Testimony of

Christopher Andrew Ollson, Ph.D.
Senior Environmental Health Scientist, Ollson Environmental Health Management
Adjunct Professor of Environmental Science, University of Toronto

Before the Senate Committee on Utilities
Regarding Senate Bill No. 353
February 10, 2022

Chairman Thompson and Committee Members,

My name is Dr. Christopher Ollson, Ph.D. and I am an Environmental Health Scientist with Ollson Environmental Health Management (OEHM). I also hold an Adjunct Professorship at the University of Toronto in the School of the Environment, where I teach graduate level courses.

For the past decade, I have been engaged in research and reviewing the potential health effects that may be associated with living in proximity to wind turbines. I have conducted extensive research and published numerous peer-reviewed articles and government white papers on the topic. This work has been presented at international conferences on wind turbines, noise, and health. The focus of my work is establishing appropriate siting criteria for the protection of public health.

I have applied the results of this research with industry and governments across the country to determine the proper siting of wind turbines to ensure the protection of both participating and non-participating residents. I have 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. I have appeared before County Planning & Zoning and County Commissions across the country, including in Kansas, to provide an overview of potential health concerns during their deliberations on review of wind turbine ordinances and granting permits for wind generating facilities. I have also appeared before North Dakota and Indiana Senate Committees and provided testimony on proper siting of wind turbines.

Thank you for allowing me to appear before you to provide my serious concerns with many aspects of Senate Bill No. 353 (the "Bill").

1 <u>Overview of Concerns with the Bill</u>

There is no question that setting appropriate wind turbine siting guidelines for sound and distance setback to homes is a complicated undertaking. As with any energy production project one needs to balance community concerns (annoyance) with the need for the renewable energy and economic benefits, while still ensuring the protection of public health and welfare of the local population.

Over the past fifteen years there has been extensive research evaluating public health and welfare concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government agencies has taken place in many different countries on a variety of turbine models, which have been in communities for years.

Senators, you have before you Senate Bill No. 353, which lays out a series of regulations that would govern the siting of wind turbines in the Kansas. I have a number of concerns with the content of the Bill, including the level of restrictions on:

a. Required setback distances from a number of buildings and property lines;

b. Sound level

c. Shadow Flicker

Each of these issues do require thoughtful consideration and reasonable restrictions to ensure that the wind projects will co-exist with their neighbors.

Overall, in my experience many of the constraints that are in the proposed Bill are not based on the fundamental science and research on proper siting of wind turbines that has been conducted over the past two decades around the world. They are far too restrictive and would result in a Bill that would make it impossible to site another wind turbine, let alone project, in Kansas.

Simply put, as I will describe in my testimony, the measures contained within the Bill are excessive and not based on our experience of 20 years of wind generation in Kansas or the scientific research and evidence from around the world on proper siting of wind turbines.

2 Experience with Local and State Control of Wind Turbine Project Siting

Kansas has over 20 years of experience with the responsible and successful siting of wind energy projects at the local level. These projects are an integral part of the rural fabric of the state. In Kansas in 2020, there were 40 wind projects, with over 3,500 wind turbines that generated over 7,000 MW of energy. There are several more wind projects in construction and seeking local permits, as I speak.

Since 2016, I have had first-hand experience working with wind developers in proper siting in Kansas. I have worked for wind developers seeking project approvals in both zoned and unzoned counties; including: Kingman, Ninnescah, Pratt, Reno, Marshall, Nemaha, Neosho, and Marion. I have appeared before Planning & Zoning Committees and County Commissioners in both the setting of local wind energy conversion system (WECS) ordinances and when companies are seeking Conditional Use Permits (CUPs) for individual projects.

Although each of these counties may have slightly different approaches to siting of wind turbines, in all cases (zoned or unzoned) they establish minimum setback distances to homes, property lines, other infrastructure, sound levels and shadow flicker levels that are applicable to individual projects or across the county that local elected officials feel are reasonable.

It often takes years to advance a wind project, with the developers working with local elected officials and the public to set the rules. None of these Kansas counties have set the unreasonable requirements that are proposed in the current Bill.

