The authors also opined that:

> *Field studies are clearly the most ecologically valid and most representative of real-world WTN conditions in comparison to in-laboratory studies.*

To date, this is the most comprehensive review of wind turbine sound exposure and 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. Therefore, the 50 dBA L_{10} sound level at a home is protective and should not affect the sleep of those living in proximity to wind turbines.

2.1.2 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. The study of wind turbine health concerns began in Europe in the early 2000s and most recently examined in Canada.

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).

Hubner et. al. (2019) Monitoring annoyance and stress effects of wind turbines on nearby residents: A comparison of U.S. and European Samples. Environment International.

This is the most recent paper that examines potential health impacts in people living in proximity to U.S. wind turbine projects. The U.S. sample included 1441 residents living near 231 wind farms, across 24 states. People living between 262 feet and up to 3 miles from a turbine were included in the research. Sound levels in the study ranged from <30 dBA to >50 dBA. From the abstract of the paper:

> *"As wind turbines and the number of wind projects scale throughout the world, a growing number of individuals might be affected by these structures. For some people, wind turbine sounds and their effects on the landscape can be annoying and could even prompt stress reactions. This comparative study analyzed a combined sample of survey respondents from the U.S., Germany and Switzerland. It utilized a newly developed assessment scale (ASScale) to reliably characterize these stress-impacted individuals living within populations near turbines. Findings indicate low prevalence of annoyance, stress symptoms and coping strategies. Noise annoyance stress (NASScale) was negatively correlated with the perceptions of a lack of fairness of the wind project's planning and development process, among other subjective variables. Objective indicators, such as the distance from the nearest turbine and sound pressure level modeled for each respondent,* ***were not found to be correlated to noise annoyance****. Similar result patterns were found across the European and U.S. samples (emphasis added)."*

According to the study authors:

> *"Our findings provide evidence that WT annoyance and related stress effects are not a widespread problem. Average annoyance levels of residents near wind farms in Europe and the U.S. were low, with the levels for noise similar across both samples, with European levels slightly higher for shadow-flicker, lighting and landscape change. In all cases the annoyance levels were comparable to the levels associated with traffic noise."*

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 consisted of socio-demographics, modules on community noise and annoyance, self-reported health effects, lifestyle behaviors, 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. 2016b. Personal and situational variables associated with wind turbine noise annoyance. (Health Canada)

This paper is a continuance of the work reported in Michaud et al. (2016a). In the first paper (2016a) they provide Figure 2 that illustrates the overall level of annoyance associated with wind turbine noise across varying sound levels. In Michaud et al. 2016b, they provide Table I. that provides numerous variables that at least provide some contribution to the overall annoyance levels. As reported by others, this is a clear illustration that wind turbine annoyance is not based solely on sound levels but that there are numerous factors that contribute to reported annoyance levels in relation to living in proximity to wind turbines.

The authors state (Michaud et al., 2016b):

> *The complex relationship that exists between community annoyance and noise is a well-established phenomenon that has been further illustrated in the current study. This study found that the R2 for the model with only WTN levels was merely 9% and that any efforts aimed at mitigating the community response to WTN will profit from considering other factors associated with annoyance. Although the final models had R2 's of up to 58%, their predictive strength for WTN annoyance was still rather limited.*

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. Most notable was that only 9% of the annoyance from wind turbines could be correlated to the sound. 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.

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.

Freiberg et al. 2019 Health effects of wind turbines on humans in residential settings: Results of a scoping review. Environmental Research 169 (2019) 446–463

This is the most recent and comprehensive systematic review of the potential health effects of wind turbines on humans living in proximity to wind turbines. The researchers retrieved 84 articles that varied significantly in methods and health outcomes assessed that met their study inclusion criteria. Overall, they found:

> *Multiple cross-sectional studies reported that wind turbine noise is associated with noise annoyance, which is moderated by several variables such as noise sensitivity, attitude towards wind turbines, or economic benefit.*
>
> *Wind turbine noise is not associated with stress effects and biophysiological variables of sleep.*
>
> *Findings from cross-sectional studies of higher methodological quality – that were supported by findings from lower-quality observational studies – illustrated an existing association between wind turbine noise and annoyance and no association between noise from wind turbines and stress effects and biophysiological variables of sleep.*
>
> *In higher quality studies, wind turbine noise was not associated with restricted quality of life, sleep disturbance, and anxiety and/or depression, which contrasts – at least partly – with findings from lower-quality studies."*

Not surprisingly this review is consistent with the individual reports from above.

