Swan Lake Wind Project

Overview

- Located in Yankton and Turner counties, South Dakota
- Expected maximum capacity of up to 248 megawatts produced by 97 wind turbines
- Owned and operated by a subsidiary of NextEra Energy Resources, LLC
- Pending local and state approvals, expected to begin commercial operation by the end of 2027

About NextEra Energy Resources, LLC

- A leading clean energy provider operating wind, natural gas, solar and nuclear power plants
- A portfolio of power generating facilities across the United States and in Canada
- The world's largest generator of wind and solar energy
- A subsidiary of NextEra Energy, Inc., with headquarters in Juno Beach, Florida
- Approximately 99% of the electricity we generate comes from clean or renewable sources
- We operate more than 155 wind projects in 22 states and Canada with more than 23,380 megawatts of generation from more than 11,000 wind turbines

NextEraEnergyResources.com

Benefits

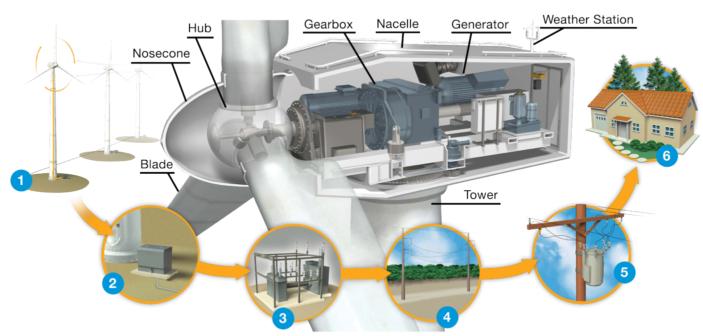
- Provides employment opportunities
- Adds tax revenue benefiting schools and local civic service
- Supports economy through purchases of regional goods and services
- Provides landowner lease payments
- Increased local spending for goods and services during construction
- Charitable contributions to local organizations
- Creates no air or water pollution
- Uses no water in power generation
- Allows land to remain in agricultural use

Projected Local Economic Impact

Construction Jobs:	Approx. 400
Full-Time Operations Jobs:	Approx. 3-5
Taxes:	Approx. $1.1 million per year
Landowner Payments:	Approx. $1.3 million per year

All figures are estimated and subject to change.

How a Wind Turbine Works





Proposed Setback Siting Guidelines for Wind Energy Projects in Yankton County

Christopher Ollson, PhD
Ollson Environmental Health Management

OLLSON Environmental Health Management

Dr. Ollson Qualifications

- Doctorate in Environmental Health Science
- Over 25 years in international environmental risk assessment and health consulting
- Owner of Ollson Environmental Health Sciences for the past 10 years
- Adjunct Professor University of Toronto
- 15 years of researching potential health impacts for those living in proximity to renewable energy and transmission lines
- Testified before numerous county commissions, state hearings, and court cases as a qualified expert in the field
- Involved in over 25 GW of renewable energy projects across 26 States.
- Consultant of record for State of Vermont during wind siting rule making and appeared before Senate Committees in Kansas, North Dakota and Indiana

frontiers in PUBLIC HEALTH
REVIEW ARTICLE
published: 19 June 2014
doi: 10.3389/fpubh.2014.00063

Wind turbines and human health

Loren D. Knopper[1]*, Christopher A. Ollson[1], Lindsay C. McCallum[1], Melissa L. Whitfield Aslund[1], Robert G. Berger[1], Kathleen Souweine[2] and Mary McDaniel[2]

Health-based audible noise guidelines account for infrasound and low-frequency noise produced by wind turbines

Robert G. Berger[1], Payam Ashtiani[2], Christopher A. Ollson[3], Melissa Whitfield Aslund[3], Lindsay C. McCallum[3,4], Geoff Leventhall[5] and Loren D. Knopper[3]*

Review
Highly accessed
Open Access

Health effects and wind turbines: A review of the literature

Loren D Knopper[1]* and Christopher A Ollson[2]

McCallum et al. Environmental Health 2014, 13:9
http://www.ehjournal.net/content/13/1/9
ENVIRONMENTAL HEALTH
RESEARCH Open Access

Measuring electromagnetic fields (EMF) around wind turbines in Canada: is there a human health concern?

Lindsay C McCallum[1,2], Melissa L Whitfield Aslund[2], Loren D Knopper[2], Glenn M Ferguson[2] and Christopher A Ollson[2*]

Energy Policy 62 (2013) 44–50
Contents lists available at ScienceDirect
Energy Policy
journal homepage: www.elsevier.com/locate/enpol

Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada

Melissa L. Whitfield Aslund, Christopher A. Ollson, Loren D. Knopper*

Noise & Health

Letter to Editor: Are the findings of "Effects of industrial wind turbine noise on sleep and health" supported?

Christopher A. Ollson, Loren D. Knopper, Lindsay C. McCallum, Melissa L. Whitfield-Aslund

Noise & Health, March-April 2013, Volume 15:63, 148-52

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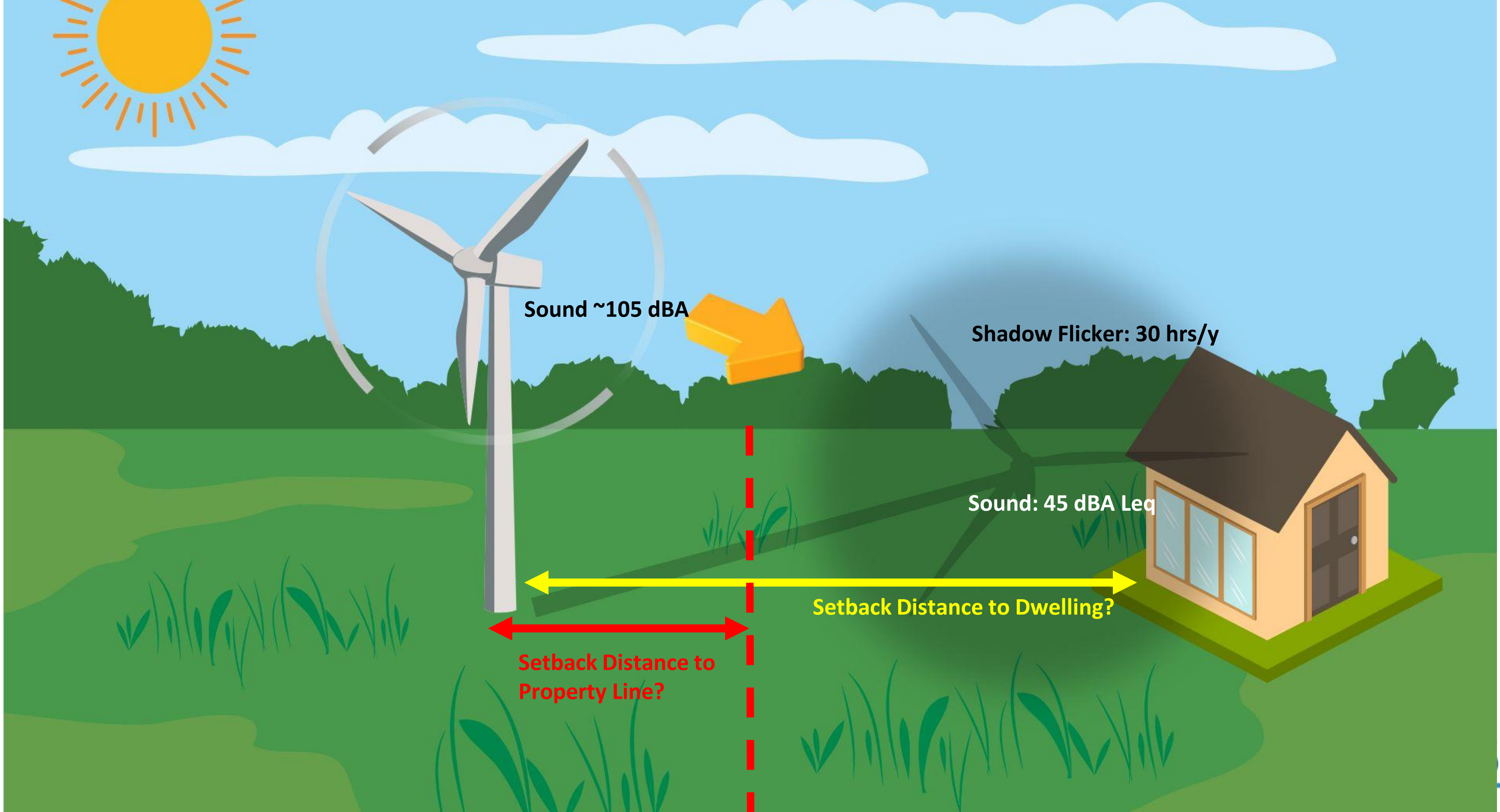
Setback Considerations



Management

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Other Jurisdiction Turbine Setbacks

State Examples	Minimum Setback for Wind Turbines from Residential Dwellings
North Dakota (State)	One and one-tenth times the height of the turbine from the property line of a nonparticipating landowner and three times the height of the turbine from an inhabited rural residence of a nonparticipating landowner, unless a variance is granted.
Wisconsin (State)	The lessor of 1,250 feet or 3.1 times the maximum blade tip height to homes.
New York (State)	Non-participating, non-residential Structures 1.5 times, non-participating residences 2 times
Illinois (State)	1.1 times tip height to non-participating property lines, 2.1 times tip height to non-participating receptors.
Michigan (State)	2.1 times from occupied community buildings and residences on nonparticipating properties 1.1 times from non-participating property lines
South Dakota (County and PUC)	Typically 1,500 ft to non-participating homes and 1.1x total height to non-participating property lines.
Nebraska (County)	Varies county by county but most common between 1,000 ft to 1,500 ft
Kansas (County)	Varies county by county but most common between 1,000 ft to 1,500

- Typical setback to a non-participating residence is 1,500 ft or 2-3x total height
- 1.1x to total turbine height to non-participating property lines

State of Wind Turbine Research and Health Effects

- 20 years of research in the field
- Over 150 peer-reviewed research papers published in the field
- Findings support:
  - Sound levels 45 dBA at non-participating homes
  - Shadow flicker <30 hours a year
  - Setbacks 1.1x tip height to roads, property lines, transmission lines, etc..
  - Setbacks 2-3x tip height to non-participating homes (based primarily on achieving sound limits) and no great than 1,500 ft is required.

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Largest study ever undertaken around the world.

The following were not found to be associated with wind turbine noise:

a. self-reported sleep (e.g., general disturbance, use of sleep medication, diagnosed sleep disorders);

b. self-reported illnesses (e.g., dizziness, tinnitus, prevalence of frequent migraines and headaches) and chronic health conditions (e.g., heart disease, high blood pressure and diabetes); and

c. self-reported perceived stress and quality of life.

The overall conclusion to emerge from the study findings is that the study found no evidence of an association between exposure to WTN and the prevalence of self-reported or measured health effects.

Support by US, Australian and European Studies.

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Wind Turbine Sound Guidelines

- The majority of South Dakota Counties and the Public Utilities Commission has approved a 45 dBA 10-minute Leq at non-participating homes.
- The use of a non-participating property sound standard is not advised, however, those that have it typically require no more than 50 dBA at non-participating property lines that have existing residences.
- 45 dBA sound level at non-participating residences is the most common county and State-level standard across the US.

Sound Standard 45 dBA at non-participating residences protects public health.

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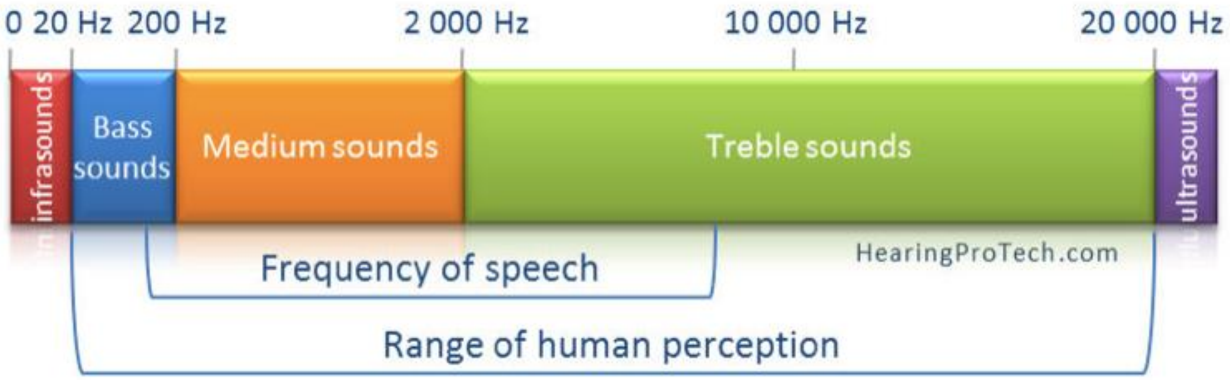
LOW FREQUENCY NOISE
AND
INFRASOUND



Scale of sound frequencies

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Shadow Flicker

- Shadow flicker does not induce seizures.
- Wind turbines quite simply don't rotate fast enough.
- Shadow flicker is not a health concern

<u>OEHM Agrees with the Wind Task Force Shadow Flicker Recommendation</u>

- No more than 30 hours a year of shadow flicker ensures a reduction of annoyance in neighbors.

