Review of the Application for Special Use Permit for Utility Scale Wind System Updated Overland Pass Energy East Wind Project with Respect to Public Health and Safety

Prepared for:

Sedgwick County Commissioners

Original Submitted August 3, 2023

Updated September 9, 2024

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Environmental Health Management

Executive Summary

National Renewable Solutions (NRS) has retained Dr. Christopher Ollson, Ph.D., of Ollson Environmental Health Management (OEHM) to review the Overland Pass Energy (OPE) East Wind Project SUP application to evaluate its adequacy to protect the public health and safety of county 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 in his curriculum vitae (Appendix A). This report was first prepared by Dr. Ollson on August 3, 2023. The project was approved by Sedgwick County in August, 2023 (Resolution 2023-027).

However, in May 2024 OPE submitted an Updated Application to Sedgwick County that, if approved, is intended to supersede the 2023 permit. The reason for the updated permit was as result of:

- Increasing the Project acreage and Project size
- Providing the County with more transparency related to the maximum number of wind turbines requested
- Providing the County with more defined Project plans

Previously, the Overland Pass Energy East Wind Project was a 750 MW project to be built in two phases in Sedgwick County, Colorado. It was to have included include up to 167 primary turbine locations with 15 alternates. The Updated OPE has been increased to an approximately 1275 MW wind project, with up to 310 wind turbines. The model of turbine contemplated is the same as the original Application, namely, a Vestas V163 4.5MW wind turbine was selected with a hub height of 341 ft (104m), blade length of 267.5 ft (81.5 m) and total height of the wind turbine to the tip at the 12 o'clock position of 608.6 ft (185.5 m).

There is no question that wind turbine siting taking into account sound and distance setback to homes is a complicated undertaking. Dr. Ollson has reviewed the "*Sedgwick County 13-105: Utility Wind and Solar Requirements and Standards*". Overall, it was found that adherence to the Sedgwick County wind ordinance will ensure the protection of public health and safety of the local residents. This includes adherence to the *Colorado Noise Statute 25-12-103 Maximum Permissible Noise Levels* of 50 dBA Leq at the exterior of homes.

OEHM understands that Overland Pass Energy East in updated SUP Application Section 4: Request for Reduction of Setback is requesting the county approve the same setbacks that were approved the in 2023 Permit.. This is consistent with *Sedgwick County 13-105: Utility Wind and Solar Requirements and Standards Section C(3)(d)(2): The public health, safety, welfare, and the environment will not be harmed by the proposed waiver or reduction of setback.* NRS has provided a number of economic and siting constraints for the project that necessitate a reduction of setbacks to make the project viable. Section 4 of this report provides the rationale to ensure that the requested reduction of setbacks will ensure the health, safety and welfare of Sedgwick County residents will not be compromised.

It is the opinion of OEHM that the Updated Overland Pass Energy East project is properly designed in accordance to best practices for setback distances from roads, infrastructure, property lines and roads. The setback that were approved by Sedgwick County Board of County Commissioners in the 2023 Permit, which OPE is requesting approval for in this application are reasonable, often greater than required in other state and industry standards, and will still ensure the protection of Sedgwick County residents. Therefore, OEHM believes that it would be appropriate for the Sedgwick County Commissioners to again grant the currently approved setbacks in the Updated SUP Application.

Section 5 of the report provides a review of the scientific literature on living in proximity to wind turbines and potential health impacts. Over the past decade there has been considerable research conducted around the world on the potential for wind turbines to adversely impact health. 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 the community for a number of years. Based on scientific principles, and the collective findings of over 100 scientific articles, OEHM believes that the Updated Overland Pass Energy East project is properly sited to ensure the protection of public, health and safety.

OEHM has reviewed the Updated Overland Pass Energy East SUP application, the project layout, and sound requirements and believes that the project is designed in a manner that will protect the public health and safety of the Sedgwick County residents. OEHM believes that the Updated Overland Pass Energy East Project should be approved by the County for construction and operation.

OLLSON
Environmental Health Management

Table of Contents

List of Tables

Appendices

1 Introduction and Qualifications

National Renewable Solutions (NRS) has retained Dr. Christopher Ollson, Ph.D., of Ollson Environmental Health Management (OEHM) to review the Overland Pass Energy (OPE) East Wind Project SUP application to evaluate its adequacy to protect the public health and safety of county 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 in his curriculum vitae (Appendix A). This report was first prepared by Dr. Ollson on August 3, 2023. The project was approved by Sedgwick County in August, 2023 (Resolution 2023-027).

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Over the past twenty 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, including the United States, on a variety of models of turbines that have been in communities for numerous years. There are now over 100 scientific articles that allow us to understand the proper siting of wind turbines. The three main areas covered in this report deal with sound (audible, low frequency noise and infrasound), general health concerns and setback distances for public safety.

Although there have been a handful of additional wind project research articles in the past year, none of them materially change the outcome of the previously submitted 2023 report. Therefore, only minor updates have been made to this report.

1.1 Qualifications

I am the owner and a Senior Environmental Health Scientist at Ollson Environmental Health Management (OEHM). A copy of my current *curriculum vitae* is provided in **Appendix A**.

My 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.

My area of expertise is in the field of environmental health science. I am trained, schooled and practiced in the evaluation of potential risks to, and health effects on, people and ecological receptors associated with environmental health issues.

For fifteen years I have been engaged by a number of private companies, regulatory authorities and government agencies 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. I have published six peer-reviewed scientific articles in the field and my research has been presented at numerous international scientific conferences. I have also continued to follow the research on terrestrial wildlife and livestock and potential concerns with siting of wind turbines on agricultural lands.

I have been qualified to provide expert opinion evidence on wind turbines and potential health effects at a number of North American hearings, tribunals and legal cases. In a number of those cases I was also qualified to provide expert opinion evidence on wind turbines and potential effects on mammalian wildlife and livestock.