It is true that that across the country there are a mixture of state and local siting guidelines. There are states (e.g., North Dakota, Minnesota, Wisconsin, and New York) that have state level siting guidelines that have been codified into law. These have been established over a number of years through consideration of local government regulations, experience gained during testimony during permitting of existing projects, testimony by experts in the field, debate, and a public comment period. Again, none of these state statutes have established setback, sound or shadow flicker requirements that are as unreasonably restrictive as those contemplated in Bill 353.

Senators, in the event that this Committee wishes to establish state-level siting requirements for wind projects I would urge you not to adopt the measures contained within this Bill.

3 Health Concerns with Living in Proximity to Wind Turbines

Senators, I want to be clear with you from the outset that there are potential health issues for those living in proximity to wind turbines if they are not properly sited. However, this is not the case for operating project in Kansas. This is an area that has been extensively studied around the world by academics, government scientists and researchers for the past two decades. In no way is this an emerging field of research, there are no longer significant gaps in the research or unknowns as to how people react living with wind turbines.

I have included a brief attachment to my testimony that outlines an overview of the science in the field. I wish to emphasize that this is not a comprehensive review. Rather it provides scientific justification for my testimony today.

The following are my thoughts on the specifics contained in the Bill.

4 Sound

The Bill proposes in Section 1.(4) to limit instantaneous wind turbine noise in excess of 35 decibels (dBA) as measured at the property line of adjacent landowners.

Senators, please remember that wind turbines are sited in rural Kansas. Although some would have you believe that our rural landscape is a pristinely quiet soundscape, you know that is not the case. Farming activities are loud. For example, we use heavy machinery to sow and harvest our crops, cattle and other livestock make noise, and grain drying is loud.

A 35 dBA restriction of sound at a property line is below the background sound that we experience in our everyday rural environment. There is no reasonable scientific health basis for setting such a low sound level. In addition, the majority of sound ordinances in Kansas and elsewhere appropriately set the regulated sound level at the non-participating homes and not the property line.

You have heard testimony that living in proximity to wind turbines causes sleep disturbance, that then has the potential to cascade into potential health impacts, such as cardiovascular disease. Unfortunately, Dr. Johnson's testimony before this Committee was not fully informed by the peer-reviewed research in this field. Health Canada (Michaud, 2016) has conducted the largest epidemiological study in the world for those living around wind turbines. In a number of peer-reviewed published papers they did not find that wind turbines cause sleep disturbance at levels of up to 46 dBA at the exterior of people's homes. A recent review from Australia (Liebich, 2020) of the science published around the world on wind turbines and sleep disturbance found that wind turbine noise had no significant impact on the key indicators of objective sleep. Senators, the speculation that you have heard indicating you must limit wind turbine noise to 35 dBA at a property line to protect against sleep disturbance and cardiovascular disease is quite simply not true.

In my experience the majority of Kansas wind projects are sited using a sound level of 50 dBA Leq at the exterior of non-participating homes. There are some counties that have adopted a more restrictive level of 45 dBA Leq. These levels were set based on understanding of their own county resident's experience with wind projects and testimony on the science of noise and protection of sleep and health. These sound levels are also consistent with other states and counties in the Midwest.

5 Shadow Flicker

Section 1.(5)(A)(i)(ii) seeks to limit shadow flicker to not fall on any nonparticipating landowner's property. It is simply not possible to site a wind project that guarantees no shadow flicker on a non-participating property and would preclude any future development. Senators, shadow flicker is not a health concern. There has been extensive research to show that shadow flicker does not cause health impacts, including those related to epileptic seizures.

Instead, shadow flicker can be a nuisance issue. The most commonly adopted shadow flicker limit applied in counties in Kansas and across the Midwest is a limit of no more than 30 hours a year of modelled actual shadow flicker at a non-participating home. This represents no more than 0.5% of the daylight hours a year. It is a reasonable limit that has worked well for decades across the country.

6 Setback Distances

Perhaps the most unreasonable measures provided in Bill 353 are those of setbacks from wind turbines to nonparticipating landowner properties, and other features. The Bill contemplates a setback distance of 10 times the wind turbine height or 5,280 feet, whichever is greater from nonparticipating property lines. This 1-mile setback or 10 times the height of a turbine is completely unnecessary for the protection of health and safety of local residents. It would not be possible to site any wind turbine in Kansas under these proposed setback.