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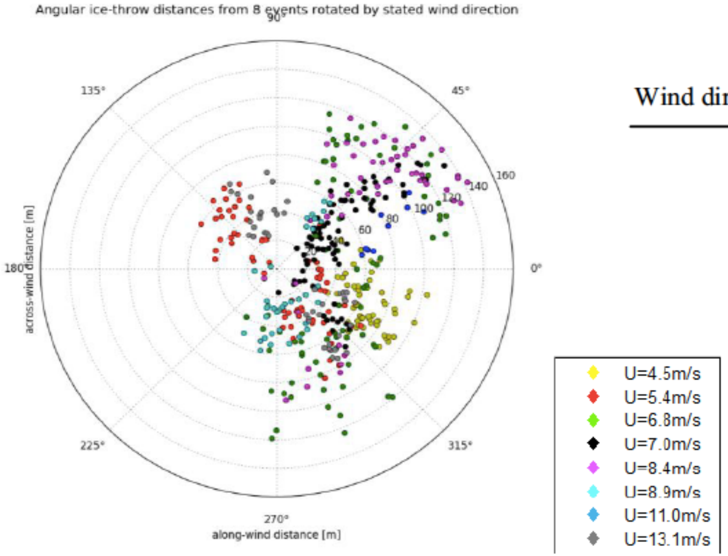
PHYSICAL SAFETY CONSIDERATIONS

Risk Assessment of Ice Throw

PAPER • **OPEN ACCESS**

Understanding and acknowledging the ice throw hazard - consequences for regulatory frameworks, risk perception and risk communication

To cite this article: R. E. Bredesen *et al* 2017 *J. Phys.: Conf. Ser.* **926** 012001



Wind direction →

Figure 6. 417 ice pieces from the IceThrower database for the considered V90 turbine with a tipheight of 140 m. The location of all ice pieces are rotated by the given wind direction for each given case. Events are listed A-H by colored markers for increasing wind velocities.

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Blade Fragment Throw and Tower Collapse

Source of Fatality	*Annual Risk*	*Assumptions*
Wind turbine - Direct impact by blade/fragment	10^{-9}	At 2x hub height from wind turbine
Wind turbine - Indirect impact by blade/fragment	10^{-8}	At 2x hub height from wind turbine
Cancer	2.58×10^{-3}	Averaged over population. England & Wales 1999
Lightning	5.35×10^{-8}	England & Wales 1995-1999
Mining Industry	1.09×10^{-4}	GB 1996-2001
Construction Industry	5.88×10^{-5}	GB 1996-2001
Agriculture	5.81×10^{-5}	GB 1996-2001
Service Industry	3.00×10^{-6}	GB 1996-2001
Fairground Rides	4.79×10^{-9}	Assumes 4x rides per annum. UK 1996-2000
Road Accidents (all forms)	5.95×10^{-5}	UK 1999
Rail Travel Accidents (per passenger journeys)	2.32×10^{-8}	Fatality per passenger journeys GB 1996-1997
Rail Travel Accidents (annual risk - commuter)	1.05×10^{-5}	Annual risk of fatality: 2 daily journeys, 45 weeks per year
Aircraft Accident (per passenger journeys)	8.00×10^{-9}	Fatality per passenger journeys UK 1991-2000
Aircraft Accident (annual risk – holidaymaker)	1.60×10^{-8}	Annual risk of fatality: 2 flights per annum

HSE Health and Safety Executive

Study and development of a methodology for the estimation of the risk and harm to persons from wind turbines

Prepared by **MMI Engineering Ltd**
for the Health and Safety Executive 2013

RR968
Research Report

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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

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

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OEHM Setback Recommendations

	Yankton Existing Ordinance	Yankton Wind Task Force Recommendation	OEHM Recommendation
Participating Residences	Distance from on-site or lessor's residence shall be one thousand (1,000) feet.	1.5 times total height	1,000 feet or 1.5x total height, whichever is greater
Non-Participating Residences	Distance from existing off-site residences, business and public buildings shall be one thousand three hundred and twenty feet (1,320) feet.	2 miles	1,500 feet or 3x total height, whichever is greater
Non-Participating Property Lines	Distance from any property line shall be 500 feet or one point one (1.1) times the height of the wind turbines depending upon which is greater, measured from the ground surface to the tip of the blade when in a fully vertical position unless wind easement has been obtained from adjoining property owner.	2 miles	1.1 x (110%) total height of the turbine
Participating property lines		1.5 times total height	No setback
Public ROW and Roads	500 feet or one point one (1.1) times the height of the wind turbines depending upon which is greater	1.5 times total height	1.1 x (110%) total height of the turbine
Municipal Boundaries		2 miles	5,280 feet (1 mile)
Utilities		1.5 times total height	1.1 x (110%) total height of the turbine
Lakes, Rivers and Stream		1 Mile from all lakes, rivers and streams	1 mile from identified Lake Districts o valued recreational lakes, no setbacks for rivers or streams

OEHM Sound / Shadow Flicker Recommendations

	Yankton Existing Ordinance	Yankton Wind Task Force Recommendation	OEHM Recommendation
Sound	Noise level shall not exceed 60 dB, including constructive interference effects, measured at the closest point on the closest property line from the base of the system.	Noise level shall not exceed 45 dB, including constructive interference effects, measured at the closest point on the closest non-participating property line from the base of the system. The noise level shall not exceed 35 dB at the nearest non-participating residence.	Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity. Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

<u>Sound</u>

Participating: 50 dBA

Non-participating: 45 dBA

No property line standard

<u>Shadow Flicker</u>

No more than 30 hours a year at residences

	Yankton Existing Ordinance	Yankton Wind Task Force Recommendation	OEHM Recommendation
Shadow Flicker		A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and dwellings within a two (2) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed thirty (30) hours per year within the analysis area. A Shadow Flicker Control System shall be installed upon all turbines which will cause a shadow effect upon an occupied residential dwelling. Exception: The Board of Adjustment may allow for a greater amount of flicker than identified above if the participating or non-participating landowners agree to said amount of flicker. If approved, such agreement shall be permanently attached to the approved conditional use permit and shall be filed as a permanent encumbrance against the legally described parcel(s) for which the waiver is granted.	Use language proposed by Yankton County Wind Task Force replace receptor with residence

Conclusion

- The Wind Task Force sound and setback recommendations are excessive and provide no additional protection of public health, safety and welfare of Yankton County Residents over standard regulations that have been in place for 20 years across South Dakota.

- Adopting the draft ordinance would effectively sterilize the County from any wind development.

- The Planning Commission is urged to establish setbacks and sound levels based on science, engineering and best practices.

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Environmental Health Management

Proposed Setback Siting Guidelines for Wind Energy Projects In Yankton County, SD

Prepared for:

Yankton County Planning Commission
321 West 3rd Street, Suite 100
Yankton, SD, 57078

May 13, 2024

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Environmental Health Management

Proposed Setback Siting Guidelines for Wind Energy Projects in Yankton County, SD

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The United States continues to see exponential growth in the installation of wind turbines across the country. Over the years onshore wind turbines have grown from 1.5 megawatt (MW) machines (~400 feet tall) to the current models typically ranging from >2.5 MW to 7 MW (500 feet to over 700 feet). There are over 70,000 wind turbines across the United States and more than 1,000 in South Dakota. It is anticipated that the need for wind energy will continue to expand, especially in light of state and federal renewable energy targets.

With the growth of the industry has come the need to develop proper siting guidelines to ensure the protection of wildlife, the environment, and public health. There are no overarching federal guidelines that govern wind turbine installation and their interaction with local residents. The South Dakota Public Utilities Commission (PUC) has recently approved a number of wind turbine projects that have established reasonable sound, shadow flicker and setback guidelines for wind turbine projects.

Yankton County appointed a number of interested citizens to a Wind Turbine Task Force. Over the past couple of months, the Task Force met on several occasions to establish recommended changes to the Yankton County Ordinance Article 26 – Wind Energy Conversion Systems (WECS). These proposed changes have been sent to the Yankton County Planning Commission for consideration for recommendation to the Yankton County Commissioners.

Dr. Christopher Ollson of Ollson Environmental Health Sciences (OEHM) has been commissioned by NextEra Energy Resources to review the changes proposed to the Yankton County Ordinance. Dr. Ollson has over 15 years of experience researching and working in the wind industry across North America to develop science-based wind turbine siting criteria that ensures the protection of public health and safety. Dr. Ollson's research has been presented at numerous international scientific conferences. He has been formally qualified to provide expert opinion evidence on wind turbines and potential health effects at a number of North American hearings, tribunals and legal cases. Dr. Ollson has appeared before numerous County Planning & Zoning and County Commissions across the country, including in South Dakota and before the South Dakota PUC.

OEHM recommends that the Yankton County Planning Commission not adopt the proposed draft LWECS ordinance. Based on the available scientific literature the draft ordinance is excessive and will not allow for construction of wind projects in the county. The common sound, shadow flicker and setback distances in place across numerous South Dakota counties with operating wind turbines are more than sufficient to ensure the protection of the public health and safety of residents. There is no scientific basis to increase these setbacks. It would afford no additional protection of public health and safety and would unduly restrict areas for development.

I have had the opportunity to watch all of the Wind Task Force meetings in their entirety. Although I applaud the efforts and time taken by the Wind Turbine Task Force, I cannot support all of the proposed changes. This report provides comments and suggestions for the Planning Commission to consider that will ensure the public health and safety of local residents in the event that any wind project is constructed in Yankton County.

Setting Science-Based Wind Energy Siting Requirements

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

Appropriate setback distances to dwellings go hand in hand with sound and shadow flicker standards to ensure protection of public health and welfare. In addition, setbacks need to account for public safety issues with respect to potential ice throw, blade failure, and tower collapse. Public safety setback distances are often set both to non-participating property lines and dwellings themselves.

Over the past twenty years there has been extensive research evaluating public health, safety and welfare concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government agencies has taken place in many different countries on a variety of turbine models, many of which have been in communities for years. It is on the basis of this research that municipalities should set appropriate setbacks to dwelling. Caution should be exercised to not establish excessive setbacks that afford no additional benefit or protection of public health and safety.

Common Sound, Shadow Flicker and Setback Standards for Wind Energy Projects

The most common audible sound limit used across South Dakota counties and accepted by the PUC is a 45 dBA (10 min Leq) at the exterior of non-participating homes and 50 dBA at participating homes. This protects against direct and indirect potential health impacts, while ensuring people's quality of life and enjoyment of their property. This sound standard has been adopted by several states (North Dakota and New York), while other states have higher sound limits of 50 dBA or greater at non-participating homes (Minnesota, Illinois and Michigan)

The setback distance required to meet this stringent 45 dBA sound standard at most dwellings would be approximately 1,500 ft. This is confirmed by individual sound modeling reports produced for each new proposed project. The PUC has also established condition of approval at many projects of a shadow flicker guideline of no more than 30 hours a year.

There is no overarching South Dakota setback siting criteria, guidelines or regulations for wind energy projects. Instead, local counties establish what they believe to be reasonable siting criteria for wind turbines in relation to dwellings. Setbacks in South Dakota typically are fixed distances that range from 1,000 to 1,500 ft or a multiplier of turbine height to the home (3 times total turbine height).

Setbacks to property lines tend to range from 1.1 times total height to 1.5 times total height to property lines and roads that ensures the protection of public safety.