From 2014 to 2017, I provided expert advice on wind turbines, health and proper siting requirements for the Vermont Public Services Department. I have also appeared before the Indiana State Senate Energy Committee Meeting on Wind Turbine Siting (2017), the North Dakota State Senate Energy and Natural Resources Committee, Senate Bill 2313 (2017) and the Kansas State Senate Committee on Utilities, Senate Bill No. 353 (2022).

Between 2020 and 2022 I was a member of the American Clean Power (ACP) Expert Working Group contributing to the development of the American National Standards Institute (ANSI)/ACP 111-1 Sound Modelling Standard for wind turbine sound that was published in April 2022. In 2021, I was appointed as an expert to the International Electrotechnical Commission (IEC) Technical Specifications committee developing the IEC 61400-31 Wind Turbines Siting Risk Assessment standard. In addition to my consulting practice, I hold an appointment of Adjunct Professor and teach in the School of the Environment at the University of Toronto.

2 Understanding of the Sedgwick County, Colorado Comprehensive Plan and Zoning Ordinance Wind and Solar Amendment, Effective January 1, 2022

As with any energy facility, it is important that proper setbacks and sound regulations are in place for wind turbines to ensure public health and safety. Dr. Ollson has reviewed the "*Sedgwick County 13-105: Utility Wind and Solar Requirements and Standards*". Overall, it was found that adherence to the Sedgwick County wind ordinance will ensure the protection of public health and safety of the local residents.

Key components of the ordinance and Colorado state statutes that will ensure public health and safety include:

- Section C(3)(b) Safety Setback: This section includes a number of setbacks to infrastructure, roads, property lines, participating and non-participating homes. These setback distances include a 2 times (x) multiplier of the turbine height and/or a minimum distance. All setbacks will ensure the protection of public safety in the unlikely event of a turbine collapse, blade throw, ice throw or fire. However, some of these setbacks are greater than those in other states and industry best practice.
    - I note that Overland Pass Energy East has requested a setback waiver to a number of these setback requirements. However, after review of the project layout I believe

that the requested waiver setback distances will still ensure projection of public health and safety of County residents. This is further discussed in Section 3.

- OPE has agreed to increase the County residential setback from 2x the system height or 2,000’n to the property line, whichever is greater, to 2x the system height or 2,500’ to the property line located outside the property boundary. This setback is far greater than in most other jurisdictions. It will result in low sound levels across properties and less shadow flicker.
- Sound standard is governed by *Colorado Noise Statute 25-12-103 Maximum Permissible Noise Levels*. This requires that sound levels not exceed 50 dBA Leq at residential homes between the hours of 7 pm to 7 am. This sound level is consistent with many county regulations across the Midwest. Given the setback distances to property lines it is anticipated that modeled and actual sound levels will be far below this standard.

From my review of the updated Overland Pass Energy East SUP Application, I believe that the project is properly designed and will ensure the protection of public health and safety of County residents.

3 The Appropriateness of Overland Pass Energy East’s Setbacks

There is no question that wind turbine siting taking into account distance setback to homes, roads, and other infrastructure is a complicated undertaking. As with any energy production project one needs to balance community concerns with the need for the renewable energy and economic benefits, while always ensuring the protection of public safety of the local population.

OEHM understands that Overland Pass Energy East in SUP Application Section 4: Request for Reduction of Setback is requesting the county approve the same setbacks that were approved the in 2023 Permit.. This is consistent with *Sedgwick County 13-105: Utility Wind and Solar Requirements and Standards Section C(3)(d)(2): The public health, safety, welfare, and the environment will not be harmed by the proposed waiver or reduction of setback.* OEHM understands that NRS has provided a number of economic and siting constraints for the project that necessitate a reduction of setbacks to make the project viable. This section provides the rationale to ensure that the requested reduction of setbacks will ensure the health, safety and welfare of Sedgwick County residents will not be compromised.

Table 1 provides the Sedgwick County ordinance requirements, the requested setback reduction request, safety considerations and a list of State-level setback requirements in other jurisdictions that are used to protect public health and safety. As can be seen that many of these jurisdictions have lessor setback distances that are consistent with those being requested by Overland Pass Energy East.

Setback distances for wind turbines must ensure the protection of public health from failure or emergency issues that include wind turbine collapse, blade failure/throw, and ice throw. These events are extremely rare, although they do occur. The following are the type of failures that can occur:

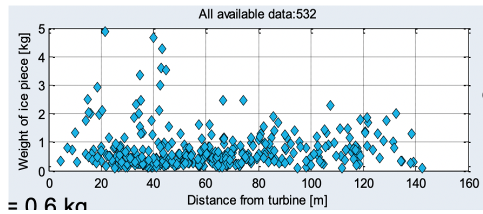
<u>*Tower collapse*</u>

Tower collapse is a rare circumstance where a tower may collapse due to unstable ground, a violent storm, structural fatigue or another catastrophic event. Towers collapse within the total height of the turbine height and typically even a shorter distance. Therefore, use of a 110% (1.1x) tip height setback distance to neighboring property lines, roads and infrastructure will not only ensure protection of public safety, but will also ensure that the tower collapses on the participating property that host the turbine.

Ice Throw

When a turbine is in operation and if the ice detaches from the moving blades, it can be projected away from the turbine. Wind direction, wind speed, rotational speed as well as position and size of the ice fragments on the blade will influence the landing position of the projected ice pieces.

A number of studies have been conducted around the world about the distance and potential risk of ice throw impacting people. A field study conducted in Sweden collected actual ice throw fragements in the field around wind projects (Lunden, J., "ICETHROWER Mapping and Tool For Risk Analysis," Winterwind, Skelleftea, 7 February 2017). The total height of the wind turbine was 145 m in this field study and all ice pieces were recovered within that height from around the wind turbines.



Persimia is the leading ice throw modeling group in North America. In their *Ice Throw Modeling Software Validation Report* they report that 98% of ice fragments thrown from a turbine will be within 1.1x total height of a wind turbine (Persimia, 2019).

Therefore, the use of a 1.1x tip height setback of a wind turbine to roads, infrastructure and neighboring property lines is appropriate to ensure that ice throw will be confined to the participating property and would not pose a risk to public safety.