Instead, it is common in Kansas to have setback distances of 1,500 feet (ranging up to 2,500 feet) from non-participating homes. As wind turbines become taller it has become common for counties or states across the Midwest to use a multiplier on the height of the turbine for setbacks from homes, property lines and other infrastructure (e.g., roads, rail lines, and transmission lines). In my experience this multiplier is typically 3 times the wind turbine height to non-participating homes and 1.1 times the turbine height to nonparticipating property lines.

These common setback distances ensure that sound levels of between 45 to 50 dBA can be achieved at nonparticipating homes and ensures public safety from issues such as ice throw, blade failure and tower collapse.

Reasonable setback distances need to be coupled with limits on sound and shadow flicker that all act together. This is certainly not the case for those setback distances proposed in Bill 353.

7 Infrasound

Over the past couple of years some have speculated that wind turbine infrasound and low frequency noise (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 include ocean waves, thunder, and even the wind itself. Other sources include road traffic, refrigerators, air conditioners, machinery, and airplanes.

There have been numerous studies on wind turbine infrasound and its potential impact on health. From a recent study conducted in Germany (2016)

> *"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."*

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, allowing a reasonable audible sound level at residences will ensure that infrasound and low frequency noise also do not pose a health threat.

8 Annoyance

You have heard from others that an individual's annoyance from near wind turbines constitutes a significant health effect. This is simply not the case. The first step in understanding how communities feel about a new sound (noise) source is to ask people to rate their level of annoyance on a scale of 1 (not at all) to 5 (very). The term annoyance has been used for decades in the research of sound sources (e.g., airplane, train, and road traffic). This is in no way a new or novel term being used to measure annoyance for those living in proximity to wind turbines and their feelings towards the noise they generate.

There will always be a percentage of people that self-report annoyance with having to live near wind projects, regardless of whatever sound or setback distances are permitted. This is a well-understood scientifically documented phenomenon. On balance the scientific research on people's self-reported annoyance towards wind energy projects reveals:

- Annoyance is not a medical condition. It is not a recognized medical disease and it is not classified in the World Health Organization's International Statistical Classification of Disease and Related Health Problems 11th revision (ICD 11).
- People tend to notice sound from wind turbines almost linearly with increasing sound pressure level (in other words, the louder the wind turbine at ground level the more people notice them).
- There is at best only a weak association between wind turbine sound at the exterior of people's homes and the reported level of annoyance. The results of European, Canadian and U.S. studies found that only 9-13% of the annoyance can be correlated to the sound level itself.
- Self-reported annoyance levels are not correlated to the distance to the nearest wind turbine from people's homes.
- Self-reported annoyance is much more strongly related to the subjective factors of people's attitude of the visual impact of turbines on the landscape and fairness in the siting process.

- People who economically benefit from wind turbines often experience higher sound levels outside their homes (45 to 50 dBA) than non-participants and report almost zero annoyance with the wind project.
- The level of annoyance is not correlated to stress mediated health outcomes. Based on the results of a recent U.S. study wind turbine annoyance and related stress effects are not a widespread problem.
- Wind turbine sound levels or distance to the exterior of homes does not impact quality of life outcomes.

Levels of self-reported annoyance are largely driven by one's feelings towards how the turbines change the visual nature of the landscape and their perception of the perceived fairness in the permitting process for a project. Therefore, it would be inappropriate to base wind turbine sound and setback standards on annoyance levels.

9 Information Heating by Dr. Johnson, Dr. Punch and Mr. James

It is my understanding that by the time I provide oral testimony before the Committee that Dr. Ben Johnson, M.D., Dr. Jerry Punch, Ph.D. and Mr. Richard James will have appeared before you in Informational Hearings. I will watch their testimony with great interest this week. All of these gentlemen, their writings on the topic, and previous testimony are known to me through previous hearings. With all due respect to them, I do not believe that they provide a balanced, scientific based approach to coming to their conclusions on potential health impacts living around wind turbines.