Potential Health Effects and Wind Energy Projects

Wind turbine setbacks from homes and property lines should, at least in part, be based on the science of potential health implications for those living in proximity. The most significant public health research on how living near a wind energy project could impact health was published after 2015. The weight of public health scientific evidence finds:

- There is no association between wind turbine sound levels of up to 46 dBA at the exterior of non-participating homes and impact on sleep.
- There is no association between distance from wind turbine to homes and does not impact sleep or other potential health impacts.
- The level of low frequency noise or infrasound from wind turbines at non-participating homes does not cause sleep disturbance or other health effects. The levels are typically within background levels at homes and are well below levels that could induce health impacts.
- The results from the largest study in the world conducted by Health Canada 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. In other words, individuals with these conditions were equally distributed among people living at all sound levels and distances from 1000 ft to 7 miles in the study area. This is supported by numerous other studies in the United States and around the world.
- There will always be a percentage of people that self-report annoyance with having to live near wind projects, regardless of whatever sound or setback distances are permitted. This is a well-understood scientifically documented phenomenon. Levels of self-reported annoyance are largely driven by one’s feelings towards how the turbines change the visual nature of the landscape and their perception of the perceived fairness in the permitting process for a project. The level of annoyance one feels towards the wind projects has been shown to not impact one’s health. Therefore, it would be inappropriate to base wind turbine sound and setback standards on people’s annoyance levels.
- Public safety setbacks of 110% (or 1.1 times) tip height of a wind turbine to property lines and roads ensure protection against ice throw, blade failure, and tower collapse.

Socio-Economic Determinants of Health and Wind Energy Projects

Wind energy projects bring clear socio-economic health benefits to host communities. These are in the form of taxes, landowner payments, jobs, potential impact on healthcare costs and an offset for the need for fossil fuel derived energy. These all have indirect health benefits at the individual and community level. At the same time wind energy projects allow for continued use and enjoyment of rural areas.

Consideration of Visual Impact of Wind Turbines in the County

Another issue in determining appropriate setbacks is the cumulative effect and visual impact of projects on community members. Often the question becomes how many turbines in a community are enough and how far should they be setback for impact on viewscape. There are two distinct issues with respect to this topic. The first is the cumulative effect of the number of wind turbines on public health from sound and shadow flicker. The second is the visual aspect of the turbines on the horizon.

First, health impacts are assessed by the adherence to the sound and shadow flicker standards, regardless of the number of turbines in an area. Each of the sound and shadow flicker standards require an assessment of the cumulative effect of the individual project, as well as any adjacent project within the area. That is because the largest zone of influence of sound from one turbine to the next is within 1.5 miles and the same is true for shadow flicker. That means that cumulative effects from all proposed and existing wind turbines are always accounted for.

In terms of the visual aspect of turbines on the horizon, beauty is truly in the eye of the beholder. There are numerous studies that describe that approximately 10% of the population living in proximity to a wind turbine will be annoyed by their presence. However, given that wind turbines do not impact property values, impact health or result in other impacts on quality-of-life OEHM does not believe that Counties should use visual cue as the basis to increase setback distances to turbines. This would effectively be a roundabout way of zoning out wind turbines based on visual appearance. There are Counties across the United States that host hundreds of wind turbines without impact on their communities. In addition, setbacks to try and limit the impact of wind turbines on the landscape are not effective, essentially if one can see a turbine on the horizon and they do not want them, no setback distance will be effective in changing their mind.

OEHM Recommended Sound and Setback Siting Guidelines for Consideration by Yankton County

The Yankton County Wind Task Force proposed sound and setback amendments to the zoning ordinance are far too restrictive, are not aligned with other counties or jurisdictions that have hosted operating turbines, in some cases for 20 years in South Dakota, and afford no greater protection of public health and safety that other jurisdictions.

Based on totality of these findings OEHM believes that the following siting guidelines are protective of public health, while providing a reasonable balance between community concerns and achievable project siting constraints:

- Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

  Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

- Shadow flicker at residences shall not exceed 30 hours per year unless the owner of the residence has signed a waiver. Prior to construction, the Applicant shall obtain and file with a waiver for any occupied structure which will experience more than 30 hours of shadow flicker per year. If no waiver is obtained, Applicant shall file a mitigation and obtain approval of the plan prior to construction. (This is similar language as proposed by the Wind Task Force).
- Infrasound and low frequency noise, although emitted from wind turbines, have been demonstrated to be at level that is too low to be of health concern. Therefore, no additional setback standard is required.
- Public safety setbacks of 110% (or 1.1 times) tip height of a wind turbine to non-participating property lines, utilities and roads ensure protection against ice throw, blade failure, and tower collapse. Further distances are not recommended and not required to protect public safety. There is no need to published setback restrictions to participating property lines.
- Setback to Municipal boundaries: 5,280 ft or 1 mile
- Setback to residences:
  - Participating residences: 1,000 ft or 1.5x total height
  - Non-Participating residences: 1,500 ft or 2-3x total height

These recommended siting guidelines are consistent with requirements of other South Dakota Counties, have been approved by the SD PUC, many counties in Midwestern states, and in most State-level requirements across the United States.

OLLSON Environmental Health Management

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1 Introduction

The United States continues to see exponential growth in the installation of wind turbines across the country. Over the years onshore wind turbines have grown from 1.5 megawatt (MW) machines (~400 feet tall) to the current models typically ranging from >2.5 MW to 7 MW (500 feet to over 700 feet). There are over 70,000 wind turbines across the United States and more than 1,000 in South Dakota. It is anticipated that the need for wind energy will continue to expand, especially in light of state and federal renewable energy targets.

With the growth of the industry has come the need to develop proper siting guidelines to ensure the protection of wildlife, the environment, and public health. There are no overarching federal guidelines that govern wind turbine installation and their interaction with local residents. The South Dakota Public Utilities Commission (PUC) has recently approved a number of wind turbine projects that have established reasonable sound, shadow flicker and setback guidelines for wind turbine projects.

In recent years, communities have raised concerns about having wind turbines placed in close proximity to their homes. These issues include concerns around distance of the towers to their homes and property lines, the change to the landscape that comes with construction of a wind project, the sound they will experience at their homes, shadow flicker and safety issues involving ice throw and structural failure of the turbines. It is these issues that need to be addressed when determining appropriate siting criteria for protection of public health, while still ensuring that regulations are not so overly restrictive that projects cannot be built.

Community concerns have led to an explosion of misinformation on the Internet with respect to how living in proximity to wind turbines may impact health. This is not unique to wind turbines and is similar to other modernization efforts and changes to the environment that are typically accompanied by unsupported health claims (e.g., EMF from transmission lines, cellular towers, and cellular phones).

Yankton County appointed a number of interested citizens to a Wind Turbine Task Force. Over the past couple of months, the Task Force met on several occasions to establish recommended changes to the Yankton County Ordinance Article 26 – Large Wind Energy Conversion Systems (LWECS). These proposed changes have been sent to the Yankton County Planning Commission for consideration for recommendation to the Yankton County Commissioners. I have had the opportunity to watch all of the Wind Task Force meetings in their entirety.

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

The purpose of this report is to provide science-based factual information to support siting guidelines that are protective of public health, understands community concerns and recognizes the economic benefits and the desire for wind energy development. The focus of this review is on non-participating homes and property. Although the science on appropriate sound levels to protect against direct and indirect health impacts is well supported, it is acknowledged that issues surrounding level of community annoyance is far more subjective. This is also addressed within the paper.

2 Considerations for Developing Science-Based Setback Regulations

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

Appropriate setback distances to dwellings go hand in hand with sound and shadow flicker standards to ensure protection of public health and welfare (Figure 1). In addition, setbacks need to account for public safety issues with respect to potential ice throw, blade failure, and tower collapse. Public safety setback distances are often set both to non-participating property lines and dwellings themselves.

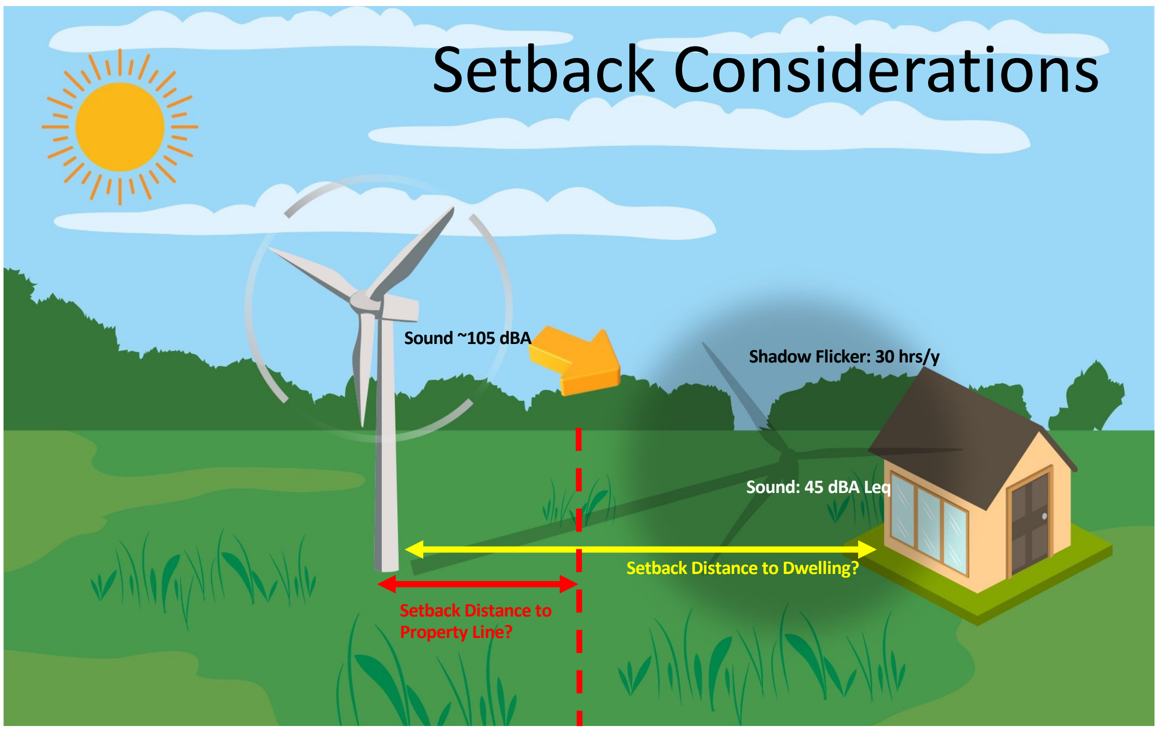

Figure 1. Setback considerations for Siting of Wind Turbines

Over the past twenty years there has been extensive research evaluating public health, safety and welfare concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government agencies has taken place in many different countries on a variety of turbine models, many of which have been in communities for years. It is on the basis of this research that municipalities should set appropriate setbacks to dwelling. Caution should be exercised to not establish excessive setbacks that afford no additional benefit or protection of public health and safety.

The following sections will first describe guidelines for sound and shadow flicker are appropriate for protection of public health. This is important to understand so that they can be used to establish minimum setback distances to homes. Next discussion on setback requirements for ensuring protection of public safety from physical issue will be explored. Finally, putting these two issues together OEHM will describe recommended setbacks for Yankton County to residences.

3 Review of Health Research with Living in Proximity to Wind Turbines

An extensive review of the findings of the bulk of peer-reviewed scientific literature on living in proximity to wind turbines is found in Appendix A. Readers are encouraged to consult the appendix for any questions they have on health impacts and siting.

Wind turbine setbacks from homes should, at least in part, be based on the science of potential health implications for those living in proximity. The most significant public health research on how living near a wind energy project could impact health was published after 2015. The weight of public health scientific evidence finds:

- There is no association between wind turbine sound levels of up to 46 dBA at the exterior of non-participating homes and impact on sleep.
- There is no association between distance from wind turbine to homes and does not impact sleep or other potential health impacts.
- The level of low frequency noise or infrasound from wind turbines at non-participating homes does not cause sleep disturbance or other health effects. The levels are typically within background levels at homes and are well below levels that could induce health impacts.
- The results from the Health Canada 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 dB. In other words, individuals with these conditions were equally distributed among people living at all sound levels and distances from <500 m to 11 km in the study area.
- There will always be a percentage of people that self-report annoyance with having to live near wind projects, regardless of whatever sound or setback distances are permitted. This is a well-understood scientifically documented phenomenon. Levels of self-reported annoyance are largely driven by one's feelings towards how the turbines change the visual nature of the landscape and their perception of the perceived fairness in the permitting process for a project. The level of annoyance one feels towards the wind projects does not impact one's health. Therefore, it would be inappropriate to base wind turbine sound and setback standards on people's annoyance levels.
- Public safety setbacks of 110% (or 1.1 times) tip height of a wind turbine to property lines and roads ensure protection against ice throw, blade failure, and tower collapse.
- Setbacks to residences should align with the setbacks required to achieve sound and shadow flicker guidelines, while also ensuring the protection of public health.