Blade Failure

During operation, there is the remote possibility of turbine blade failure due to fatigue, severe weather (e.g., lightening), or other events not related to the turbine itself. If one of these events should occur, pieces of the blade may be thrown from the turbine. The pieces may or may not break up in flight, and are expected to behave similarly to ice thrown from the blade.

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.

Therefore, the use of a 1.1x tip height setback of a wind turbine to roads, infrastructure and neighboring property lines is appropriate to ensure that blade throw will be confined to the participating property and would not pose a risk to public safety.

Table 1 Safety Setback Reduction Request and Public Safety Justification

Feature	Sedgwick County Requirement	Reduction of Setback Request by Overland Pass	Public Safety Consideration	Other State Requirements
Setback of Wind Turbine from above-ground public electric power lines or communication lines1	2 times system height	1.5 times system height	Tower Collapse	NY – 1.5x WI – 1.1x IL – 1.1x
Setback of Wind Turbine from public road or highway or railroad	2 times system height	1.5 times system height	Tower collapse, blade failure, ice throw	NY – 1.1x WI – 1.1x IL – 1.1x
Setback of Wind Turbine from public road or highway with ADT of 7,000 or more	2 times system height or 420 feet, whichever is greater	2 times system height or 420 feet, whichever is greater	Tower collapse, blade failure, ice throw	NY – 1.1x WI – 1.1x IL – 1.1x
Setback of Wind Turbine from an inhabited structure located on-site, including residence, school, hospital, church or public library.	2 times system height, or 1000 feet, whichever is greater	2 times system height, or 1500 feet, whichever is greater	Tower collapse, blade failure, ice throw	NY – none WI – 1.1x ND – 1.1x IL – 1.1x
Setback of Wind Turbine from an inhabited structure located outside the site boundary, including residence, school, hospital, church or public library.	2 times the system height or 2000 feet from the property line, whichever is greater	No change requested	Tower collapse, blade failure, ice throw	NY – 2x WI - The lesser of 1,250 feet or 3.1 times the maximum blade tip height ND – 3x (lesser with variance) IL – 2.1x
Setback from all other property lines, unless appropriate easements are secured from adjacent property owners or other acceptable mitigation is approved by the Board	2 times system height or 1000 feet, whichever is greater.	1.5 times system height or 1000 feet, whichever is greater.	Tower collapse, blade failure, ice throw	NY – 1.1x WI – 1.1x IL – 1.1x
OPE's agreement to increase the County residential setback from 2x the system height or 2,000', whichever is greater, to 2x the system height or 2,500' is an adequate compromise for the County's findings that OPE's request for reductions meet the County's criteria for approving the same.	2x the system height or 2,000', whichever is greater	Note this is a greater setback - 2x the system height or 2,500'	This is a greater setback than required to ensure protection of public health and safety	

1. For a V163 total height 608.6 ft – 2x system height 1,217.2 ft; 1.5x system height 912.9 ft.; 1.1x system height 669.5 ft
2. State Legislation: New York (NY): Charter XVIII Title 19 of NYCRR Part 900 (Subparts 900-1 – 900-15).; Wisconsin (WI): Wisconsin Administrative Code PSC 128.01; North Dakota (ND):N.D. Century Code 49-22-01 et seq; Illinois (IL): Public Act 102

Overland Pass Energy East has modelled a Vestas V163 wind turbine. Although Vestas does not have a published safety setback distance for their turbines, in OEHM's experience there are numerous similar Vestas turbines across the country sited to the setbacks being requested.

GE is one of North America's most prolific wind turbine manufacturers. They have published *Setback Considerations for Wind Turbine Siting (2018).* Table 1 of the report (reproduced to the right) that provides the minimum setbacks to homes, buildings, roads, and electrical infrastructure for all turbine sites to infrastructure. The GE setback recommendations of 1.1x total height of the turbine to various features is based on the science of risk of ice throw, blade failure and tower collapse that is provided above (complete report provided in Appendix B).

Setback Distance from center of turbine tower	Objects of concern within the setback distance

All turbine sites (blade failure/ice throw):
1.1 x tip height[1], with a minimum setback distance of 170 meters
	- Public use areas
	- Residences
	- Office buildings
	- Public buildings
	- Parking lots
	- Public roads
	  - Moderately or heavily traveled roads if icing is likely
	  - Heavily traveled multi-lane freeways and motorways if icing is not likely
	- Passenger railroads

All turbine sites (tower collapse): 1.1 x tip height[1]	- Public use areas - Residences - Office buildings - Public buildings - Parking lots - Heavily traveled multi-lane freeways and motorways - Sensitive above ground services[2]
All turbine sites (rotor sweep/falling objects): 1.1 x blade length[3]	- Property not owned by wind farm participants[4] - Buildings - Non-building structures - Public and private roads - Railroads - Sensitive above ground services

Colorado does not have state-level overarching wind turbine setback requirements. However, there are a number of States across the country that do legislate setback distances to various features. These are provided in Table 1. Such states include New York, Wisconsin, North Dakota and Illinois. As can be seen, the typical setback distance requirement for wind turbines to electrical infrastructure, roads, and non-participating property lines are 1.1x total turbine height. These setback distances are based on the science and engineering studies that are provided above to ensure the protection of public health.

It is understood that the Sedgwick County ordinance requirement is 2x turbine height for these features. Overland Pass Energy East is requesting a setback waiver to one that middles these distances, to 1.5x times turbine height. OEHM believes that it would be reasonable, and science based, for Sedgwick County to grant this waiver under the SUP Application. This 1.5x turbine height setback distance to these features will ensure the protection of public health and safety.

With respect to participating homes most States require a minimum setback distance of 1.1x tip height to homes. However, OEHM believes that this distance is too close to homes and in practice turbines are not sited this close. The Sedgwick County ordinance requires a minimum 2x total height, or 1000 ft, whichever is greater. For a Vestas V163 turbine with a total height of 608.6 ft this would be 1,217.2 ft to a participating home. In fact, Overland Pass Energy East is actually proposing a greater setback of 2x turbine height, or 1500 ft, whichever is greater. OEHM believes that this is actually a more appropriate setback distance to any home.