They tend not to report, may not be aware of, or simply overlook the considerable body of research that has been conducted around the world on wind turbines and health, including right here in the United States by the Lawrence Berkley National Laboratory.

10 Conclusions

I would like to thank the Committee Members for letting me appear before you to provide this testimony. 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 has been conducted by university professors, consultants and government medical agencies in many different countries, on a variety of models of turbines that have been in communities for numerous years.

Based on scientific principles, our experience in Kansas, and the collective findings of over 80 scientific articles, the measures proposed in Bill 353 are in no way aligned with setting reasonable, health-based requirements for the proper siting of wind projects. They do not afford any greater protection of public health than those already set in place by Kansas counties.

Attachment A

Brief Overview of Potential Health Concerns Living Around Wind Turbines
Dr. C.A. Ollson, Ph.D.
Ollson Environmental Health Management

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 Kansas 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 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.

This letter serves to provide background on issues that are commonly raised and need to be addressed to protect public health and safety. This attachment provides information on:

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

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. 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.

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 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.*

This research will be discussed as appropriate throughout this report.

A. Audible Sound (Noise)

A.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. It should also be noted that wind turbine noise modeling in the United States is more conservative than that in the Health Canada study. Therefore, the 46 dBA modeled in the Health Canada study is more equivalent to 48-49 dBA that would be modeled for a turbine project in Kansas.

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, 4 dBA greater than typical Kansas 50 dBA sound design goals.

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. It is acknowledged that the authors did suggest that further in home studies are needed to provide "conclusive evidence". This additional research is currently underway in Australia.

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, setting a sound level of between 45 dBA to 50 dBA should not affect the sleep of those living in proximity to wind turbines.

B. 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.

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, the proper design of wind projects will ensure that wind turbines would not impact the health of neighbouring residents.

C. 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 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.

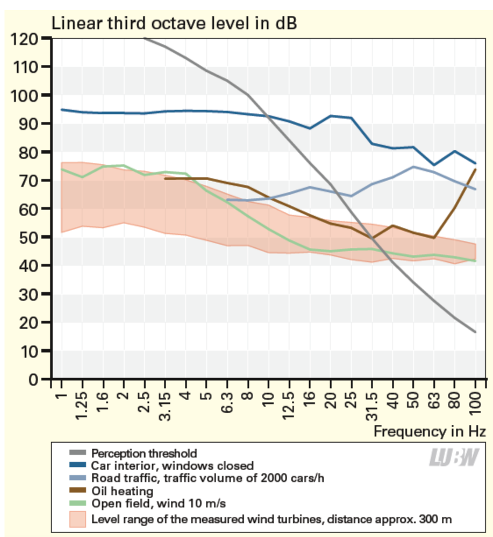

Figure 1. Measurements of infrasound and low frequency noise 300 m from wind turbines compared to other sources. [from MECE, 2016].

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, allowing an audible sound level at 50 dBA at residences will ensure that infrasound and low frequency noise also do not pose a health threat.

D. 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.

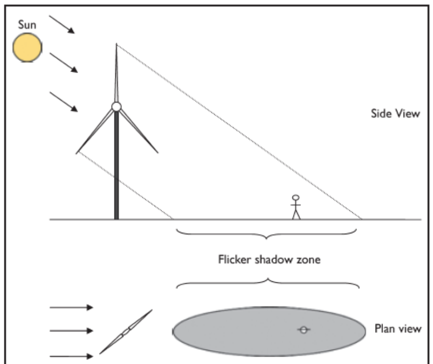

Figure 1.
Generalized geometry for turbine flicker, showing an observer in the shadow area. Note the main analysis assumes the observer and turbine blades are directly facing each other.
Epilepsia © ILAE

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 has only been one study 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."*

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.

Eliminating shadow flicker at non-participating homes does not afford any additional protection for health. Therefore, OEHM suggests that a no more than 30 hours of shadow flicker a year at non-participating residences could be adopted. To put this in perspective it represents less than 0.5% of the daylight hours a year.

E. Physical Health and Safety

Wind projects are developed to ensure protection of public health and safety. The following describes the suitability of wind project design 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.