4 Sound and Shadow Flicker Guidelines in South Dakota

The first step in setting health-based guidelines for any infrastructure project is to understand its emissions and how they could interact with people in the surrounding area. For wind turbines the emissions of concern are sound and shadow flicker. The studies that justify appropriate standards are later in this document. However, OEHM can attest that the previously approved SD PUC requirements for sound and shadow flicker are indeed protective of public health.

4.1.1 South Dakota Sound Standards

In April 2020, the SD PUC issued its Final Decision and Order Granting Permit to Construct the Crown Ridge II Facility Permit Conditions. The decision requires the following condition be met for sound:

> *The Crowned Ridge Wind II Project (CRW II), exclusive of all unrelated background noise except for that associated with the pre-existing Crowned Ridge Wind I Project (CRW I), shall not generate a sound pressure level (10-minute equivalent continuous sound level, Leq) of more than 45 dBA as measured within 25 feet of any nonparticipating residence unless the owner of the residence has signed a waiver, or more than 50 dBA (10-minute equivalent continuous sound level, Leq) within 25 feet of any participating residence unless the owner of the residence has signed a waiver. The Project owner shall, upon Commission formal request, conduct field surveys and provide monitoring data verifying compliance with specified noise level limits. If the measured wind turbine noise level exceeds a limit set forth above, then the Project owner shall act in accordance with prudent operating practice to rectify the situation.*

This standard aligns with the majority of counties within South Dakota with operating wind projects.

The existing Yankton County Zoning Ordinance, 2020 provides the following noise requirement:

> *Noise level shall not exceed 60 dB, including constructive interference effects, measured at the closest point on the closest property line from the base of the system.*

The Yankton County Wind Task Force has proposed the following standard:

> *Noise level shall not exceed 45 dB, including constructive interference effects, measured at the closest point on the closest non-participating property line from the base of the system. The noise level shall not exceed 35 dB at the nearest non-participating residence.*

OEHM acknowledges that the existing Yankton County Zoning Ordinance noise level is too high and requires amendment. However, the Wind Task Force level is excessively low and should not be adopted by the Planning Commission. It would effectively lead to a ban of wind projects in the County. OEHM understands that in no way was this the intention of the Wind Task Force when they were proposing sound limits.

Table 1 provides a list of the sound zoning ordinance requirements in Grant, Deuel and Codington Counties, along with the existing Yankton County Ordinance. Table 2 provides a list of noise requirements from a number of states. The most common sound standard across South Dakota and the Midwestern states is typically 45 dBA at all participating and non-participating residences. There are some jurisdictions that allow for a 50 dBA sound standard. It is rare to have a sound standard at non-participating property lines. When this is the case, it is typically a 50 dBA standard at the property line of existing off-site non-participating residences.

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Table 1. Noise/Sound standards in South Dakota Counties.

	Codington County Ordinance #68	Deuel County Section 1215. Wind Energy System (Wes) Requirements.	Grant County Section 1211. Wind Energy System (Wes) Requirements	Yankton County Existing Ordinance	Yankton Wind Task Force Recommendation	OEHM Recommendation
Sound	Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects at the property line of existing off-site non participating residences, businesses, and buildings owned and/or maintained by a governmental entity.	Noise level for non-participating residences shall not exceed 45 DBA, average A-Weighted Sound pressure. The noise level is to be measured at the perimeter of existing non-participating residences.	Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity. Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.	Noise level shall not exceed 60 dB, including constructive interference effects, measured at the closest point on the closest property line from the base of the system.	Noise level shall not exceed 45 dB, including constructive interference effects, measured at the closest point on the closest non-participating property line from the base of the system. The noise level shall not exceed 35 dB at the nearest non-participating residence.	Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity. Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

Table 2. State-level sound requirements

State Examples	
North Dakota (State)	Sound levels of wind turbines within one-hundred *(*100*)* feet of any non-participating residence will *not exceed* 45 dBA (Leq).
Wisconsin (State)	Section PSC 128.14 Noise Criteria (3)(a) Noise Limits. Except as provided in par. (b), subs. (4) (c) and (5), an owner shall operate the wind energy system so that the noise attributable to the wind energy system does not exceed 50 dBA during daytime hours and 45 dBA during nighttime hours
New York (State)	A maximum noise limit of forty-five (45) dBA Leq (8-hour), at the outside of any existing non-participating residence, and fifty-five (55) dBA Leq (8-hour) at the outside of any existing participating residence.
Illinois (State)	A county may not set a sound limitation for wind towers in commercial wind energy facilties or any components in commercial solar energy facilities that is more restrictive than the sound limitations established by the Illinois Pollution Control Board under 25 Ill. Adm. Code Parts 900, 901, and 901. This effective results in a 47 dBA sound level at the exterior of non-participating homes.
Michigan (State)	The wind energy facility does not generate a maximum sound in excess of 55 average hourly decibels as modeled at the nearest outer wall of the nearest dwelling located on an adjacent nonparticipating property. Decibel modeling shall use the A-weighted scale as designed by the American National Standards Institute.
Nebraska (County)	Typically 45 dBA to 50 dBA to non-participating residences
Kansas (County)	Typically 45 dBA to 50 dBA to non-participating residences

There have been hundreds of sound model reports generated for the wind projects across North America. Review of these reports shows that a minimum setback distance from wind turbines, modeled with multiple turbines in a project, to achieve a 45 dBA sound level at a home typically requires a setback distance of approximately 1,500 ft (Whitfield Aslund, 2013).

In recent years there have been a number of changes in wind turbine technology. Wind turbine nameplate capacity in megawatts (MW) has been increasing. This has resulted in taller hub heights, longer blades (rotor diameter) and overall height of the wind turbines. In addition, there has been improvement in blade technology, where blades typically now have serrated edges to reduce sound levels emitted from the turbines. The resulting sound power level (SPL) from these newer turbines varies considerably across turbine type and manufacturer. In many instances the sound emitted from the larger turbines is similar and, in many cases, lower than the smaller, older turbines.

Regardless of how tall the wind turbines are, or their SPL, it is still incumbent on the wind energy project developers to ensure that the regulated sound level at homes is met. The SPL of the wind turbine model to be used will directly affect how far it must be setback to meet permitted wind turbine sound levels at homes. Therefore, sound levels and setback distances to homes must be evaluated in tandem to ensure compliance with permit requirements. Setback distances from homes should not be set at a distance that would be far in excess than those required to meet the permitted sound level.

Once a project becomes operational it is possible to measure the sound levels at exterior of homes to ensure compliance with permit conditions. This is commonly referred to as post-construction sound monitoring. Field verification testing has demonstrated that proper modeling of sound in the pre-construction permitting process ensures compliance once the wind turbines are operational. If post-construction sound monitoring does reveal compliance issues, the operator is required to bring the offending turbine back within permitted levels. This can be achieved through the noise reduction modes (NRO) in turbines, but is not desirable for the operators as it can affect power output. Therefore, it is imperative that the pre-construction sound modeling is conducted correctly by trained professional acousticians.

OEHM Recommended Sound/Noise Ordinance

Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

OEHM cannot support the Yankton Wind Task Force's proposed amendments to the noise standards. There is no jurisdiction with a 35 dBA sound standard at the exterior of non-participating residences where wind projects are in construction or operation. This is because the setback distance to the home would be far in excess of 1 mile and would exclude the development of wind energy in a county, this is equally true of a 45 dBA sound limit at all non-participating property lines.

Instead, the Planning Commission should consider adopting a commonly applied standard of 45 dBA 10-min Leq at non-participating homes that would align with other South Dakota counties and the PUC requirements, and other Midwestern states. It is a level that ensures the protection of sleep and health of residents.

4.1.2 Shadow Flicker

Shadow flicker occurs when interruption of sunlight by the wind turbine blades results in a change in light intensity within a home or building. The flickering phenomenon does not occur unless one is inside a building or structure with windows.

OEHM Recommends Adopting the Wind Task Force Shadow Flicker Standard

A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and dwellings within a two (2) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any ~~receptor~~ residence shall not exceed thirty (30) hours per year within the analysis area. A Shadow Flicker Control System shall be installed upon all turbines which will cause a shadow effect upon an occupied residential dwelling.

As demonstrated in Appendix A, shadow flicker does not cause health impacts. Instead, governments around the world have set what they believe to be reasonable limits on the amount of shadow flicker that non-participating dwellings should experience.

The internationally developed shadow flicker models are very accurate in predicting shadow flicker at dwellings. Similar to the sound model, it is a cumulative effects model where the location of each of the turbines in a project and those within 1.5 miles of a neighboring project are inputted along with the location of the dwellings. Then based on a simple physics model using the location of the sun throughout the year it generates the dates and times that shadow flicker could occur at dwellings from all of the surrounding turbines.

As the height of turbines has increased, so has the distance from which shadow flicker can be cast from the turbine to a dwelling. For those turbines greater than 500 ft to the total tip height it is possible that you could have exceedances of the 30 hour a year of shadow flicker at a residence. That said, there are curtailment measures that can be put in place to ensure that the turbines can be stopped during any shadow flicker events that exceed the proposed ordinance.

OEHM believes that the Yankton Wind Task Force proposed change to the ordinance be adopted, with the only change from ‘receptor’ to ‘residence’. It is aligned with other counties in South Dakota and other Midwestern states (Table 3).

Table 3. Shadow Flicker

	Codington County **Ordinance #68**	**Deuel County** **Section 1215. Wind Energy System (Wes) Requirements.**	**Grant County** **Section 1211. Wind Energy System (Wes) Requirements**	**Yankton Existing Ordinance**	**Yankton Wind Task Force Recommendation**	**OEHM Recommendation**
Shadow Flicker	A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and occupied dwellings within a one (1) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed thirty (30) hours per year within the analysis area.	Limit for allowable shadow flicker at existing residences to no more than 30 hours annually.	A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and occupied dwellings within a one (1) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed thirty (30) hours per year within the analysis area.		A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and dwellings within a two (2) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any receptor shall not exceed thirty (30) hours per year within the analysis area. A Shadow Flicker Control System shall be installed upon all turbines which will cause a shadow effect upon an occupied residential dwelling. Exception: The Board of Adjustment may allow for a greater amount of flicker than identified above if the participating or non-participating landowners agree to said amount of flicker. If approved, such agreement shall be permanently attached to the approved conditional use permit and shall be filed as a permanent encumbrance against the legally described parcel(s) for which the waiver is granted.	Use language proposed by Yankton County Wind Task Force with the exception of replacing “receptor” with “residence”

5 Setback Guidelines in Other Jurisdictions

The SD PUC does not prescribe any setback to residences and differs to the local counties. However, they have adopted as part of conditions to wind projects a setback to non-participating property lines:

> *Wind turbines shall be set back at least 1.1 times the tip height, with a minimum set back distance of 500 feet, from any surrounding property line. However, if the Project owner has a written agreement with an adjacent landowner allowing the placement of the wind turbine closer to the property line, the wind turbine may be placed closer to the property line shared with that adjacent landowner.*

OEHM agrees that it is appropriate to divide setback distances between participating and non-participating residences. It is also important to ensure that setback distances to non-participating property lines, road ROWs, and utilities ensure protection against ice throw, blade failure and tower collapse. It is also common practice to establish a reasonable setback to municipal boundaries that allow for expanded growth of urban areas. In some jurisdictions setback distances to recreational important lakes have also been established.

OEHM cannot support the majority of the Yankton Wind Task Force proposed setback distances. In most instances they are excessive, do not afford any greater protection for public health and safety and would result in the sterilization of Yankton County for the development of wind projects. OEHM is not aware of any jurisdictions with such setbacks as recommended by the Wind Task Force that have wind projects under construction or in operation. There are over 1,000 operating wind turbines in South Dakota and none of the counties in which they operate have such restrictive setback requirements.

Table 4 provides example setback distances to many features in several counties in South Dakota that recently underwent ordinance revisions and have numerous operating wind projects. Table 5 provides state-level setbacks that have recently been legislated by these states. They are setbacks that have been proven to ensure the protection of public health and safety and should be considered for adoption by the Yankton County Planning Commission.

In many jurisdictions setbacks are a fixed distance to homes, whereas in others a multiplier on the total turbine height is used to establish the setback distances.