For non-participating homes state-level setback distances to non-participating homes vary but are typically 2x turbine height to the home. It is understood that the Sedgwick County ordinance requires a 2x times system height, or 2,000 ft from the property line, whichever is greater and that OPE has agreed to a 2x system height or 2,500 ft from the property line. OEHM understands that Overland Pass Energy East has not requested a waiver to this setback distance. OEHM believes that this is an appropriate setback distance to ensure the protection of public health and safety to the non-participating homes.

3.1 Conclusion on OPE's Request to approve the existing Setback Waiver Request

It is the opinion of OEHM that the Overland Pass Energy East project is properly designed in accordance to best practices for setback distances from roads, infrastructure, property lines and roads. The requested setback waivers requested by Overland Pass Energy East are reasonable, often greater than required in other state and industry standards, and will still ensure the protection of Sedgwick County residents. Therefore, OEHM believes that it would be appropriate for the Sedgwick County Commissioners to grant the requested setback waivers in the SUP Application.

4 Health Research Supporting the Proper Siting of 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 Colorado achieving high levels of wind power capacity.

Over the past 20 years there have been over 100 studies that 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.

In the past five years we have seen additional publications from Health Canada, in the United States by the Lawrence Berkely National Laboratory (LBNL), Australian academics with federal funding, and numerous other research groups around the world.

The scientific evidence continues to support the use of a nighttime noise limit of between 45 to 50 dBA at the exterior of homes as protective of sleep, general health and does not exacerbate pre-existing medical conditions. Publications on exposure of wind turbine low frequency noise and infrasound have demonstrated that although present, the levels are well below those that would impact health. Annoyance studies continue to indicate that although a small percentage of people will report being annoyed living around wind turbines, linked to their visual impact on the landscape and their feeling towards the project, it does not result in increased stress levels or cascading health impacts.

There have been numerous peer-reviewed scientific publications related to wind turbine sound measurements, potential health impacts and annoyance. In this section I have selectively included several of these articles that I believe are most pertinent to this proceeding based on my experience and expertise – this account is not exhaustive of the research conducted since 2002.

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.

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 Attachment as the "Michaud papers".

4.1 Sleep Studies

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.

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".*

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

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. 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.*

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.*

Michaud et al., 2021. Sleep actigraphy time-synchronized with wind turbine output. SLEEPJ, 2021, 1–12. (Health Canada)

In March of 2021, the Health Canada team published their findings on a re-evaluation of their original collection of sleep data for those living around wind turbines. They further refined the data evaluation of the sleep actigraphy data to 10-minute intervals and time synchronized it to wind turbine supervisory control and data acquisition. Overall, they concluded:

> *Maximum calculated nightly average wind turbine SPL reached 44.7 dBA (mean = 32.9, SD = 6.4) outdoors and 31.4 dBA (mean = 12.5, SD = 8.3) indoors. Wind turbine SPL in 10 min intervals, and nightly averages, was not statistically associated with actigraphy outcomes. However, the variability in wind turbine SPL due to changes in wind turbine operation across the sleep period time, as measured by the difference between the 10 min SPL and the nightly average SPL (ΔSPL), was statistically related to awakenings (p = 0.028) and motility (p = 0.015) rates. These diminutive differences translate to less than 1 min of additional awake and motility time for a 5 dBA increase over a 450 min sleep period time. Overall results showed that wind turbine SPL below 45 dBA was not associated with any consequential changes in actigraphy-measured sleep. Observations based on ΔSPL provided some indication that a more sensitive assessment of sleep may be one that considers variations in wind turbine SPL throughout the sleep period time.*

The findings of the recent Health Canada research on sleep and wind turbine noise are consistent with their previous findings and the meta-analysis of sleep outcomes provided by Liebich et al. (2020).

Liebich et al. 2022. The effect of wind turbine noise on polysomnographically measured and self-report sleep latency in wind turbine noise naïve participants. SLEEPJ. Vol 45. No. 1. pg 1-11.

The objective of the study was to assess the impact of wind turbine noise (WTN) on polysomographically measured and diary-determined self-reported sleep latency compared to a controlled background in a laboratory sleep chamber. There were 23 urban participants that were naïve (never heard before) to wind turbine sound. They were exposed to 33 dBA of interior bedroom previously recorded wind turbine sound. This mimics the expected sound level of a home that would have windows open and an exterior wind turbine sound level of 40 dBA or greater. They concluded:

> *"WTN effects on objective and subjective sleep latency were assessed via a two-night sleep study in a controlled sleep laboratory setting using polysomnography and sleep diary measures in a sample of health sleeps not typically exposed to WTN. No differences were found in objective or subjective sleep latency when WTN at 33 dB(A) was presented during the sleep onset period compared to control background noise at 23 dB(A). Furthermore, no differences were found in latency to N2 sleep, nor in the proportion of individuals who took >20 or >30 min to fall asleep in the presence versus absence of WTN."*

Liebich et al. 2022a. An experimental investigation on the impact of wind turbine noise on polysomnography-measured and sleep diary-determined sleep outcomes. SLEEPJ. Vol 45. No. 8. pg. 1-16.

In this study the authors expanded the group of participants to 68 that included residents living close to turbines that previously reported sleep disruption, residents who report traffic sleep disruption and two control grounds. The groups participated in a four-night laboratory sleep study in which control background noise was 19 dBA and interior bedroom previously recorded WTN of 25 dBA. This level of sound was to reproduce the expected sound levels inside an Australian home with windows open and a 40 dBA sound level at the exterior of the home.