Summary of Potential Health Effects

What can be seen from these peer-reviewed articles (and many others) is that the relationship between wind turbines and human responses to them is extremely complex and influenced by numerous variables.

McCunney et al. (2014) published a comprehensive review of the issue "*Wind Turbines and Health A Critical Review of the Scientific Literature*". This work involved review of the publications on wind turbines and health that were available. The authors provide the following summary:

> *1. Measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds.*
>
> *2. No cohort or case–control studies were located in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better quality, no clear or consistent association is seen between wind turbine noise and any reported disease or other indicator of harm to human health.*
>
> *3. Components of wind turbine sound, including infrasound and low frequency sound, have not been shown to present unique health risks to people living near wind turbines.*

4. 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.

Therefore, existing Speaker Township Ordinance will ensure that wind turbines would not impact the health of neighbouring residents.

2.2 Low Frequency Noise (LFN) and Infrasound (IS)

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 not 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.

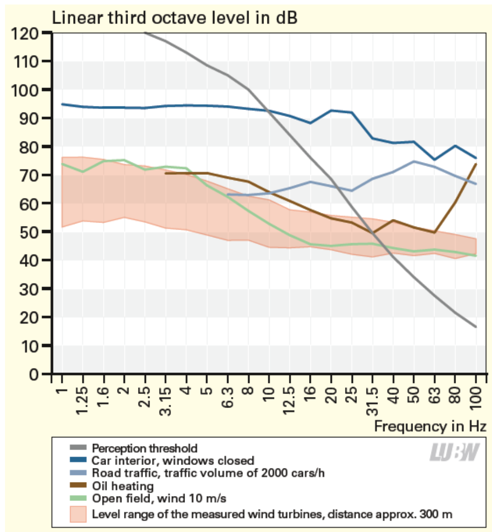

Figure 1. Measurements of infrasound and low frequency noise 300 m from wind turbines compared to other sources. [from MECE, 2016].

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, Speaker Township Ordinance of 50 dBA L_{10} at homes will ensure that infrasound and low frequency noise also do not pose a health threat.

2.3 Shadow Flicker

Shadow flicker occurs when interruption of sunlight by the wind turbine blades. Figure 1 was taken from Smedley et al. (2010) and demonstrates the shadow flicker phenomenon from wind turbines. Shadow flicker is unavoidable for wind turbines, however, it typically only occurs for a limited number of hours a year at a home. This is due to the fact that certain factors must be present:

a. the sun must be in a precise location in the sky such that sunlight will cast a shadow from the wind turbine;

b. the wind turbine must be in operation during this period (i.e., the wind must be of sufficient speed for the wind turbine to be operational);

c. shadow will not be cast on overcast of cloud cover days; and,

d. the shadow will typically not be cast any further than 10x the total height of the turbine to any appreciable extent. For most modern turbines this would mean shadow flicker would not extend past 5,000 feet.

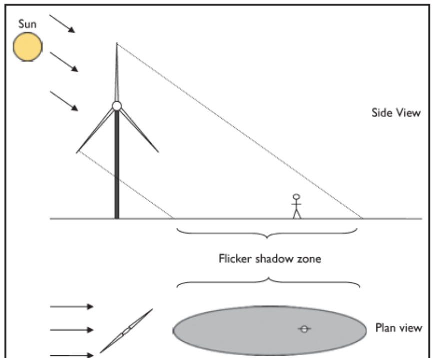

Figure 1.
Generalized geometry for turbine flicker, showing an observer in the shadow area. Note the main analysis assumes the observer and turbine blades are directly facing each other.
Epilepsia © ILAE

Conducting shadow flicker modeling has become common practice for proposed wind farm projects across the United States. It is often completed using commercially available software, such as WindPro.