In many cases the rationale for establishing the setbacks has not been provided in a manner easily accessible by the public. However, Dr. Ollson of OEHM has been involved in the development of many of these standards and can attest that the setbacks are typically based on the distance needing to meet sound and shadow flicker requirements, protection of public safety and in some cases with an additional buffer for community acceptance.

Table 4. Setback Distances South Dakota

	Codington County Ordinance #68	Deuel County Section 1215. Wind Energy System (Wes) Requirements.	Grant County Section 1211. Wind Energy System (Wes) Requirements	Yankton Existing Ordinance	Yankton Wind Task Force Recommendation	OEHM Recommendation
Participating Residences	550' plus 2.5' feet for each additional vertical foot more than 500' in height	Distance from existing Participating residences, businesses and public buildings shall not be less than fifteen hundred feet.	1,500 ft	Distance from on-site or lessor's residence shall be one thousand (1,000) feet.	1.5 times total height	1,000 feet or 1.5x total height, whichever is greater
Non-Participating Residences	1,500' plus 2.5' feet for each additional vertical foot more than 500' in height	Distance from existing Non-participating residences and businesses shall not be less than four times the height of the wind turbine.	1,500 ft	Distance from existing off-site residences, business and public buildings shall be one thousand three hundred and twenty feet (1,320) feet	2 miles	1,500 feet or 3x total height, whichever is greater
Non-Participating Property Lines	110% of the height of the wind turbine*	Distance from any property line shall be one hundred ten percent (110%) the height of the wind turbine, measured from the ground surface to the tip of the blade when in a fully vertical position unless wind easement has been obtained from adjoining property owner.	500 Feet or 110% of the vertical height of the wind turbine, whichever is greater	Distance from any property line shall be 500 feet or one point one (1.1) times the height of the wind turbines depending upon which is greater, measured from the ground surface to the tip of the blade when in a fully vertical position unless wind easement has been obtained from adjoining property owner.	2 miles	1.1 x (110%) total height of the turbine
Participating property lines					1.5 times total height	No setback
Public ROW and Roads	110% of the height of the wind turbine	one hundred ten percent (110%) the height of the wind turbines	500 Feet or 110% of the vertical height of the wind turbine, whichever is greater	500 feet or one point one (1.1) times the height of the wind turbines depending upon which is greater	1.5 times total height	1.1 x (110%) total height of the turbine
Municipal Boundaries	5,280 feet (1 mile)	Distance from the municipalities of Altamont, Astoria, Brandt and Goodwin of 1 mile from the nearest residenceand1½ miles from the city limits of the towns of Gary, Toronto and Clear Lake, except the area of Clear Lake located in sections 11, 12 and 14.	5,280 ft		2 miles	5,280 feet (1 mile)
Utilities					1.5 times total height	1.1 x (110%) total height of the turbine
Lakes, Rivers and Stream		Distance from the Lake Park District located at Lake Cochrane: 3 miles; Distance from the Lake Park District located at Lake Alice: 2 miles; and 1 mile from the Lake park District located at Bullhead Lake.			1 Mile	1 mile from identified Lake Districts or valued recreational lakes, no setbacks for rivers or streams

Table 5. Typical North American Jurisdiction Wind Turbine Setbacks from Homes.

State Examples	Minimum Setback for Wind Turbines from Residential Dwellings
North Dakota (State)	*One and one-tenth times the height of the turbine from the property line of a nonparticipating landowner and three times the height of the turbine from an inhabited rural residence of a nonparticipating landowner, unless a variance is granted.*
Wisconsin (State)	The lessor of 1,250 feet or 3.1 times the maximum blade tip height to homes.
New York (State)	Non-participating, non-residential Structures 1.5 times, non-participating residences 2 times
Illinois (State)	1.1 times tip height to non-participating property lines, 2.1 times tip height to non-participating receptors.
Michigan (State)	2.1 times from occupied community buildings and residences on nonparticipating properties 1.1 times from non-participating property lines
Nebraska (County)	Varies county by county but most common between 1,000 ft to 1,500 ft
Kansas (County)	Varies county by county but most common between 1,000 ft to 1,500

The typical setback distance in South Dakota to non-participating residences is 1,500 ft. This is similar to what many counties have established across the United States, while some states have adopted multipliers on turbine height setback distances of 2 – 3x total turbine height between non-participating homes and wind turbines.

OEHM Recommended Setbacks

OEHM recommends that Yankton County Planning Commission adopt the recommended setbacks in Table 4.

There is no scientific basis to increase these setbacks. It would afford no additional protection of public health and safety and would unduly restrict areas for development. It would also be consistent, or greater than, other jurisdictions' setback standards in South Dakota and across the United States.

In all cases these jurisdictions have successfully hosted wind projects for one to two decades. It is true that there are jurisdictions that have greater setbacks. However, in most, if not all instances these setbacks (>1,500 ft or 3 times tip height) were designed to exclude wind projects from being built in their communities. These excessive setback distances afford no greater health protection for resident's health.

6 Consideration Cumulative Effects and Visual Aspect of Wind Turbines

Another issue in determining appropriate setbacks is the cumulative effect and visual impact of projects on community members. Often the question becomes how many turbines in a community are enough and how far should they be setback for impact on viewscape. There are two distinct issues with respect to this topic. The first is the cumulative effect of the number of wind turbines on public health from sound and shadow flicker. The second is the visual aspect of the turbines on the horizon.

First, health impacts are assessed by the adherence to the sound and shadow flicker standards, regardless of the number of turbines in an area. Each of the sound and shadow flicker standards require an assessment of the cumulative effect of the individual project, as well as any adjacent project within the area. That is because the largest zone of influence of sound from one turbine to the next is within 1.5 miles and the same is true for shadow flicker. That means that cumulative effects from all proposed and existing wind turbines are always accounted for.

In terms of the visual aspect of turbines on the horizon, beauty is truly in the eye of the beholder. There are numerous studies that describe that approximately 10% of the population living in proximity to a wind turbine will be annoyed by their presence. However, given that wind turbines do not impact property values, impact health or result in other impacts on quality-of-life OEHM does not believe that Counties should use visual cue as the basis to increase setback distances to turbines. This would effectively be a roundabout way of zoning out wind turbines based on visual appearance. There are Counties across the United States that host hundreds of wind turbines without impact on their communities.

> **Implications of Cumulative Effects for Yankton County Setback to Residences:**
>
> The sound and shadow flicker studies inherently include a cumulative effects assessment. There are numerous counties across North America that have wind turbines that have been operating harmoniously with the communities for over a decade.

In addition, setbacks to try and limit the impact of wind turbines on the landscape are not effective, essentially if one can see a turbine on the horizon and they do not want them, no setback distance will be effective in changing their mind. OEHM does not support the use of the Wind Task Force proposed 2 mile setback to non-participating homes or property lines.

7 Conclusion on Setting a Proper Siting Guidelines for Wind Energy Projects

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

Wind energy projects bring clear socio-economic health benefits to host communities. These are in the form of taxes, landowner payments, jobs, potential impact on healthcare costs and an offset for the need for fossil fuel derived energy. These all have indirect health benefits at the individual and community level. At the same time wind energy projects allow for continued use and enjoyment of rural areas.

The Yankton County Wind Task Force proposed sound and setback amendments to the zoning ordinance are far too restrictive, are not aligned with other counties or jurisdictions that host operating turbines and afford no greater protection of public health and safety that other jurisdictions. If the Planning Commission were to adopt these recommendations it would effectively ensure that no wind projects could be built anywhere in Yankton County.

Based on totality of these findings OEHM believes that the following siting guidelines are protective of public health, while providing a reasonable balance between community concerns and achievable project siting constraints:

- Noise level shall not exceed 45 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from at the perimeter of the principal and accessory structures of existing off-site non-participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

  Noise level shall not exceed 50 dBA, average A-weighted Sound pressure including constructive interference effects measured twenty-five (25) feet from the perimeter of participating residences, businesses, and buildings owned and/or maintained by a governmental entity.

- A Flicker Analysis shall include the duration and location of flicker potential for all schools, churches, businesses and dwellings within a two (2) mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sun-rise to sun-set over the course of a year. The analysis shall account for topography but not for obstacles such as accessory structures and trees. Flicker at any ~~receptor~~ residence shall not exceed thirty (30) hours per year within the analysis area. A Shadow Flicker Control System shall be installed upon all turbines which will cause a shadow effect upon an occupied residential dwelling. Exception: The Board of Adjustment may allow for a greater amount of flicker than identified above if the participating or non-participating landowners agree to said amount of flicker. If approved, such agreement shall be permanently attached to the approved conditional use permit and shall be filed as a permanent encumbrance against the legally described parcel(s) for which the waiver is granted. (This is similar language as proposed by the Wind Task Force).

- Infrasound and low frequency noise, although emitted from wind turbines, have been demonstrated to be at level that is too low to be of health concern. Therefore, no additional setback standard is required.
- Public safety setbacks of 110% (or 1.1 times) tip height of a wind turbine to non-participating property lines, utilities and roads ensure protection against ice throw, blade failure, and tower collapse. Further distances are not recommended and not required to protect public safety. There is no need to published setback restrictions to participating property lines.
- Setback to Municipal boundaries: 5,280 ft or 1 mile
- Setback to residences:
  - Participating residences: 1,000 ft or 1.5x total height
  - Non-Participating residences: 1,500 ft or 3x total height

These recommended siting guidelines are consistent with requirements of other South Dakota Counties, many counties in Midwestern states, and in most State-level requirements across the United States. OEHM urges the Yankton County Planning Commission not to adopt the recommendations of the Wind Task Force, rather take additional time to study the issue and recommend reasonable wind turbine siting guidelines that ensure the protection of public health and safety of your residents.

OLLSON ENVIRONMENTAL HEALTH MANAGEMENT

Christopher Ollson, PhD

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Appendix A

Review of Health Implications for Living Around Wind Turbines as the Relate to Setbacks to Residences

9 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 one of the fastest growing sources of new electric power generation, with several countries achieving high levels of wind power capacity.

Over 150 studies have been published worldwide to examine the relationship between wind turbines and possible human health effects. Based on the findings and scientific merit of these studies, lead health and medical authorities have stated that when sited properly (i.e., based on distance and/or noise guidelines and setbacks), wind turbines are not causally related to adverse effects.

Appropriate science-based setbacks and sound limits are required to ensure the protection of public health and safety. One needs to ensure these protections for issues on:

- Sound (audible noise)
- Low frequency noise and infrasound
- Shadow Flicker
- Setback Distances – public safety

The focus of this review is on the non-participating residences.

9.1 Sound (Noise): Audible, Low Frequency and Infrasound

Perhaps one of greatest areas of research on proper siting of wind turbine to avoid health issues is in relation to wind turbine sound and setback distances to homes. The past decade has seen numerous independent research efforts undertaken in the U.S., Canada, Europe and Australia.

In 2014, Health Canada released the findings of their Wind Turbine Noise (WTN) and Health Study. This is most comprehensive study of its kind to date and its results will be referenced a number of times in this report. The following provides a high-level overview of the study design. This study was initiated in 2012 and was a partnership between Health Canada and Statistics Canada to understand the potential impacts of wind turbine noise on health and wellbeing of communities in Southern Ontario and Prince Edward Island (PEI). A total of 1238 households participated in the study, with an almost 80% response rate of all households within 6 miles (10 km) of projects investigated, making it the largest and most comprehensive study ever undertaken around the world.

Households were located between 820 ft (250 m) and 6 mi (10 km) from operational wind turbines. The A-weighted (dBA) sound levels (audible sound/noise) were grouped into 5 dBA increments with the loudest level in the study at the exterior of a home being 46 dBA Leq (highest nighttime level). These levels are lower than the typical Western state standards of 50 dBA at the exterior of homes.

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

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

Health Canada'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."*

I note that Health Canada has provided the following limitations to their study results (Health Canada, 2014):

> *As with other studies of this nature, a number of limitations and considerations apply to the study findings including:*
>
> - *results may not be generalized to areas beyond the sample as the wind turbine locations in this study were not randomly selected from all possible sites operating in Canada;*
> - *results do not permit any conclusions about causality; and,*
> - *results should be considered in the context of all published peer-reviewed literature on the subject.*

It is with these limitations in mind, that I have provided my interpretation of the significance of the results in relation to setting of appropriate sound and setback standards.

Since 2015, Health Canada has published numerous peer-reviewed scientific publications with their results. This research will be discussed as appropriate throughout this report and is often referred to the "Michaud" work as Dr. David Michaud was typically the first author on these papers.