> *Overall, these results do not support that acute WTN exposures approximating median WTN exposure levels around 3 km from a windfarm, measurably impact sleep assessed using conventional sleep scoring metrics, including in individuals with self-reported sleep difficulties attributed to WTN living at a similar distance. However, further studies remain warranted to test for effects of higher WTN exposure levels on traditional sleep macrostructure outcomes, subtle microstructural sleep parameters, and impacts on nextday mood, anxiety, and performance.*

*Ellenbogen, J.M.; Kellan, C.B.; Hankard, M. 2024. Noise-induced sleep disruption from wind turbines: scientific updates and acoustical standards SLEEP, 2024, **47**, 1–8*

Dr. Jeffrey Ellenbogen a renowned sleep physician expert who has been studying wind turbine sound and effects on sleep published this recent article with his acoustician collegues in 2024. The objective was to review the scientific research that has been conducted with those living in proximity to wind turbines and the effect of sound levels on sleep. Overall they concluded:

> *"Though the upper limit is not established, noise from wind turbines measured outside the residence, up to 46 dBA (or modeled up to 49 dBA using the new standard), poses no risk to human sleep. Not at this audible range, nor its associated infrasound or low-frequency noise levels. When there is controversy concerning whether wind turbine noise causes*

sleep disruption, this threshold can serve as a reasonable and evidence-based level, below which sleep disruption would not be expected. This value can be used to resolve specific conflicts by measurement of wind turbine noise at the residence in dispute. It can also be used to avoid future disputes when modeling proposed turbines with the ANSI/ACP standard of 2022."

Conclusion on Wind Turbine Noise and Sleep

No individual study can answer all of questions about wind turbine noise and sleep. These studies were well executed, used sound scientific methodological approaches, and provided full details of their potential limitations. Overall, both Australian sleep studies and the recent Health Canada study are aligned with the previous international findings on wind turbine noise and sleep. Dr. Ellenbogen's review of the literature also contains strong conclusions and recommendations. This suggests that the continued use of a 45 to 50 dBA sound limit is appropriate for ensuring the protection of sleep.

The recent published findings reveal that there is no association between exterior wind turbine sound levels and impact on sleep.

4.2 Case-control Study of Self-reported Health Effects

This section is focused on the literature investigating both self-reported and physical measures of health for those living around wind turbines.

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).

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.

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 132, 105090

In 2015, the U.S. Department of Energy (DOE) funded the Lawrence Berkely National Laboratory (LBNL) to conduct a 4-year investigation to collect attitude data on a nationally representative sample of individuals living near U.S. wind energy projects. The objective was to better understand how U.S. communities are reacting to living in proximity to wind turbines.

This research was an attempt to ascertain the significance of the reported annoyance on stress effects for those in the U.S. and compare the results to a set of European results from Germany and Switzerland. The researchers developed a novel Annoyance Stress-Scale (Scale) to characterize stress-impacted individuals living near wind turbines.

The U.S. sample included 1441 residents living within 8 km of 231 wind farms, across 24 states. Sound levels in the study ranged from <30 dBA to >50 dBA. From the abstract of the paper:

> "*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."*

This study continues to demonstrate that although some people report annoyance for living around wind turbines that is not a widespread problem and similar to annoyance levels reported with traffic noise.

Radun et al. 2022. Health effects of wind turbine noise and road traffic noise on people living near wind farms. Renewable and Sustainable Energy Reviews 157 (2022) 112040. Pg. 1-11.

The objective of this case-control study was to investigate the self-reported health effects of both wind farms and road traffic. Wind turbine sound levels ranged between 17 to 39 dBA, while daytime traffic noise levels were 32.5 to 63.5 dBA. A masked environmental survey was completed by 676 residents in Finland. The authors concluded:

> *"Increased wind turbine noise level was associated with an increased probability of noise annoyance, but no other associations with health effects were found. However, increased road traffic noise level was associated with an increased probability of various self-reported health effects, for example, heart disease and related symptoms, road traffic noise annoyance, and different stress related symptoms like, migraine, headache, and dizziness as well as ear related problems of impaired hearing and blocked ears or pressure in ears."*

> *"The findings of our study are expected to be applicable also to other wind turbine areas, where wind turbine sound level is under 40 dB among the whole population."*

> *"Our results suggest that when the level of wind turbine noise is under 40 dB L_{Aeq}, noise annoyance is the only health effect and the prevalence of annoyance is very low."*

These results are entirely consistent with those published by Dr. Michaud and his team at Health Canada in their WTN Noise Health Study and by research that has been conducted around the world over the past 20 years. Therefore, this research continues to support the use of the Colorado sound levels to protect health of local residents.

4.3 Systematic Literature Reviews and Editorials

Van Kamp, I & van den Berg, F. 2018. Health Effects Related to Wind Turbine Sound, Including Low-Frequency Sound and Infrasound Acoust Aust (2018) 46:31–57

Both authors work for public health agencies in the Netherlands and are highly regarded experts in wind turbine health research field. They conducted a systematic review of the published literature between 2009 to 2017 on health effects related to wind turbine sound, with particular emphasis on LFN and infrasound.

They concluded that there was no evidence of a specific health effect of the LFN or infrasound components of wind turbine sound. With respect to Dr. Alves-Pereira's work in relation to infrasound from turbines they found:

> *Vibroacoustic disease and the wind turbine syndrome are controversial and scientifically not supported. At the present levels of wind turbine sound, the alleged occurrence of vibroacoustic disease (VAD) or the disease (VVVD) causing the wind turbine syndrome (WTS) is unproven and unlikely.*

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

The authors conducted a comprehensive systematic review of the potential health effects in 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."*

Van Kamp, I & van den Berg, F. 2021. Health Effects Related to Wind Turbine Sound: An Update. Int. J. Environ. Res. Public Health 2021, 18, 9133

The authors conducted an updated systematic review of the published literature between 2017 to 2020 on health effects related to wind turbine sound. Their conclusions were consistent with their previous literature review (van Kamp & van den Berg, 2018). They reaffirmed:

> *There is no indication that the low-frequency component has other effects on residents other than normal sound nor that infrasound well below the hearing threshold can have any effect.*

Ellenbogen, J. 2022 Wind turbine noise and sleep. Editorial. SLEEP. 2022 1-3

Dr. Ellenbogen, MD is a highly regarded neurologist and sleep specialist whose focus is on noise-induced sleep disruption. He has been researching the potential for wind turbine noise to impact sleep since he was the lead author on the *Wind Turbine Health Impact Study: Report of Independent Expert Panel* report, prepared for the Massachusetts Department of Health (Ellenbogen et al., 2012). In this editorial he opines that:

> *Between Health Canada and this paper by Liebich et al., it appears that the reasonable placement of wind turbines does not pose a risk to human sleep. …If companies wish to remain in the reasonable window of protection against noise-induced sleep loss, they would do well to limit themselves to using the data demonstrated by Health Canada—allowing noises to not exceed 46 dBA measured outside the residence [8]. The actual, population-based threshold may be higher, but existing data support this number.*

The weight of scientific evidence continues to demonstrate that the siting guidelines of Colorado will ensure the protection of the community's health.