A search of both the primary scientific literature and the Internet was conducted for wind turbine shadow potential health concerns, and report of annoyance or nuisance. Of this body of literature three of the published papers address shadow flicker.

The main health concern that has been raised with shadow flicker is the potential risk of seizures in those people with photosensitive epilepsy. Photosensitive epilepsy affects approximately 5% of people with epilepsy where their seizures can be triggered by flashing light. The Epilepsy Society first investigated this issue in the United Kingdom in the late 2000s. They polled their members and determined that no one had experienced an epileptic seizure living, or being, in proximity to a wind farm from shadow flicker (Epilepsy Society, 2012).

Following on this informal polling two of the United Kingdom's academic experts in epilepsy published scientific research articles in the area. Harding et al. (2008) and Smedley et al. (2010) have published the seminal studies dealing with this concern. Both authors investigated the relationship between photo-induced seizures (i.e., photosensitive epilepsy) and wind turbine shadow flicker. Both studies suggested that flicker from turbines that interrupt or reflect sunlight at frequencies greater than 3 Hz pose a potential risk of inducing photosensitive seizures in 1.7 people per 100,000 of the photosensitive population. For turbines with three blades, this translates to a maximum speed of rotation of 60 revolutions per minute (rpm).

Modern turbines commonly spin at rates well below this threshold and are typically below 20 rpm. Therefore, shadow flicker from these wind turbines is not at a flash frequency that could trigger seizures and not a concern.

In 2011, the Department of Energy and Climate Change (United Kingdom) released a consultant's report entitled "Update of UK Shadow Flicker Evidence Base". The report concluded that:

> *"On health effects and nuisance of the shadow flicker effect, it is considered that the frequency of the flickering caused by the wind turbine rotation is such that it should not cause a significant risk to health.*

Therefore, there are no requirements to limit shadow flicker for health concerns.

Two of the most comprehensive and widely cited published scientific review articles on this topic are Knopper & Ollson (2011) and McCunney et al. (2014). Both papers review the potential health impacts of shadow flicker and concluded that there are no health effects associated with this issue living in proximity to wind turbines. Knopper & Ollson (2011) concluded:

> *"Although shadow flicker from wind turbines is unlikely lead to a risk of photo-induced epilepsy there has been little if any study conducted on how it could heighten the annoyance factor of those living in proximity to turbines. It may however be included in the notion of visual cues. In Ontario it has been common practice to attempt to ensure no more than 30 hours of shadow flicker per annum at any one residence."*

Since 2011, there have been two studies conducted that examined the potential for shadow flicker to lead to increased annoyance for those living near wind turbines. Health Canada recently completed the most comprehensive study of wind turbine health and annoyance issues of its kind in the world (Health Canada, 2014). In 2016, Health Canada published a paper "*Estimating annoyance to calculated wind turbine shadow flicker is improved when variables associated with wind turbine noise exposure are considered*" (Voicescu et al., 2016). By using the questionnaires of over 1200 people living as close as 800 feet from a turbine they attempted to determine if they could predict the percentage of people that were highly annoyed by varying levels of hours of shadow flicker (SF) a year or number of minutes on a given day. However, although annoyance did tend to increase with increasing minutes a day they could not find a statistical relationship:

> *"For reasons mentioned above, when used alone, modeled SF_m results represent an inadequate model for estimating the prevalence of HA_{WTSF} as its predictive strength is only about 10%. This research domain is still in its infancy and there are enough sources of uncertainty in the model and the current annoyance question to expect that refinements in future research would yield improved estimates of SF annoyance."*

In a US based study published by the Lawrence Berkley National Laboratory "In the shadow of wind energy: Predicting community exposure and annoyance to wind turbine shadow flicker in the United States", the authors state:

> *This study modeled SF exposure at nearly 35,000 residences across 61 wind projects in the United States, 747 of which were also survey respondents. Using these results, we analyzed the factors that led to perceived SF and self-reported SF annoyance. We found that perceived SF is primarily an objective response to SF exposure, distance to the closest turbine, and whether the respondent moved in after the wind project was built. Conversely,*

SF annoyance was not significantly correlated with SF exposure. Rather, SF annoyance is primarily a subjective response to wind turbine aesthetics, annoyance to other anthropogenic sounds, level of education, and age of the respondent.