9.1.1 Audible Sound

With any sound source sleep is the critical health endpoint that needs to be protected at residences. However, there are a number of other concerns that have been raised with living in proximity to wind turbines. The past decade of rapid increase in wind power development in North America has been coupled with some who believe that wind turbines should be set miles back from residences, or else it will result in public health impacts. However, the weight of scientific evidence does not hold this to be true. The following section provides an overview of the most up to date, peer-reviewed published, evidence to understand how the proper operation of a wind turbine project should not interfere with sleep.

9.1.1.1 Sleep

The critical effect from a health perspective in setting any nighttime 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 in the American context.

The following provides an overview of a number of wind turbine specific sleep studies in relation to nighttime noise levels at exterior of homes.

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 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, 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."*

The importance of this study is that for the first time self-reported sleep concerns, Pittsburgh Sleep Quality Index (PSQI – a self-report questionnaire on sleep activity) results and objective measures of sleep using actigraphy were investigated for wind turbine noise.

> *"Table 2 presents the summary statistics for PSQI as both a continuous scale and a binary scale (the proportion of respondents with poor sleep; i.e., PSQI above 5) by WTN exposure categories. Analysis of variance was used to compare the average PSQI score across WTN exposure groups (after adjusting for provinces). There was no statistical difference observed in the mean PSQI scores between groups (P = 0.7497) as well as no significant difference between provinces (P = 0.7871) (data not shown). Similarly, when modeling the proportion of respondents with poor sleep (PSQI > 5) in the logistic regression model, no statistical differences between WTN exposure groups (P = 0.4740) or provinces (P = 0.6997) were observed (see supplemental material)."*

Table 6 is an excerpt from Michaud et al. (2016; their Table 1), provides an overview of the self-reported sleep magnitude and contribution of disturbance. It was reported that there was no statistical difference in self-reported sleep disturbance for participants living with exterior to home sound levels from <25 dBA to 40-46 dBA. They reported:

> "*The prevalence of reported sleep disturbance was unrelated to wind turbine noise levels.*"

Table 6. Self-reported magnitude and contributing sources of sleep disturbance.

Table 1—Self-reported magnitude and contributing sources of sleep disturbance.

Variable	Wind Turbine Noise, dB(A) < 25	25–30	30–35	35–40	40–46	Overall	CMH P value[a]
n	83	95	304	519	234	1,235	
Self-reported sleep disturbance n (%)							
Not at all	29 (34.9)	44 (46.3)	112 (36.8)	208 (40.1)	85 (36.3)	478 (38.7)	
At least slightly[b]	54 (65.1)	51 (53.7)	192 (63.2)	311 (59.9)	149 (63.7)	757 (61.3)	0.7535
Highly[c]	13 (15.7)	11 (11.6)	41 (13.5)	75 (14.5)	24 (10.3)	164 (13.3)	0.4300
Source of sleep disturbance (among participants at least slightly sleep disturbed) n (%)							
n[d]	53	51	186	298	138	726	
Wind turbine	0 (0.0)	2 (3.9)	4 (2.2)	45 (15.1)	31 (22.5)	82 (11.3)	< 0.0001
Children	9 (17.0)	12 (23.5)	21 (11.3)	36 (12.1)	20 (14.5)	98 (13.5)	0.2965
Pets	7 (13.2)	12 (23.5)	9 (4.8)	45 (15.1)	22 (15.9)	95 (13.1)	0.3582
Neighbors	6 (11.3)	5 (9.8)	9 (4.8)	13 (4.4)	5 (3.6)	38 (5.2)	0.0169
Other	41 (77.4)	35 (68.6)	162 (87.1)	232 (77.9)	87 (63.0)	557 (76.7)	0.0128
Stress/anxiety	6 (11.3)	2 (3.9)	21 (11.3)	33 (11.1)	11 (8.0)	73 (10.1)	0.8938
Physical pain	11 (20.8)	9 (17.6)	50 (26.9)	48 (16.1)	18 (13.0)	136 (18.7)	0.0289
Snoring	5 (9.4)	6 (11.8)	17 (9.1)	20 (6.7)	12 (8.7)	60 (8.3)	0.4126

Participants were asked to report their magnitude of sleep disturbance over the last year while at home by selecting one of the following five categories: not at all, slightly, moderately, very, or extremely. Participants that indicated at least a slight magnitude of sleep disturbance were asked to identify all sources perceived to be contributing to sleep disturbance. [a]The Cochran Mantel-Haenszel chi-square test was used to adjust for provinces. [b]At least slightly sleep disturbed includes participants indicating the slightly, moderately, very or extremely categories. [c]Highly sleep disturbed includes participants who reported the very or extremely categories. The prevalence of reported sleep disturbance was unrelated to wind turbine noise levels. [d]Of the 757 participants who reported at least a slight amount of sleep disturbance, 31 did not know what contributed to their sleep disturbance. Of the remaining 726, at least one source was identified. Columns may not add to sample size totals as some participants did not answer questions and/or identified more than one source as the cause of their sleep disturbance.

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) [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) [820 ft] had no statistically significant effect on any measure of sleep quality.*

The findings of Michaud et al., (2016) supports the position that residents living with exterior nighttime sound levels of <46 dBA at the exterior of homes should not experience sleep disturbance from the wind turbine sound.

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

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

Bakker et al., (2012) completed the most compelling research, prior to the Health Canada Study (2014), into wind sound awakenings. 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 in Table 7 (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 from wind turbines at the exterior of neighboring homes.

Table 7. Sound sources of sleep disturbance in rural and urban area types, only respondents who did not benefit economically from wind turbines (Bakker et al, 201)

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 the Health Canada sleep study (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".*

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

The first study to be published on before-after operation effect of wind turbine noise on objectively measured sleep was conducted in 16 participants living within 1.25 mi (2 km) to a five-wind turbine project in Ontario, Canada. It should be noted that outdoor sound measurements ranged between 40 – 45 dBA before operation and 38-42 dBA after the turbines became operational. The average indoor sound level in the bedrooms was reported as 31 dBA while the wind turbines were operational. For the first time authors used portable polysomnography (PSG), which is a comprehensive system that objectively monitors people's sleep in their homes.

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

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

These findings are consistent with the previous reported studies.

Smith et al. 2020. A laboratory study on the effects of wind turbine noise on sleep: results of the polysomnographic WiTNES study. SLEEPJ, 2020, 1–14

This Swedish study was the first of its kind to be conducted in a sleep laboratory setting. A total of 50 participants were recruited for the study. Twenty-four "Exposed" participants were selected from a group who lived within 1 km of a wind turbine and self-reported annoyance or sleep disturbance at their homes. There were 26 participants in the "Reference" group that did not live close to wind turbines.

Each of the group's physiologic and self-reported sleep effects was analyzed using polysomnography, electrocardiography, salivary cortisol and questionnaire endpoints. Their sleep was monitored over three consecutive nights (23:00 to 7:00): habituation night, quiet control night, and wind turbine noise night that simulated a 32 dBA Leq wind turbine sound in homes. Although this study does have some merit the results should be viewed with caution. It involved only a single night exposure to wind turbine noise in a laboratory setting, there may have been self selection bias with those living in proximity to wind turbines and the results could at best be used to establish in home future studies.

The researchers reported:

> *Physiologic effects of WTN were not found for the majority of sleep measures, which implies that nocturnal WTN may not be of major public health relevance. On the other hand, the self-reported data give indications of poorer sleep quality and restoration, which may contribute to a risk for long-term health effects in ways not captured by PSG.*

However, the researchers also reported:

> *The Exposed study group gave a more negative rating of sleep quality, tiredness, and sleeping worse than usual compared to the Reference group in both the Control and WTN-night. They also reported higher noise-induced sleep disturbance overall, in both the Control and WTN-night compared to the Reference group.*

When reviewed in context to the sleep studies that were actually completed inside homes of those living in proximity to wind turbines (Michaud et al.,2016 and Jalali et al., 2016) the Smith et al. (2020) study is consistent in that physiological are unlikely of major public health relevance. The self-reported sleep results in such a small number of participants is not consistent with the field studies involving many more participants.

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

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

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

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

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

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

The authors also opined that:

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

To date, this is the most comprehensive review of wind turbine sound exposure and sleep. It is acknowledged that the authors did suggest that further in home studies are needed to provide “conclusive evidence”. This additional research is currently underway in Australia.

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.*

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. This suggests that the continued use the 45 dBA sound limit commonly used in South Dakota is appropriate for ensuring the protection of sleep.

Conclusion on Wind Turbine Noise and Sleep

The recent published findings reveal that there is no association between exterior wind turbine sound levels of up to 46 dBA and impact on sleep. The link between reported sound levels, annoyance and sleep disturbance does not appear to hold. In other words, regards of the reported wind turbine sound levels or annoyance levels, sleep outcomes are not different for people living with up to 46 dBA at their home to those with 30 dBA at their homes.

9.1.2 Low Frequency Noise 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 typically measured and reported on the C-weighted scale (dBC) to account for higher-level measurements and peak sound pressure levels.

Universally wind turbine sound standard are set using audible dBA levels, as they are in South Dakota, and approved based on modeling. Over the past couple of years there have been a limited number of researchers that have speculated that wind turbine infrasound and LFN could be the potential cause of potential 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. In addition, just because there may be a distinct acoustical signature that allows sound engineers to distinguish between low levels of infrasound or LFN from turbines does not mean that it results in health impacts.

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 LFN and infrasound include ocean waves, thunder, and even the wind itself. Anthropogenic sources include road traffic, refrigerators, air conditioners, machinery, and airplanes.

Given the growing attention being paid to this issue several recent studies have been published.

Berger et al., 2015. *Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines*" in the journal Frontiers in Public Health Vol 3, Art. 31

The purpose of this paper was to investigate whether typical audible noise-based guidelines for wind turbines account for the protection of human health given the levels of infrasound and LFN typically produced by wind turbines. New field measurements of indoor infrasound and outdoor LFN at locations between 1,312 ft (400 m) and 2,952 (900 m) from the nearest turbine, which were previously underrepresented in the scientific literature, were reported and put into context with existing published works. 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.

The paper discusses two guidelines for exposure to infrasound (dBG), although neither is specific to wind turbine noise. The Queensland Department of Environment and Resource Management's

Draft *ECOACCESS Guideline- Assessment of Low Frequency Noise* proposed an interior infrasound limit of 85 dBG (Roberts, 2004). This value was derived based on a 10 dB protection level from the average 95 dBG hearing threshold (Watanabe, 1990) and previous Danish recommendations for infrasound limits (Jakobsen, 2001). The Japanese Handbook on Low Frequency Noise provides an infrasound reference value of 92 dBG at 10 Hz and 1/3 octave bands up to 80 Hz (Kamigawara, 2006). These values were derived from investigations that monitored complaints of mental and physical discomfort from healthy adults exposed to low frequency sounds in a room (Kamigawara, 2006).

These guidelines for infrasound would not be reached in homes situated near the Crazy Mountain Wind Power Project. Quite simply, the homes are located too far back from the turbines based on audible sound criteria to have the accompanying infrasound levels exceed these guidelines. In fact, these levels of infrasound are not reached even in close proximity to the wind turbines themselves.

Collective, these data in conjunction with previous reports indicate that levels of infrasound and LFN are not sufficient to induce adverse health effects; therefore health-based audible noise guidelines are suitable for the protection of human health.

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, nighttime sound level on the A-weighted scale, and the setback to homes, act as a surrogates to ensure that levels of LFN and infrasound will not impact health or sleep.

In 2012, Turnbull *et al*. published a peer-reviewed paper titled *Measurement and Level of Infrasound from Wind Farms and Other Sources* to put this issue into context with other LFN and infrasound sources (Turnbull et al., 2012). The study was conducted in Australia around wind turbines and other common sources of infrasound and included the Clements Gap Wind Farm and the Cape Bridgewater Wind Farm. The Clements Gap Wind Farm is comprised of 27 Suzlon S88 2.1 MW wind turbines and the Cape Bridgewater Wind Farm is comprised of 29 Repower MM82 2.0 MW wind turbines. They determined that infrasound from wind turbines reached ambient (background) levels within 656 ft (200 m) to 1,180 ft (360 m) (Table 8). The levels were found to be lower than those measured around beaches, gas fired plants and major roadways. Indeed, humans are regularly exposed to infrasound from several natural and engineered sources at levels that exceed those produced by wind turbines. These findings are consistent with other scientific papers in the field.