4.4 Low Frequency Noise (LFN) and Infrasound

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

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

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

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

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

From the abstract of Berger et al., 2015:

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

Simply put, the 50 dBA noise level at participating dwellings will ensure that levels of LFN and infrasound will 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.

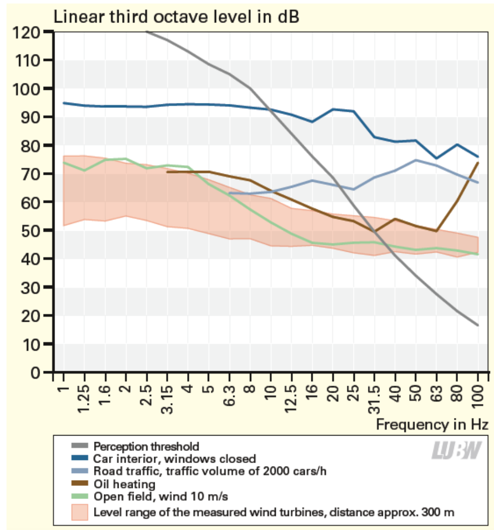


Figure 1. Measurements of infrasound and low frequency noise 300 m from wind turbines compared to other sources. [from MECE, 2016].

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."*

The newest article that has appeared in the scientific literature relates to the potential health impacts associated with exposure to wind turbine infrasound.

Marshall et al. 2023. The Health Effects of 72 Hours of Simulated Wind Turbine Infrasound: A Double- Blind Randomized Crossover Study in Noise-Sensitive, Healthy Adults. Environmental Health Perspectives. 131(3) March 2023

As part of the large Australian National Health and Medical Research Council of Australia (NHMRC) Targeted Call for Research into Wind Farms and Human Health a group of researchers undertook a study to better understand the potential impacts of wind turbine infrasound on human physiology and sleep. Starting at noon, participants were subjected to either wind turbine infrasound, sham infrasound (same speakers not generating infrasound) and traffic noise for a 72-hour period, including 3 nights. The subjects did not leave the test setting that consisted of a bedroom with ensuite mimicking a studio apartment. Each of the 37 noise-sensitive but otherwise health adults (age 18 – 72; 51% female) were exposed to all three noise conditions for the 72-hour period, resulting in a double-blind triple arm study design.

Physiological and psychological measures and systems were tested for their sensitivity to infra-sound: wake after sleep onset (WASO; primary outcome) and other measures of sleep physiology, wake electroencephalography, Wind Turbine Syndrome (WTS) symptoms, cardiovascular physiology, and neurobehavioral performance.

The researchers found:

> *Our findings did not support the idea that infrasound cause WTS. High level, but inaudible, infrasound did not appear to perturb any physiological or psychological measure tested in these study participants.*

This is yet another study that strengthens the findings that although infrasound is emitted from wind turbines it is not at a level that causes health impacts, wind turbine syndrome symptoms, sleep effects or impairment of neurobehavioral performance.

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.

5 Ollson Final Position on Overland Pass Energy East SUP Application

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

During this undertaking, OEHM would encourage the Sedgwick County Commissioners to once again to make its decision based on sound scientific evidence. Colorado has a twenty-year history of successfully siting wind projects under regulations similar those of Sedgwick County and the updated layout proposed by Overland Pass Energy East. The firsthand Colorado experience with wind projects is clear indication that they can be properly sited, while ensuring the protection of health.

There are over 70,000 wind turbines in the United States. Many of these wind turbines have been in operation for over a decade. Over the past decade there has been considerable research conducted around the world on the potential for wind turbines to adversely impact health. 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 the community for a number of years. Based on scientific principles, and the collective findings of over 100 scientific articles, OEHM believes that the Updated Overland Pass Energy East project is properly sited to ensure the protection of public, health and safety.

In addition, the Ohio Department of Health recently published their review Wind Turbines and Wind Farms Summary and Assessment. This has been attached for your consideration in Appendix C. 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 Updated Overland Pass Energy East SUP application, the project layout, and sound modeling results and believes that the project is designed in a manner that will protect the public health and safety of the Sedgwick County residents. OEHM believes that the Updated Overland Pass Energy East Project should be approved, with the previously approved setback waivers, by the County for construction and operation.

Sincerely,

OLLSON ENVIRONMENTAL HEALTH MANAGEMENT

Christopher Ollson, PhD
Senior Environmental Health Scientist

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Van Kamp, I & van den Berg, F. 2021. Health Effects Related to Wind Turbine Sound: An Update. Int. J. Environ. Res. Public Health 2021, 18, 9133

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APPENDIX A

Curriculum Vitae

Christopher Andrew Ollson, Ph.D.

OLLSON
Environmental Health Management

.

Ancaster, Ontario
Canada

CHRISTOPHER OLLSON, PH.D., QP$_{RA}$

Owner and
Senior Environmental Health Scientist

Dr. Ollson is Owner and Senior Environmental Health Scientist at Ollson Environmental Health Management (OEHM). He has 25 years of international consulting experience in environmental health sciences and toxicology. Dr. Ollson has worked across the United States and is well versed in Federal and State environmental legislation. His Canadian experience spans from coast-to-coast-to-coast, having worked in all Provinces and Territories. Throughout his career, Chris has led some of North America's most high profile and controversial multi-disciplinary environmental health assessments.