They go on to state:

Regulated SF exposure limits are designed to mitigate annoyance, yet we find no clear dose-response relationship between SF exposure and self-reported annoyance when subjective variables are considered.

Therefore, there is nothing in the scientific literature that suggests that shadow flicker should be limited, either for hours per year or total minutes at a time, to protect health.

That said OEHM does believe that limits on shadow flicker are prudent to keep nuisance levels to a minimum at non-participating residences. A number of Counties and States have adopted various ordinances and rules limiting shadow flicker on non-participating land. A no more than 30 hours of shadow flicker modeled on a residence has almost become the universally adopted standard. To put this in perspective it represents less than 0.5% of the daylight hours a year.

There is no need to limit shadow flicker to no more than 30 minutes of duration at a time to protect health.

Attachment 3

Qualifications of Dr. Christopher Ollson of OEHM

Qualifications of Dr. Christopher Ollson of OEHM

Dr. Ollson is owner and a senior environmental health scientist with OEHM. His expertise is in the field of environmental health science. Dr. Ollson is trained, schooled and practiced in the evaluation of potential risks and health effects to people and ecosystems associated with environmental issues. Dr. Ollson's formal education includes:

- Doctorate of Philosophy, Environmental Science, Royal Military College of Canada, Kingston, Ontario, Canada, 2003.
- Master of Science, Environmental Science, Royal Military College of Canada, Kingston, Ontario, Canada, 2000.
- Bachelor of Science (Honours), Biology, Queen's University, Kingston, Ontario, Canada, 1995.

In addition to his consulting practice he holds an appointment of Adjunct Professor in the School of the Environment at the University of Toronto. In 2013, he was appointed to the Governing Council, and was Vice-Chair of the Academic Affairs Committee, of the University of Toronto Scarborough until 2016. Dr. Ollson teaches a graduate course at the University of Toronto in Environmental Risk Analysis and co-supervises doctoral students.

Approximately one third to half of Dr. Ollson's practice on an annual basis has been devoted to better understanding the relationship between people, animals and wind energy. For almost a decade, he has been engaged by a number of private companies to review the potential health effects that may be associated with living in proximity to wind turbines as part of their preparation of planning and permitting documentation. Since 2014, he has provided expert advice on wind turbines, health and proper siting requirements for the Vermont Public Services Department. He has published numerous scientific peer-reviewed articles in the field of wind turbines and public health:

*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.*

*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*

*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*

*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.*

***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*

*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*

Dr. Ollson's research has been presented at numerous international scientific conferences. He has been formally qualified to provide expert opinion evidence on wind turbines and potential health effects at a number of North American hearings, tribunals and legal cases. Dr. Ollson has appeared before numerous County Planning & Zoning and County Commissions across the country to provide an overview of potential health concerns during their deliberations on review of wind turbine regulations and granting Conditional/Special Use Permits for wind generating facilities

Attachment 4

OHIO DEPARTMENT OF HEALTH
WIND TURBINES AND WIND FARMS
SUMMARY AND ASSESSMENTS (2022)

OHIO DEPARTMENT OF HEALTH
WIND TURBINES AND WIND FARMS
SUMMARY AND ASSESSMENTS

Prepared By:
Health Assessment Section
Bureau of Environmental Health and Radiation Protection
Ohio Department of Health

Last Updated April 12, 2022

Contents

Introduction

The Ohio Department of Health's (ODH) role in the Ohio Power Siting Board has historically been to assess cases to determine whether the construction, alteration, or decommissioning of any power-generating structure or facility will have an impact on the health and wellness of the public. ODH works in partnership with fellow state agencies, including the Ohio Department of Natural Resources (ODNR), which assesses ecological impacts, and the Ohio Environmental Protection Agency (OEPA), who is responsible for environmental licensing and regulation, to provide a robust, holistic assessment.