E.1 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 a hypothetic 2.0 MW turbine with the same hub height (80 m) as common modern wind turbines. They examined meteorological conditions in Ontario, Canada, which are similar to winter environment in Kansas. Three scenarios were examined – Scenario A House, Scenario B Road and Scenario C Individual. The setback distances they used were consistent or less than those commonly found in Kansas. 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

The results indicate an extremely low probability that an individual or vehicle would ever be struck. Therefore, the common setback distances of 1,500 feet to nonparticipating homes and 1.1 times the turbine height to roadways are more than sufficient to protect public health and safety from risk of ice throw.

E.2. Blade Failure

With respect to turbine failure, the Garrad Hassan report (2007) determined that the risk of a failure of a piece of a Fblade is 1 in 4,000 turbines per year and that the risk of a full blade failure is 1 in 2,400 turbines a year. They also reported that maximum distance for an entire blade to travel was 150 m (500 feet) and for a blade fragment 500 m (1640 feet).

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. They studied a 2.3 MW wind turbine with a hub height of 80 m, similar to that of modern wind turbines. 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 lightening.

Given the very low probability of risk of fatality or injury from blade failure a 1.1 times tip height to nonparticipating property lines would ensure the protection of public safety.

F. Electromagnetic Fields (EMF) from Wind Turbines and Associated Transmission Line

As with any electrical generation project there maybe interest in the high voltage transmission line that will carry the power from the Project to the energy grid. Electricity produced by each wind turbine will be transmitted by a system of underground collection lines of typically 34.5 kV and brought to the Project substation. At this point electricity will be stepped up to a high voltage line.

Use of electricity in our everyday lives creates electric and magnetic fields (“EMF”). Power lines and utility facilities are not the only sources of EMF. We are exposed to EMF from many sources at many different levels and durations throughout our daily environments. These sources include the appliances we use, the wiring in our homes, the power lines and utility facilities that bring electricity to us, and the electrical equipment and devices we use at work.

There have been thousands of scientific studies related to EMF. In 1992, one of the largest EMF research and evaluation programs ($45 million) was established by the U.S. Congress and completed by the U.S. National Institute of Environmental Health Sciences (NIEHS) in 1999.

After this extensive research and evaluation program, the NIEHS reported to the U.S. Congress that scientific evidence for an EMF-cancer link is weak. From their 2002 report:

> *No regulatory action was recommended or taken based on the NIEHS report. The NIEHS director, Dr. Kenneth Olden, told the Congress that, in his opinion, the conclusion of the NIEHS report was not sufficient to warrant aggressive regulatory action.*

Since 1977 expert scientific panels, public health organizations, and governmental bodies have completed over 170 reviews of the science. Some of the most prestigious U.S. and international scientific and government organizations have evaluated the EMF research, including the:

- U.S. National Institute of Environmental Health Sciences (a National Institutes of Health)

- US National Cancer Institute (NCI)
- U.S. National Academy of Sciences
- Health Canada
- World Health Organization

None of these organizations has found that exposure to power frequency EMF causes or contributes to cancer or any other disease or illness. Their reviews generally conclude that while some epidemiology studies report a weak association with childhood leukemia, controlled laboratory studies do not support that association and the scientific studies overall have not demonstrated that EMF causes or contributes to any type of cancer or other disease. The NCI has found that "*researchers conclude that there is little evidence that exposure to extremely low frequency (ELF)-EMFs from power lines causes leukemia, brain tumors or other cancers in children.*"

However, expert professional organizations, including the International Commission on Non-Ionizing Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE) International Committee on Electromagnetic Safety on Non-Ionizing Radiation (IEEE/ICES), have developed voluntary guidelines for public exposures to power frequency (60 Hz) electric and magnetic fields because short-term exposure to EMF at very high levels (not seen in the typical public environment), can cause central nervous system and muscle stimulation. The guidelines established are as follows:

ICNIRP	2,000 mG
IEEE/ICES	9,040 mG

These exposure guidelines have been endorsed by the World Health Organization and identify levels of power frequency electric and magnetic fields that the expert organizations consider safe for public exposures based on their reviews of the scientific research.