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

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

Dr. Ollson has testified at more than a thirty environmental review tribunals, commissions, hearings and court proceedings with respect to potential health concerns in living in proximity to renewable energy projects and associated transmission lines. In 2023, Dr. Ollson appeared before the Kansas Corporation Commission, providing expert testimony on potential health effects of EMF from a proposed 345 kV transmission line. With six peer-reviewed scientific journal articles, numerous invited conference presentations and invited university lectures he is the leading expert in North America on renewable energy health issues.

Dr. Ollson was the health expert on the American Clean Power (ACP) Expert Working Group contributing to the development of the ACP Sound Modelling Standard for wind turbine sound under the American National Standards Institute (ANSI). In 2021, he was appointed the Canadian Standards Council (CSC) as the Canadian expert to the International Electrotechnical Commission (IEC) Technical Specifications committee developing the IEC 61400-31 Wind Turbines Siting Risk Assessment standard. Dr. Ollson has testified before State Senate Utilities Committees in Kansas, North Dakota and Indiana and was the consultant of record for the State of Vermont for setting wind turbine siting and sound standards.

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

EDUCATION

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

AREAS OF SCIENTIFIC EXPERTISE

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

EMPLOYMENT HISTORY

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

PROFESSIONAL AFFILIATIONS

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

Expert on International Wind Turbine Standards Development Committees

American Clean Power (ACP) Expert Working Group development of the ACP Sound Modelling Standard for wind turbine sound under the American National Standards Institute. 2019 - Present

Canadian Expert to the International Electrotechnical Commission (IEC) Technical Specifications committee developing the IEC 61400-31 Wind Turbines Siting Risk Assessment standard. 2021 - Present

ACADEMIC EXPERIENCE

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

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

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

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

2004 - 2018 **Royal Military College of Canada**
Adjunct Assistant Professor

AWARDS

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

Wind Turbine Peer Reviewed Scientific Publications

Primary Research

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

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

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

Systematic Literature Reviews

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

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

Published Critique

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

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

In the following proceedings I testified and was formally qualified as an expert in energy human health impacts

Diana's Great Idea, LLC, et. al. v. Crazy Mounty Wind, LLC et. al. Cause No. Dv 18-161 Montana Sixth Judicial District Court Park County (2019)

Rivard & Bourque v. Éoliennes de l'Érable S.E.C. Superior Court of Québec. Case No. 415-06-000002-128. (2019)

Queen's Bench of Saskatchewan in McKinnon v. Martin in Red Lily Wind (2010)

Kansas Corporation Commission

NextEra Energy Transmission Southwest, LLC's ("NEET Southwest") Line Siting application in Docket No. 23-NETE-585-STG.

New York State Board on Electric Generation Siting and the Environment

High Bridge Wind Farm Case No. 18-F-0262 (2020)
Deer River Wind Farm Case No. 16-F-0267 (2019)

South Dakota Public Utilities Commission.

Crowned Ridge Wind Project. II. Case EL19-027 (2019)
Crowned Ridge Wind Project. Case EL19-003 (2019)

North Dakota Public Services Commission 2015

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

Alberta Utilities Commission (AUC)

Proceeding No. 1955, Bull Creek Wind Project (2013)
Proceeding No. 3329, Grizzly Bear Creek Wind Project (2016)
Proceeding No. 22563, Halkirk 2 Wind Project (2017)
Proceeding No. 26214 Buffalo Plains Wind Farm (2021)
Proceeding No. 26677 Grizzly Bear Creek Wind Project (2022)
Proceeding No. 27240, Buffalo Trail Wind Project (2022)
Proceeding No. 27561, Forty Mile Wind Project (2023)

Ontario Environmental Review Tribunal

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

Clinton County Planning and Zoning Commission, MO, County Ordinance Changes (2016)Chowan County and Perquimins County Board of Commissioners hearings for the Timbermill Wind Project (2016)

Appearances before Government Bodies

Kansas State Senate Committee on Utilities, Senate Bill No. 353. February 2022.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Wind Turbine Conference Proceedings

Ollson, C.A., Bastasch, M., Knopper, L., Anderson, A., Leventhall, G. 2023. How Misinformation Derails Discussions for Permitting of Wind Turbine Energy Projects. 11th International Conference on Wind Turbine Noise. June 21-23, 2023. Conference Paper Accepted for Presentation.

Ollson, C.A. & Bastasch, M. Establishing Sound Limits for Wind Energy: What is the Role of Annoyance? 9th International Conference on Wind Turbine Noise Remote from Europe – 18th to 21st May 2021. Conference Paper published in the Proceedings

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

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

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

Conference Presentations on Wind Turbines and Health

Ollson, C.A & Bastasch, M. 2021. Establishing Sound Limits for Wind Energy: What is the Role of Annoyance? 9th International Conference on Wind Turbine Noise Remote from Europe – 18th to 21st May 2021

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

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

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

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

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

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

Court Proceedings Unrelated to Wind Turbine Projects

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

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

Additional Peer-Reviewed Scientific Publications

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

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

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Tool: A Value Versus Investment Approach. Journal of Environmental Assessment Policy and Management Vol. 18, No. 2

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

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

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

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

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

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

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

Gregor, D., Stow, J., Kennedy, D., Reimer, K., **Ollson, C**. 2003. Local Sources of Contaminants in the Canadian Arctic. Canadian Arctic Contaminants Assessment Report /I(CACAR /I) Physical Environment 157-183

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

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

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

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

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

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

APPENDIX B

GE *Setback Considerations for Wind Turbine Siting*

GE Renewable Energy

– Original –

Technical Documentation
Wind Turbine Generator Systems
All Onshore Turbine Types

General Description

Setback Considerations for Wind Turbine Siting

imagination at work

GE Renewable Energy

– Original –

Visit us at
www.gerenewableenergy.com

All technical data is subject to change in line with ongoing technical development!