The purpose of this document is to assess, based on existing research, whether living proximal to industrial wind turbine projects has the potential to cause harm to human health. ODH did not conduct independent, peer-reviewed research in order to produce this document. ODH has developed this document at the request of the Ohio Power Siting Board (OPSB) in response to an increase in the construction of new wind turbine projects in Ohio.

The determinations within this document were made based on a review of the scientific literature available at the time of its original publication. As scientific information changes over time, and as wind turbine technologies and wind energy policies within Ohio change, ODH will reevaluate these conclusions as needed. This document supersedes a similar document developed by ODH at the request of the Logan County Health Department and provided to the OPSB in 2008. It reviews the significant amount of research, investigations, and large-scale scientific reviews conducted by individual scientists and by a number of government agencies that have been published since 2008.

Reliance on power derived from industrial wind turbines has increased dramatically over the course of the last decade (6,100 Megawatts in 1996 up to 539,123 megawatts in 2017). As of 2017, there are over 3,300 megawatts (MW) of new wind projects either approved or proposed in Ohio. If completed, these projects would generate up to $4.2 billion in local economic activity and provide enough power for more than 900,000 Ohio homes (Renewable America, 2017).

The increase in construction of new wind farms in Ohio has given rise to public concerns about potential related health effects. Reported to be caused by visual phenomena (shadow flicker) or noise (audible sound and infrasound), concerns include a range of adverse health effects from ringing in ears (tinnitus), headaches, lack of concentration, vertigo, and sleep disruption to epileptic seizures, cardiovascular issues, miscarriage, cancer, and death (Chapman and Crichton, 2017). This collection of effects has been given the name Wind Turbine Syndrome (Pierpont, 2009). Information about the proposed Wind Turbine Syndrome is largely based on a small number of anecdotal reports from people living near operating wind turbine installations. However, this syndrome is not a clinically recognized diagnosis and is not generally accepted by the scientific and medical community to date (Farboud et. al., 2013). To establish whether there was some correlation, if not causation, between proximity to wind turbine installations and negative health effects described as Wind Turbine Syndrome, further research would be needed so that more robust, complete data could be assessed.

Audible Wind Turbine Noise

There have been numerous studies that have investigated the assertion that the mechanical and aerodynamic noise created by operating wind turbines caused various physical health effects collectively called “Wind Turbine Syndrome.” Wind turbine noise (WTN) is complex and spans a broad band of frequencies, including audible noise (air pressure waves 100-1,000 Hertz), low-frequency noise (LFN) (20-100 Hertz), and infrasound (< 20 Hertz). A Hertz is a unit of frequency equal to one wave per second (1 Hz). People sense the frequency of sound by its “pitch” – high pitch is linked to high frequencies and low pitch is linked to low frequencies. Pitch is a function of the frequency and also the level of sound pressure (its loudness). Loudness or volume of sound pressure is measured in decibels (dB). Decibels can also be presented as A-weighted decibels (dBA). The difference between dBA and dB is that dBA is a scale more appropriate to use when considering healthy sound levels. dBA are based on the intensity of the sound *and* on how the human ear responds. dBs are solely based on sound intensity.

Mechanical noises from the physical movements of the gearbox, generator, and other components produce low-frequency tones and have been reduced significantly by design improvements to turbines during the past several decades, including sound-proofing the nacelles, modifying blade airfoils to make them more efficient and less noisy, and development of direct-drive turbines with no gearbox. Aerodynamic noise is associated with interactions between the surface of the turbine blades and the wind flowing over it. Aerodynamic wind turbine noise is greatly reduced by the strategic upwind placement of the wind turbines which greatly reduces the amount of air turbulence produced by the turbine action. Industrial wind turbines today are designed to minimize noise, weight, and drag and are predominantly horizontal axis wind turbines equipped with three-bladed propellers facing into the wind.