Table 8. Infrasound Measurements Near Wind Turbines and other Sources (Turnbull, 2012)

Noise Source	Measured Level (dB(G))
Clements Gap Wind Farm at 85m	72
Clements Gap Wind Farm at 185m	67
Clements Gap Wind Farm at 360m	61
Cape Bridgewater Wind Farm at 100m	66
Cape Bridgewater Wind Farm at 200m	63
Cape Bridgewater Wind Farm ambient	62
Beach at 25m from high water line	75
250m from coastal cliff face	69
8km inland from coast	57
Gas fired power station at 350m	74
Adelaide CBD at least 70m from any major road	76

With respect to low frequency noise (LFN) and infrasound it is important to understand that Health Canada's Wind Turbine Noise study (Health Canada, 2014; Keith et al., 2016; Michaud et al., 2016) also includes consideration of these sound levels and their impact on heath.

Keith et al., 2016 (part of the Health Canada Research):

> *"The simple relationship between A- and C- weighted levels suggests that there is unlikely to be any statistically significant difference between analysis based on either C- or A-weighted data."*

Michaud et al., 2016:

> *"In the current study, low-frequency noise was estimated by calculating C-weighted sound pressure levels. No additional benefit was observed in assessing low frequency noise because C- and A-weighted levels were so highly correlated. Depending on how dB(C) was calculated and what range of data was assessed, the correlation between dB(C) and dB(A) ranged from r = 0.84 to r = 0.97."*

Because LFN (dBC) and A-weighted (dBA) levels were so highly correlated, Health Canada's conclusions on the absence of direct or indirect health effects for audible wind turbine noise <46 dBA are true also for the noise in the LFN (dBC) range around the wind turbines they studied. In otherwords, one does not have to conduct additional studies on LFN to determine potential noise health related impacts or sleep disturbance from wind turbines. Therefore, exposure to these frequencies are inherently included in the findings that no sleep disturbance was found in people living with up to 46 dBA audible sound (Michaud et al., 2016).

McCunney et al. (2014), published a study entitled "Wind Turbines and Health: A Critical Review of the Scientific Literature" in the Journal of Environmental and Occupational Medicine. This review came to similar findings of those published by others (e.g., Knopper and Ollson, 2011; MassDEP, 2012; Knopper et al., 2014; Merlin et al., 2014). This review conducted a significant review of infrasound and LFN levels from turbines and potential impact on health.

> *"Sounds with frequencies lower than 20 Hz (ie, infrasound) may be audible at very high levels. At even higher levels, subjects may experience symptoms from very low-frequency sounds—ear pressure (at levels as low as 127 dB SPL), ear pain (at levels higher than 145 dB), chest and abdominal movement, a choking sensation, coughing, and nausea (at levels higher than 150 dB).80,81 The National Aeronautics and Space Administration considered that infrasound exposures lower than 140 dB SPL would be safe for astronauts; American Conference of Governmental Industrial Hygienists recommends a threshold limit value of 145 dB SPL for third-octave band levels between 1 and 80 Hz.81 As noted earlier, infrasound from wind turbines has been measured at residential distances and noted to be many orders of magnitude below these levels."*

and

> *"Components of wind turbine sound, including infrasound and low frequency sound, have not been shown to present unique health risks to people living near wind turbines."*

In 2016 the Ministry for the Environment, Climate and Energy of the Federal State of Bade Wuerttemberg in Germany reported on their study "*Low-frequency noise including infrasound from wind turbines and other sources*" (MECE, 2016). The objective of the research was to collect field measurement of infrasound and low-frequency noise around six different turbines by different manufacturers ranging in size from 1.8 to 3.2 MW. Measurements were taken at 492 ft (150 m), 984 ft (300 m) and 2,296 ft (700 m) from wind turbines. Measurements of other common sources of infrasound and low frequency noise were also collected for comparative purposes.

Figure 2 provides detail on the range of infrasound and low frequency noise measured at 984 ft (300 m) from a wind turbine. 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 an increase in low frequency sound. The levels were considerably lower than either being in the interior of a car, near the roadside traffic or in a home with oil heating. All infrasound levels (< 20 Hz) were below the perception threshold and international standards.

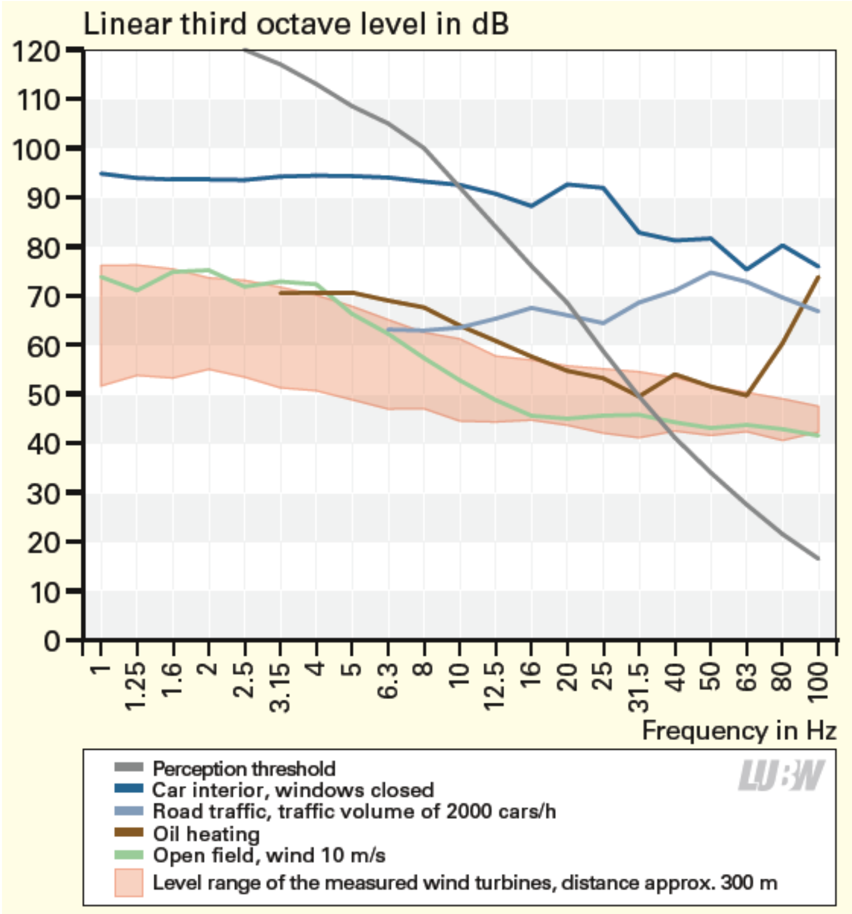

Figure 2. Measurements of infrasound and low frequency noise 300 m from wind turbines compared to other sources.

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."*

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

The hypothesis that low frequency noise or infrasound from wind turbines is a causative agent in health effects or sleep disturbance is not supported by the scientific and medical literature. Although infrasound and low frequency noise are emitted from wind turbines and their contribution above background sources can be measured close to wind turbines, the levels are typically within background levels at homes and are well below levels that could induce health impacts. Measurements at other wind farms are similar, if not lower, than natural and anthropogenic sources of infrasound that we are exposed to, and are below international guidelines on infrasound.

9.2 Other Potential Health Concerns

Although with any sound source sleep is the critical health endpoint, there are a number of other concerns that have been raised with living in proximity to wind turbines.

9.2.1 Peer Reviewed Studies on Self-Reported and Objective Measures of Health

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

There are numerous peer-reviewed studies that have explicitly examined the relationship between levels of wind turbine noise and various self-reported indicators of human health and well-being (e.g., Health Canada 2014 and associated publications; Bakker et al. 2012; Janssen et al. 2011; Pedersen 2011; Pedersen and Persson Waye 2004; 2007). These studies have included 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. 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) at noise levels below 45 dBA.

The most comprehensive study on health and living in proximity was that undertaken by Health Canada between May and September 2013. Again this study had a 78.9% response rate of those living within 10 km of numerous wind projects in Ontario and PEI. In 2016, Health Canada released a series of peer-reviewed publications on their findings in a special edition of the Journal of Acoustical Society of America in late March of 2016. Given that it was the most comprehensive study undertaken a great deal of weight on this research and its findings is placed on it, given that it is the most recent and comprehensive a cross-sectional epidemiological study undertaken on the topic. 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 following sections contain conclusions of the three papers examining the potential for health issues to manifest living as close as 820 feet from a turbine and sound levels of up to 46 dBA.

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

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

Table 5 is a reproduction of Table V. of the study provides the list of self-reported health effects in the population studied broken down by varying wind turbine noise levels (dBA). Essentially this table reports the prevalence of each self-reported health effect, across varying sound levels, and then uses statistical analysis to provide a CHM *p-value* to determine if the self-reported health effects are significant. Simply put, if the CHM *p-value* is less than < 0.05 then there is a difference amongst the reported effects across sound levels and vice versa if it is greater than > 0.05 then there is no difference in how people are reporting effects across the sound groupings.

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 dB. 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 and the evaluated health-related endpoints."

The Health Canada results are consistent with the previous decade of research in the field.

Table 9. Sample profile of health conditions (Michaud et al., 2016a).

TABLE V. Sample profile of health conditions.

	Wind turbine noise (dB)						
Variable *n* (%)	<25	[25–30)	[30–35)	[35–40)	[40–46]	Overall	CMH[a] *p*-value
n	84[b]	95[b]	304[b]	521[b]	234[b]	1238[b]	
Health worse vs last year [c]	17 (20.2)	12 (12.6)	46 (15.1)	90 (17.3)	51 (21.8)	216 (17.5)	0.1724
Migraines	18 (21.4)	24 (25.3)	56 (18.4)	134 (25.8)	57 (24.4)	289 (23.4)	0.2308
Dizziness	19 (22.6)	16 (16.8)	65 (21.4)	114 (21.9)	59 (25.2)	273 (22.1)	0.2575
Tinnitus	21 (25.0)	18 (18.9)	71 (23.4)	129 (24.8)	54 (23.2)	293 (23.7)	0.7352
Chronic pain	20 (23.8)	23 (24.2)	75 (24.8)	118 (22.6)	57 (24.5)	293 (23.7)	0.8999
Asthma	8 (9.5)	12 (12.6)	22 (7.2)	43 (8.3)	16 (6.8)	101 (8.2)	0.2436
Arthritis	23 (27.4)	38 (40.0)	98 (32.2)	175 (33.7)	68 (29.1)	402 (32.5)	0.6397
High blood pressure (BP)	24 (28.6)	36 (37.9)	81 (26.8)	166 (32.0)	65 (27.8)	372 (30.2)	0.7385
Medication for high BP	26 (31.3)	34 (35.8)	84 (27.6)	163 (31.3)	63 (27.0)	370 (29.9)	0.4250
Family history of high BP	44 (52.4)	49 (53.8)	132 (45.5)	254 (50.6)	121 (53.8)	600 (50.3)	0.6015
Chronic bronchitis/emphysema/COPD	3 (3.6)	10 (10.8)	17 (5.6)	27 (5.2)	14 (6.0)	71 (5.7)	0.7676
Diabetes	7 (8.3)	8 (8.4)	33 (10.9)	46 (8.8)	19 (8.2)	113 (9.1)	0.6890
Heart disease	8 (9.5)	7 (7.4)	31 (10.2)	32 (6.1)	17 (7.3)	95 (7.7)	0.2110
Highly sleep disturbed[d]	13 (15.7)	11 (11.6)	41 (13.5)	75 (14.5)	24 (10.3)	164 (13.3)	0.4300
Diagnosed sleep disorder	13 (15.5)	10 (10.5)	27 (8.9)	44 (8.4)	25 (10.7)	119 (9.6)	0.3102
Sleep medication	16 (19.0)	18 (18.9)	39 (12.8)	46 (8.8)	29 (12.4)	148 (12.0)	0.0083
Restless leg syndrome	7 (8.3)	16 (16.8)	37 (12.2)	81 (15.5)	33 (14.1)	174 (14.1)	
Restless leg syndrome (ON)	4 (6.7)	15 (17.4)	27 (11.0)	78 (17.3)	28 (16.5)	152 (15.0)	0.0629[e]
Restless leg syndrome (PEI)	3 (12.5)	1 (11.1)	10 (16.9)	3 (4.2)	5 (7.8)	22 (9.7)	0.1628[e]
Medication anxiety or depression	11 (13.1)	14 (14.7)	35 (11.5)	59 (11.3)	23 (9.8)	142 (11.5)	0.2470
QoL past month[f]							
Poor	9 (10.8)	3 (3.2)	21 (6.9)	29 (5.6)	20 (8.6)	82 (6.6)	0.9814
Good	74 (89.2)	92 (96.8)	283 (93.1)	492 (94.4)	213 (91.4)	1154 (93.4)	
Satisfaction with health[f]							
Dissatisfied	13 (15.5)	13 (13.7)	49 (16.1)	66 (12.7)	36 (15.4)	177 (14.3)	0.7262
Satisfied	71 (84.5)	82 (86.3)	255 (83.9)	455 (87.3)	198 (84.6)	1061 (85.7)	

[a]The Cochran Mantel-Haenszel chi-square test is used to adjust for provinces unless otherwise indicated, *p*-values <0.05 are considered to be statistically significant.
[b]Columns may not add to total due to missing data.
[c]Worse consists of the two ratings: "*Somewhat worse now*" and "*Much worse now.*"
[d]High sleep disturbance consists of the two ratings: "*very*" and "*extremely*" sleep disturbed.
[e]Chi-square test of independence.
[f]Quality of Life (QoL) and Satisfaction with Health were assessed with the two stand-alone questions on the WHOQOL-BREF. Reporting "*poor*" overall QoL reflects a response of "*poor*" or "*very poor*," and "*good*" reflects a response of "*neither poor nor good*," "*good*," or "*very good.*" Reporting "*dissatisfied*" overall Satisfaction with Health reflects a response of "*very dissatisfied*" or "*dissatisfied*," and "*satisfied*" reflects a response of "*neither satisfied nor dissatisfied*," "*satisfied*," or "*very satisfied.*" A detailed presentation of the results related to QoL is presented by Feder *et al.* (2015).