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Table of Contents

1 Introduction

This document provides setback guidance for the siting of wind turbines. This guidance considers potential safety risks associated with wind turbines such as objects (maintenance tools, ice, etc.) directly falling from the wind turbine, unlikely occurrences such as tower collapse and blade failure, and environmental / operational risks such as ice throw. The guidance is general in nature, and is based on the published advice of recognized industry associations. Local codes and other factors may dictate setbacks greater than the guidance in this document. The owner and the developer bear ultimate responsibility to determine whether a wind turbine should be installed at a particular location, and they are encouraged to seek the advice of qualified professionals for siting decisions. It is strongly suggested that wind developers site turbines so that they do not endanger the public.

2 Falling Objects

There is the potential for objects to directly fall from the turbine. The objects may be parts dislodged from the turbine, or dropped objects such as tools. Falling objects create a potential safety risk for anyone who is within close proximity to the turbine, i.e., within approximately a blade length from the turbine.

3 Tower Collapse

In very rare circumstances a tower may collapse due to unstable ground, a violent storm, an extreme earthquake, unpredictable structural fatigue, or other catastrophic events. Tower collapse presents a possible risk to anyone who is within the distance equal to the turbine tip height (hub height plus ½ rotor diameter) from the turbine.

4 Ice Shedding and Ice Throw

As with any structure, wind turbines can accumulate ice under certain atmospheric conditions. A wind turbine may shed accumulated ice due to gravity, and mechanical forces of the rotating blades. Accumulated ice on stationary components such as the tower and nacelle will typically fall directly below the turbine. Ice that has accumulated on the blades will likewise typically fall directly below the turbine, especially during start-up. However, during turbine operation under icing conditions, the mechanical forces of the blades have the potential to throw the ice beyond the immediate area of the turbine.

5 Blade Failure

During operation, there is the remote possibility of turbine blade failure due to fatigue, severe weather, or other events not related to the turbine itself. If one of these events should occur, pieces of the blade may be thrown from the turbine. The pieces may or may not break up in flight, and are expected to behave similarly to ice thrown from the blade. Blade failure presents a possible risk for anyone beyond the immediate area of the turbine.

6 Industry Best Practices

Recognized industry practices suggest the following actions be considered when siting turbines in order to mitigate risk resulting from the hazards listed above:

- Place physical and visual warnings such as fences and warning signs as appropriate for the protection of site personnel and the public.
- Remotely stop the turbine when ice accumulation is detected by site personnel or other means. Additionally, the wind turbine controller may have the capability to shut down or curtail an individual turbine based on the detection of certain atmospheric conditions or turbine operating characteristics.
- Restrict site personnel access to a wind turbine if ice is present on any turbine surface such as the tower, nacelle or blades. If site personnel absolutely must access a turbine with ice accumulation, safety precautions should include but are not limited to remotely shutting down the turbine, yawing the turbine to position the rotor on the side opposite from the tower door, parking vehicles at a safe distance from the turbine, and restarting the turbine remotely when the site is clear. As always, appropriate personnel protective gear must be worn.

7 Setback Considerations

Setback considerations include adjoining population density, usage frequency of adjoining roads, land availability, and proximity to other publicly accessed areas and buildings. Table 1 provides setback guidance for wind turbines given these considerations. GE recommends using the generally accepted guidelines listed in Table 1, in addition to any requirements from local codes or specific direction of the local authorities, when siting wind turbines.

Setback Distance from center of turbine tower	Objects of concern within the setback distance

All turbine sites (blade failure/ice throw):
1.1 x tip height[1], with a minimum setback distance of 170 meters
	- Public use areas
	- Residences
	- Office buildings
	- Public buildings
	- Parking lots
	- Public roads
	  - Moderately or heavily traveled roads if icing is likely
	  - Heavily traveled multi-lane freeways and motorways if icing is not likely
	- Passenger railroads

All turbine sites (tower collapse): 1.1 x tip height[1]	- Public use areas - Residences - Office buildings - Public buildings - Parking lots - Heavily traveled multi-lane freeways and motorways - Sensitive above ground services[2]
All turbine sites (rotor sweep/falling objects): 1.1 x blade length[3]	- Property not owned by wind farm participants[4] - Buildings - Non-building structures - Public and private roads - Railroads - Sensitive above ground services

Table 1: Setback recommendations

The wind turbine buyer should perform a safety review of the proposed turbine location(s). Note that there may be objects of concern within the recommended setback distances that may not create a significant safety risk, but may warrant further analysis. If the location of a particular wind turbine does not meet the Table 1 recommended guidelines, contact GE for guidance, and include the information listed in Table 2 as applicable.

1 The maximum height of any blade tip when the blade is straight up (hub height + ½ rotor diameter).

2 Services that if damaged could result in significant hazard to people or the environment or extended loss of services to a significant population. Examples include pipelines or electrical transmission lines.

3 Use ½ rotor diameter to approximate blade length for this calculation.

4 Property boundaries to vacant areas where there is a remote chance of future development or inhabitancy during the life of the wind farm.

Condition/object within setback circle	Data Required
If icing is likely at the wind turbine site	- Annual number of icing days
Residences	- Number of residences within recommended setback distance - Any abandoned residences within setback distance
For industrial buildings (warehouse/shop)	- Average number of persons-hours in area during shift - Number of work shifts per week - Any abandoned buildings within setback distance
For open industrial areas (storage/parking lot)	- Average number of persons-hours in area during shift - Number of shifts per week. - Any abandoned buildings within setback distance
For sports/assembly areas	- Average number of persons in area per day - Average number of hours occupied per day - Number of days area occupied per week - If area covered, what type of cover
For roads/waterways	- Plot of road/waterway vs. turbine(s) - Average number of vehicles per day - Type of road and speed limit (residential, country, # of lanes, etc.)
For paths/trails (walk, hike, run, bike, ski)	- Plot of paths/trails vs. turbine(s) - Average number # of persons per day by type of presence (walk, hike, etc.) - Flat or uneven/hilly terrain

Table 2: Setback recommendations

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Environmental Health Management

APPENDIX C

Ohio Department of Health
Wind Turbines and Wind Farms Summary and Assessment

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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