Besides noise reductions due to improvements in the mechanical and aerodynamical operation of the individual turbines, it was also determined that increasing the set-back distances between the wind turbines and the closest residences also significantly reduced the audible noise levels. Ohio House Bill 413, passed in 2014, required that wind turbines from any Ohio wind turbine project must be located at least **1,125 feet from the tip of the turbine blade to the nearest adjacent property line**. In practice, this requires set-backs of 1,300 feet from each turbine’s base to the edge of the neighboring property, even if that means the distance to the actual residence is actually much further. Ohio’s current set-back law is 2-3 times larger than those required by most other states in the U.S. (Runnerstone, 2014). In addition, in Ohio, wind farms must be operated so that facility noise does not result in noise levels at non-participating residences within one mile of the project’s boundary that exceed the project area ambient nighttime average sound level by five dB (OPSB, 2018). Average nighttime ambient sound levels reported for the largely rural wind turbine sites for which OPSB has received applications, range from 29 to 55 dB, and average about 42 dB (OPSB, personal communication, 3/06/2019).

A large study of wind turbine noise and health conducted by Health Canada in 2012 of residents living within 600 m (=1,800 feet) of 18 wind turbine projects in Ontario and Prince Edward Island (N= 2,004) determined that the audible WTN levels in homes participating in the studies reach a maximum of 46 dBA at turbine speeds of 8m/s (Health Canada, 2014). A study by the National Health and Medical Research Council of Australia (2015), similarly determined that WTN from wind farms typically range from 35 to 45 dBA for residences located from 500 m to 1,500 m (1,500 – 4,500 feet) from the wind turbines. Beyond a distance of 1,500 m (4,500 feet), WTN drops to levels below 35 dbA, below the noise levels of household devices and similar to a quiet residential area. The findings from both studies indicate that typical WTN from wind farms are only slightly higher than the World Health Organization (WHO) recommended outdoor nighttime average of 40 dBA – the level below which no health effects are expected to occur, even among the most vulnerable people (WHO, 2009).

Summary and ODH Assessment: Information to date does not indicate a public health burden from audible wind turbine noise. Peer-reviewed scientific articles and government-sponsored policy review papers regarding wind turbines and human health published during the past decade have concluded that the scientific evidence collected to date does not support a direct association between audible WTN and physical health problems or disease. These included self-reported illnesses like dizziness, tinnitus, frequent migraines and headaches, and sleep disturbances and diagnosed chronic health conditions including heart disease, high blood pressure, and diabetes, diagnosed sleep disorders, and stress.

ODH supports using the existing set-back distance requirements and noise level requirements in Ohio (as described above) to ensure audible WTN does not cause negative health effects.

Low-Frequency Noise (LFN) and Infrasound

Following significant reductions in the audible noise produced by wind turbines, concern shifted from the audible noise spectrum (200-2,000 Hz) to LFN (20-100 Hz) and infrasound (barely audible airborne pressure waves with frequencies of less than 20 Hz). Human hearing becomes gradually less sensitive as frequency decreases, so that LFN needs to be louder to be heard as loudly as mid-frequency noise (1,000 Hz). LFN and infrasound is emitted from wind turbines at maximum levels of 50 to 70 dB, which is well below the audible threshold for these low frequency sounds (McCunney, 2009). Low-frequency sounds are associated primarily with the mechanical sound generated by an operational wind turbine and were a significant component of the aerodynamic noise produced by air turbulence resulting from the operation of "downwind" turbines. However, current operating wind turbines are almost entirely now "upwind" turbines, which has greatly reduced the levels of infrasound associated with industrial wind turbines. LFN and infrasound isn't unique to wind turbine operations. Sources of LFN and infrasound are around us everywhere, including natural sources like earthquakes, volcanic eruptions, running water, the wind, and waves as well as man-made sources like automobiles, trucks, trains, aircraft, watercraft, heavy machinery, compressors, HVAC systems in buildings, and household appliances such as washing machines.