To put the 2010 ICNRP guideline into context, the average magnetic field in homes in the USA ranges between 0.5 to 4 mG (WHO 2007b), and the average measured value directly under a 230kV power transmission line is roughly 60 mG (NIEHS 2002). So even directly beneath a typical high voltage 230 kV transmission line the fields are many times lower than the ICNRP and IEEE guidelines. It is also relevant to note that fields quickly degrade to background levels in short distances from the line (Figure 2). At a distance of 200 feet from the transmission line the EMF levels would be within the background levels of a typical American home.

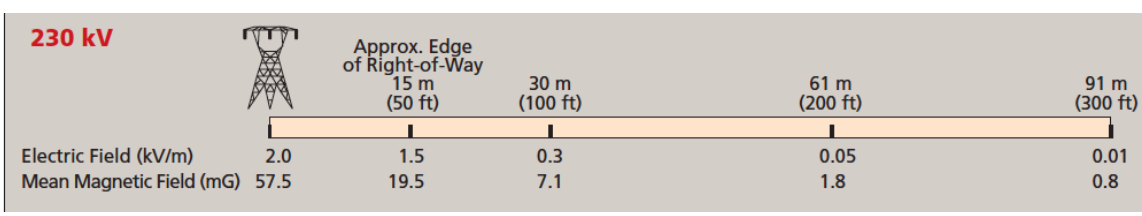

Figure 2. Magnetic field strength beneath a 230 kV line (National Institute of Environmental Health Sciences, 2002).

To put these levels of EMF in perspective, the following table from the NIEHS (2002), provides levels of EMF in mG around common household appliances.

In addition, Dr. Ollson conducted a peer-reviewed published study specific to EMF concerns surrounding wind power projects and associated transmission lines titled *Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?* (McCallum et al., 2014). It measured the magnetic flux density around 15 Vestas 1.8 MW wind turbines, two substations and various collector (34.5 kV) and overhead (500 kV) transmission lines. This study found that magnetic field levels detected at the base of the turbines under various operational scenarios were low (mean = 0.9 mG) and rapidly diminished with distance, becoming indistinguishable from background within 2 m of the base. Magnetic fields measured 1 m above buried collector lines were also within background (≤ 0.3 mG). Beneath overhead 27.5 kV and 500 kV transmission lines, magnetic field levels of up to 16.5 and 46 mG, respectively, were recorded. These levels also diminished rapidly with distance.

None of these sources appeared to influence magnetic field levels at nearby homes located as close as just over 500 m (1,640 feet) from turbines, where measurements immediately outside of the homes were ≤ 0.4 mG. The results suggest that there is nothing unique to wind farms and their associated transmission lines with respect to EMF exposure; in fact, magnetic field levels in the vicinity of wind turbines were lower than those produced by many common household electrical devices and were well below any existing regulatory guidelines with respect to human health (McCallum et al., 2014).

Sources of Magnetic Fields (mG)*

	Distance from source			
	6"	1'	2'	4'
Kitchen Sources				
BLENDERS				
Lowest	30	5	–	–
Median	70	10	2	–
Highest	100	20	3	–
CAN OPENERS				
Lowest	500	40	3	–
Median	600	150	20	2
Highest	1500	300	30	4
COFFEE MAKERS				
Lowest	4	–	–	–
Median	7	–	–	–
Highest	10	1	–	–
DISHWASHERS				
Lowest	10	6	2	–
Median	20	10	4	–
Highest	100	30	7	1
FOOD PROCESSORS				
Lowest	20	5	–	–
Median	30	6	2	–
Highest	130	20	3	–
GARBAGE DISPOSALS				
Lowest	60	8	1	–
Median	80	10	2	–
Highest	100	20	3	–
MICROWAVE OVENS***				
Lowest	100	1	1	–
Median	200	4	10	2
Highest	300	200	30	20
MIXERS				
Lowest	30	5	–	–
Median	100	10	1	–
Highest	600	100	10	–
Kitchen Sources				
ELECTRIC OVENS				
Lowest	4	1	–	–
Median	9	4	–	–
Highest	20	5	1	–
ELECTRIC RANGES				
Lowest	20	–	–	–
Median	30	8	2	–
Highest	200	30	9	6
REFRIGERATORS				
Lowest	–	–	–	–
Median	2	2	1	–
Highest	40	20	10	10
TOASTERS				
Lowest	5	–	–	–
Median	10	3	–	–
Highest	20	7	–	–
Bedroom Sources				
DIGITAL CLOCK****				
Lowest		–	–	–
Median		1	–	–
High		8	2	1
ANALOG CLOCKS (conventional clockface)****				
Lowest		1	–	–
Median		15	2	–
Highest		30	5	3
BABY MONITOR (unit nearest child)				
Lowest	4	–	–	–
Median	6	1	–	–
Highest	15	2	–	–