Pierpont (2009) linked exposure to LFN and infrasound to "visceral vibratory vestibular disturbance (VVVD)," where low levels of airborne infrasound (4-8 Hz) allegedly enters the lungs via the mouth and vibrates the diaphragm, transmitting vibrations to the viscera which sends neural signals to the part of the brains that receives information from the human vestibular system (i.e. inner ear) leading to development of vertigo, balance issues, disorientation, and nausea characteristic of "Wind Turbine Syndrome." McCunney (2009), the Massachusetts Department of Environmental Protection and Department of Public Health (MDEP/MDPH, 2012), and McCunney et al. (2014) have pointed out that the visceral receptors proposed as the mechanism for VVVD respond to gravitational body position changes, not to vibrations. If vibration-sensitive receptors were in the abdominal viscera, they would likely be constantly barraged by low-frequency body sounds like pulsatile blood flow and bowel sounds. In addition, wind turbine sound at realistic distances from nearby residents possesses little, if any acoustic energy at 4-8 Hz above ambient noise levels, providing insignificant sound energy necessary to generate these vibrations.

Research conducted by a research group headed by Castelo-Branco and Alves-Pereira (2004) suggested that infrasound and LFN may cause "vibroacoustic disease" (VAD), characterized by increased risk of epilepsy and cardiovascular effects resulting from the effects of infrasound on pericardial or cardiac valve thickening, leading to an increased risk of coronary heart defects. This illness has been suggested by studies of high-intensity occupational noise exposures (90-130 dB) involving aircraft maintenance and other aviation workers (Castelo-Branco and Alves-Pereira, 2004). An experimental animal study by Lousinha et al. (2018) linked infrasound at low frequencies (<20 Hz) and high intensities (120 dB) with development of coronary perivascular fibrosis in rats. The common denominator in these studies is exposure to infrasound (1-20 Hz) or LFN (20-200 Hz) coupled with high sound intensities (90-140 dB). None of these studies were of human populations exposed to infrasound from wind turbine projects. As indicated above, the maximum levels of infrasound associated with wind turbine farms is on the order of 50-70 dB, significantly below the sound intensities linked experimentally to this illness.

The table below shows common sources of sounds and how intense (loud) those sounds are (Kollman, 2010). A wind turbine at 1,000 feet typically generates the same intensity of sound as a large transformer at 200 feet or light traffic at 100 feet. As discussed above, Ohio's setbacks are greater than 1,000 feet, and the sound intensity would be reduced even further. The health effects on humans and animals described above do not occur until sound intensities reach volumes similar to ambulance sirens at 100 feet or lawn mowers at 3 feet. A wind turbine at 1,000 feet is too quiet to generate any of the negative health outcomes described above.

Source	**dBA**

Civil Defense Siren	140-130
Jet Takeoff at 200 feet	120
Rock Music Concert	110
Pile Driver at 50 feet	100
Lawn Mower at 3 feet	95
Ambulance Siren at 100 feet	90
Freight Cars at 50 feet	90
Vacuum Cleaner at 3 feet	85
Pneumatic Drill at 50 feet	80
Freeway at 100 feet	70
Speech Range	50-70
Light Traffic at 100 feet	50
Wind Turbine at 1,000 feet	**40-50**
Large Transformer at 200 feet	40
Soft Whisper at 5 feet	30
Rural Background at Night	20-40

Summary and ODH Assessment: Information to date does not indicate a public health burden from low-frequency noise and infrasound generated by wind turbines. Peer-reviewed scientific literature indicates that:
1) infrasound near wind turbines does not exceed audibility thresholds.
2) infrasound and LFN from wind turbines do not present unique health risks to nearby residents.
3) available evidence shows that infrasound levels near wind turbines do not impact the vestibular system.
4) there is very little or no evidence linking infrasound or LFN from wind turbines with "vibroacoustic disease" as the levels of sound associated with these effects in the laboratory are several orders of magnitude higher than what has been measured in the field in the vicinity of operating wind turbines.