G. Wind Energy Project Annoyance

Perhaps the most contentious issue involving living in proximity to wind turbines and potential effect on human health revolves around the concept of annoyance. The term annoyance has been used for decades in the research of sound sources. This is in no way a new or novel term being used to measure those living in proximity to wind turbines and their feelings towards the noise they generate.

What can be seen from these peer-reviewed articles (and many others) is that the relationship between wind turbines and human responses to them (as measured by annoyance) is extremely complex and influenced by numerous variables. Key points that have come out of these studies are:

- Annoyance is not a medical condition. It is not a recognized medical disease and it is not classified in the World Health Organization's International Statistical Classification of Disease and Related Health Problems 11th revision (ICD 11).
- People tend to notice sound from wind turbines almost linearly with increasing sound pressure level (in other words, the louder the wind turbine at ground level the more people notice them).
- A proportion of people that notice sound from wind turbines self-report finding it annoying. Approximately 10% of people with sound levels between 35 dBA and 40 dBA report high annoyance levels with the wind project.
- There is at best only a weak association between wind turbine sound at the exterior of people's homes and the reported level of annoyance. The results of European, Canadian and U.S. studies suggest that only 9-13% of the annoyance can be correlated to the sound level itself.
- Annoyance level outcomes from the Health Canada study are equally applicable to distance to nearest wind turbine. In other words, only 9% of the self-reported annoyance would be correlated with distance to closest wind turbine to a home.
- Self-reported annoyance is much more strongly related to the subjective factors of attitude of the visual impact of turbines on the landscape and fairness in the siting process.
- People who economically benefit from wind turbines often experience higher sound levels outside their homes than non-participants and have significantly decreased levels of annoyance (virtually non-existent) compared to individuals that received no economic benefit.
- The level of annoyance is not correlated to stress mediated health outcomes. Based on the results of the LBNL study U.S. wind turbine annoyance and related stress effects are not a widespread problem.
- Wind turbine sound levels or distance to the exterior of homes does not impact quality of life outcomes.

The weight of scientific evidence suggests that there will be a non-trivial level of annoyance in local populations living in proximity to wind turbines. Given the scientific evidence, one could not set a sound level from wind turbines that would completely eliminate annoyance from living in proximity to wind turbines. This is because only a fraction of reported annoyance is associated with sound and many other factors (visual cue and pre-existing attitudes) that could not be completely mitigated would still result in annoyance in the surrounding population.

The question then becomes:

> "Should one set a sound standard or setback distance to wind turbines based on annoyance alone, regardless of the cause of the annoyance?"

It is true that as a society we often regulate objectionable behaviors based on what society deems to be acceptable/tolerable, even if such actions do not result in direct health effects. However, often noise standards/regulations are imposed that weigh the health and economic benefits of the source of emission against this risk of annoying a percentage of the population.

This is certainly true of aircraft noise where *"The costs of aircraft noise regulation, on the other hand, are seen as great enough, and to affect enough people, that they outweigh the costs of merely annoying a relatively small number of people (Fidell and Mastre, 2020).*"

Similar concepts can be applied to how other sources of energy production are regulated. For example, the siting of fossil fuel electrical generation (e.g., coal plants, gas turbine plants, pipelines and energy-from-waste facilities (EFW)) can be considerably objectionable to a percentage of the population (similar concept to annoyance to wind turbines). Siting of new projects often draws strong opposition in local communities that believe that their health would be directly impacted by airborne contaminants. However, siting guidelines and air quality standards used to control such facilities are not based on the level of opposition to such projects. The health-based air quality standards are derived on science and are independent of such objections or fears. Then decision makers must decide whether the overall socio-economic need outweighs the objection some members of the community.