Shadow-Flicker

The main health concern associated with "shadow flicker" (wind turbine blade flicker created by the turbine blades movements interrupting or reflecting sunlight) is the risk of seizures in people with photosensitive epilepsy. Studies by Harding et al. (2008) and Smedley et al. (2010) suggested that shadow flicker from turbines at frequencies greater than 3 Hz (=blade rotation speed of 60 rpm) pose a risk of inducing photosensitive seizures in 1.7 people per 100,000 of the photosensitive population. Spin rates for Siemens, Repower, GE, and Vestas, four of the most popular turbines in use in wind turbine farms today, range from 6 to 17.1 rpms (Knopper et al., 2014), well below this 60 rpm threshold. This has led the Massachusetts Department of Environmental Protection and Department of Public Health (2012) to conclude that the scientific evidence suggests that shadow flicker associated with wind turbine operations does not pose a risk of inducing seizures in people with photosensitive epilepsy.

Summary and ODH Assessment: Information to date does not indicate a public health burden from shadow-flicker caused by wind turbines.

Electromagnetic Fields (see the separate Summary Sheet on EMF)

Concerns about the ever-present nature of EMF and possible health effects have been raised globally for a number of years. However, the science around EMF and possible health concerns has been extensively researched, with tens of thousands of scientific studies published on the issue and many government and medical agencies weighing in on the issue. The weight of scientific evidence does not support a causal link between EMF and health issues at the levels typically encountered by most people (Knopper et al., 2014).

Recently, concerns about exposure to EMF from wind turbines, and associated electrical transmissions, have been raised at public meetings and legal proceedings. There has been only limited research conducted on wind turbine emissions of EMF, either from the turbines themselves, or from the power lines required for the distribution of the generated electricity. Israel et al. (2011) conducted investigations of EMF, sound, and vibration measurements surrounding one of the largest wind turbine energy parks in Bulgaria. The park consisted of 55 Vesta V90 3 MW towers. EMF levels within 2-3 m of the wind turbines were between 0.133 and 0.225 mG (milligauss) (equal or lower than magnetic field measurements reported proximal to typical household electrical devices). These levels were more than four orders of magnitude below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guideline of 2,000 mG for the general public for acute exposure (ICNIRP, 2010). These authors determined that “the studied wind power park complies with requirements of the national and European legislation for human protection from electric and magnetic fields up to 1 kHz and does not create risk for both workers in the area of the park and the general population living in the nearest village.”

Summary and ODH Assessment: Information to date does not indicate a public health burden from electromagnetic fields generated by any part of a wind turbine or wind farm.

Overall Summary

There is no significant body of peer-reviewed, scientific evidence that clearly demonstrates a direct link between adverse physical health effects and exposures to noise (audible, LFN, or infrasound), visual phenomena (shadow flicker), or EMF associated with wind turbine projects.

Epidemiological studies have shown associations between living near wind turbines and annoyance. Annoyance is related to personal factors (such as noise sensitivity) and negative attitudes and expectations (the nocebo effect) towards wind turbines rather than being related to specific physical characteristics of wind turbine projects (McCunney et al., 2014; Chapman and Crichton, 2017). In their 2017 report "Wind Turbine Syndrome: A Communicated Disease", authors Chapman and Crichton conclude based upon a review of studies on Wind Turbine Syndrome available at the time:

> "…that annoyance can sometimes generate health problems consistent with those associated with stress and anxiety, but that there is no strong evidence of direct health effects from turbine exposure. Moreover, [the studies] conclude that pre-existing negative attitudes to windfarms are generally stronger predictors of annoyance than distance from the turbines or recorded levels of noise." (pp. 130-131)

To summarize, there may be some amount of negative health impact caused by stress and anxiety resulting from annoyance and negative emotions surrounding the construction of new wind installations, but not because of noise, shadow-flicker, or EMFs. In the case of wind farms, it is very likely that education which emphasizes a lack of a proven correlation between noise, visual phenomena, and EMFs and direct health effects will mitigate much of the pre-existing negative attitudes and prevent or reduce stress.

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