OEHM believes that wind turbine annoyance is now a well-understood phenomenon. There have been almost twenty years of international research that time and again result in similar findings. That is, the annoyance to living in proximity to wind turbines is most strongly linked to one's attitude of how the wind turbines impact the landscape and perceived fairness in the permitting process. Although this needs to be acknowledged, setting any annoyance target level for sound does not take into account potential health impacts, nor does it consider the potential health and economic benefits that electricity generated by wind power may provide.

References

Australian Government NHMRC (National Health and Medical Research Council). *Wind turbines and health: a rapid review of the evidence*. Canberra, ACT: Commonwealth of Australia (2010) p. 1-11.

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).

Chief Medical Officer of Health, Ontario. The potential health impact of wind turbines. Chief Medical Officer of Health (CMOH) report. Toronto, ON: Queen's Printer for Ontario (2010).

Epilepsy Society of United Kingdom. 2012. https://www.epilepsysociety.org.uk/wind-turbines-and-photosensitive-epilepsy#.WCCsnBSSom4

Garrad Hassan Canada. 2007. Recommendations for Risk Assessment of Ice Throw and Blade Failure in Ontario. Prepared for Candian Wind Energy Association.

Grimwood CJ, Skinner GJ, Raw GJ, BRE, Watford, WD25 9XX. *The UK national noise attitude survey 1999/2000*. Noise Forum Conference, London, England (2002).

Harding G, Harding P, Wilkins A. Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. *Epilepsia* (2008) **49**:1095-8.

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.

Kaperman and James. 2008. The "How To" Guide to Siting Wind Turbines to Prevent Health Risks from Sound

Keith SE, Feder K, Voicescu SA, Soukhovtsev V, Denning A, Tsang J, Broner N, Richarz W, van den Berg F. 2016. Wind turbine sound power measurements. J. Acoust. Soc. Am. 139 (3), 1431-1435

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.

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

MassDEP and MDPH. *Wind Turbine Health Impact Study: Report on Independent Expert Panel*. Massachusetts Department of Environmental Protection and Department of Public Health (2012). Available online at: http://www.mass.gov/dep/energy/wind/turbine_impact_study.pdf.

Merlin T, Newton S, Ellery B, Milverton J, Farah C. 2014. *Systematic review of the human health effects of wind farms*. National Health and Medical Research Council, Canberra, Australia.

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.

MMI Engineering Ltd, 2013. Study and development of a methodology for the estimation of the risk and harm to persons from wind turbines. Prepared by for the Health and Safety Executive of the Government of the United Kingdom

National Research Council. 2007. Environmental Impacts of Wind Energy Projects

National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health (NIH). 2002. EMF-Electric and Magnetic Fields Associated with the Use of Electric Power. Questions & Answers.

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.

Pedersen E. 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.

Pierpont. 2009. Wind Turbine Syndrome: A Report on a Natural Experiment

Smedley ARD, Webb AR, Wilkins AJ. Potential of wind turbines to elicit seizures under various meteorological conditions. *Epilepsia* (2010) **51**:1146-51.

UK DECC (Department of Energy and Climate Change). *Update of UK shadow flicker evidence base: final report*. Department of Energy and Climate Change, London, United Kingdom: (2011).

Voicescu SA, Michaud DS, Feder K, Marro L, Than J, Guay M, Denning A, Bower T, van den Berg F, Broner N, Lavigne E.n 2016. Estimating annoyance to calculated wind turbine shadow flicker is improved when variables associated with wind turbine noise exposure are considered. J Acoust Soc Am. 2016 Mar;139(3):1480. doi: 10.1121/1.4942403.

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).

World Health Organization (WHO). 2007a. Electromagnetic fields and public health, Exposure to extremely low frequency fields. Fact sheet N°322

World Health Organization (WHO). 2007b. Environmental Health Criteria 238. Extremely Low Frequency Fields. ISBN 978 92 4 157238 5