9.3 Recent Systematic Review on Wind Turbines and Health

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 common siting guideline of the 45 dBA sound level and a 1,500 ft setback, will ensure the protection of the community's health.

Conclusions on Other Potential Health Impacts

The weight of scientific evidence supports that permitting sound levels at the exterior of non-participating homes of up to 46 dBA Leq and a setback of 1,500 ft to dwellings would not impact sleep or other objective or self-reported measures of health.

10 Quality of Life and Wind Turbines

Determining if annoyance or any other perceived health effects for those living around wind projects has also been examined by determining if there has been a diminishment in their overall quality of life (QOL). This relates directly to whether or not annoyance leads to a deterioration of QOL.

There have been a few published papers in this field that have reached inconsistent findings (Shepherd, et al., 2011; Nissenbaum, et al., 2012; Mroczek et al., 2012). They are typically of very small sample size and lead to more questions than answers. The results of these peer-reviewed papers are best summarized in the review papers of Knopper et al. (2014) and McCunney et al. (2014).

However, the most comprehensive work that has been published in this field was through the Health Canada research.

Feder et al. 2015 An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines Journal of Environmental Research. (Health Canada)

They administered the World Health Organization Quality of Life – BREF (WHOQOL-BREF) questionnaire to 1238 participants that lived between 820 feet to 7 miles from wind turbines. This questionnaire evaluates self-reported physical health, psychological, social relationships and environment in relation to QOL. Regardless of sound level at people's homes wind turbine noise did not influence QOL. They start their Discussion with:

> *"The present study findings do not support an association between exposure to WTN up to 46 dBA [820 ft] and any of the WHOQOL-BREF domains (Physical Health, Psychological, Social Relationships and Environment) or the two stand-alone questions pertaining to rated QOL and Satisfaction with Health. Participants who were exposed to higher WTN levels did not rate their QOL or Satisfaction with Health significantly worse than those who were exposed to lower WTN levels, nor did they report having significantly worse outcomes in terms of factors that comprise the 4 domains."*

In addition, the Feder et al. (2015) paper includes a detailed discussion on how their findings compare with the previous conflicting report. Given the size and comprehensive nature of this study it should be given more weight than previous reports.

Overall, the work by Health Canada suggests that quality of life should not be diminished for residents around wind energy projects with sound levels as high as 46 dBA Leq and living within 1,500 ft of multiple wind turbines.

11 Shadow Flicker

Shadow flicker occurs when interruption of sunlight by the wind turbine blades results in a change in light intensity within a home or building. The flickering phenomenon does not occur unless one is inside a building or structure with windows. When one experiences shadowing from a turbine when standing outdoors it is simply a rotating shadow cast on the ground. Shadow flicker is unavoidable for wind turbines; however, it typically only occurs for a limited number of hours a year at a home. This is due to the fact that certain factors must be present:

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

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

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

d. the shadow will typically not be cast any further than 10x the total height of the turbine to any appreciable extent. For most modern turbines this would mean shadow flicker would not extend much past 2 km.

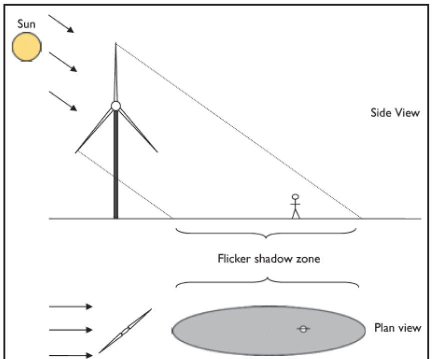

Figure 1.
Generalized geometry for turbine flicker, showing an observer in the shadow area. Note the main analysis assumes the observer and turbine blades are directly facing each other.
Epilepsia © ILAE

Conducting shadow flicker modeling has become common practice for proposed wind farm projects across Canada. There are several commercially available software packages, including WindPro that was used to model the shadow flicker for the Updated Project.

All models initially calculate a "Worst Case or Maximum Astronomical shadow" number of hours that a residence may experience shadow flicker (Assessment Case A – Updated Project). These numbers can then be adjusted to provide a "Adjusted, Realistic, Actual or Expected" number of hours of shadow flicker (Assessment Case B – Updated Project). It is important to distinguish between these scenarios, as some jurisdictions have adopted standards based on either astronomical or realistic shadow flicker hour predictions.

> ***Worst Case / Astronomical (Assessment Case A):*** *The models consider that the sun is always shining during daytime hours, the wind turbines are always rotating, and the wind direction from each turbine is such that the wind turbine is always perpendicular to the residences so that shadows could be cast at the residences. This is a predicted extreme theoretical number hours that will not occur at any residence.*
>
> ***Adjusted / Actual / Realistic / Expected (Assessment Case B):*** *The model is run in the astronomical mode and then the results are adjusted for percentage of monthly cloud cover (solar statistics) and operating hours of the wind project. Under these conditions shadow flicker will not be generated and it more accurately predicts the number of hours of shadow flicker at a residence.*

There are other obstructions that can limit both the Worst Case and the Realistic modeled numbers of shadow flicker. These include trees, shrubs, and other ancillary non-occupied structures (e.g., barns) that could interrupt the predicted shadow flicker at a home. Neither of the two Assessment Case scenarios takes into account these types of obstructions at residential receptors. Another layer of conservatism is that models are set-up and run in the "greenhouse mode". This means each residence is oriented to have omni-directional windows and thus it will produce more conservative results since it assumes that there is always a window in direct line of site of each wind turbine and the sun.

The model outputs can show the exact days, the time of day, the duration and turbine of origin of shadow flicker. These values are then summed to provide the annual number of hours of shadow flicker predicted. For the Realistic scenario (Assessment Case B) the percentage of cloud cover and operational downtime is used to adjust these values. Both Assessment Cases A and B provide a conservative estimate of shadow flicker that could be expected at a home.

11.1.1 Shadow Flicker Health, Annoyance and Nuisance

Four peer-reviewed scientific research papers were retrieved that considered the potential for shadow potential to impact health and to increase annoyance or nuisance in people living near wind turbines.

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

Following on this informal polling two of the United Kingdom's academic experts in epilepsy published scientific research articles in the area. I previously provided to the Commission that Harding et al. (2008) and Smedley et al. (2010) have published the seminal studies dealing with this concern. Both authors investigated the relationship between photo-induced seizures (i.e., photosensitive epilepsy) and wind turbine shadow flicker. Both studies suggested that flicker from turbines that interrupt or reflect sunlight at frequencies greater than 3 Hz pose a potential risk of inducing photosensitive seizures in 1.7 people per 100,000 of the photosensitive population. For turbines with three blades, this translates to a maximum speed of rotation of 60 revolutions per minute (rpm). The Nordex 155 turbine in the Updated Project has a nominal rotational speed of 11 rpm, well below a speed that could trigger epileptic seizure.

Two of the most comprehensive and widely cited published scientific review articles on this topic are Knopper & Ollson (2011) and McCunney et al. (2014). Both papers concluded that shadow flicker is not associated with health effects for those living in proximity to wind turbines. Knopper & Ollson (2011) concluded:

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

Since 2014, there have been two studies conducted that examined the potential for shadow flicker to lead to increased annoyance for those living near wind turbines.

Voicescu et al., 2016. Estimating annoyance to calculated wind turbine shadow flicker is improved when variables associated with wind turbine noise exposure are considered. J. Acoust. Soc. Am. 139 (3),

In 2016, Health Canada published a paper using the questionnaires of over 1200 people living as close as 800 feet from a turbine they attempted to determine if they could predict the percentage of people that were highly annoyed by varying levels of hours of shadow flicker (SF) a year or number of minutes on a given day. However, although annoyance did tend to increase with increasing minutes a day, they could not find a statistical relationship:

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

Haac et al. 2022. In the shadow of wind energy: Predicting community exposure and annoyance to wind turbine shadow flicker in the United States. Energy Research & Social Science 102471. Pg. 1-16.

This work was completed by the Lawrence Berkley National Laboratory (LBNL) in the United States as part of a large US Department of Energy (DOE) Wind Neighbors National Survey. The purpose of the study was to determine if the duration of shadow flicker could be correlated to shadow flicker (SF) annoyance in the population. Overall, the authors reported:

> *This study modeled SF exposure at nearly 35,000 residences across 61 wind projects in the United States, 747 of which were also survey respondents. Using these results, we analyzed the factors that led to perceived SF and self-reported SF annoyance. We found that perceived SF is primarily an objective response to SF exposure, distance to the closest turbine, and whether the respondent moved in after the wind project was built. Conversely, SF annoyance was not significantly correlated with SF exposure. Rather, SF annoyance is primarily a subjective response to wind turbine aesthetics, annoyance to other anthropogenic sounds, level of education, and age of the respondent.*

Similar to the Health Canada findings (Voicescu, 2016), the LBNL study could not correlate the number of theoretical (astronomical) or actual (adjusted case) hours a year or minutes at a time in duration of shadow flicker with annoyance in the population. In other words, limiting the number of hours of shadow flicker on an annual basis at a non-participating home is unlikely to decrease the annoyance the residents feel towards any shadow flicker at all or the turbines themselves.

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

11.1.2 Shadow Flicker Standards

However, I do believe that reasonable limits on shadow flicker are prudent to keep nuisance levels to a minimum at non-participating residences.

A number of North American jurisdictions have adopted various ordinances and rules limiting shadow flicker on non-participating land. A no more than 30 hours of actual shadow flicker modeled on a residence (Adjusted / Assessment Case B) has almost become the universally adopted standard. Erroneously this level of shadow flicker at homes has often been referred to as the "Industry Standard". It is not the wind turbine proponents that derived this standard; rather it is one that has been adopted in provincial/state or local statute.

The origins of this standard are traced to Germany in 2002. The German Territorial Committee for Emissions control released the document "Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen, Länderausschuss für Immissionsschutz [Notes on the identification and evaluation of optical emissions from wind turbines], (in German)." The standard was based on limiting the shadow flicker nuisance of local residents. They subsequently codified this formal shadow flicker guideline as part of the *Federal Emission Control Act* (Haugen, 2011). Similar standards to this have been adopted internationally with modifications for shadow flicker. The German standard is: no more that 30 hours of modeled shadow flicker (theoretical / worst case) a year, no more than 30 minutes of shadow flicker at a time, and no more than 8 hours of actual (Adjusted / Assessment Case B) shadow flicker a year on a home.

Each jurisdiction that has adopted a shadow flicker restriction at non-participating residences has had to weigh what would be a reasonable level of shadow flicker that they believe would be acceptable and avoid excessive complaints. It is clear from the Koppen et al. (2017) review of international standards for shadow flicker that they can vary considerably from jurisdiction to jurisdiction. I would caution the NSDECC that the table of shadow flicker jurisdictional standards in Koppen (2017) contains several errors, including for the North American references.

Koppen (2017) states:

> *However, there are differences in the exact implementation, like the consideration of only the worst case, only the real case or both the worst and the real case shadow impact. Other common differences are the exact definition of shadow flicker sensitive receptors and the zone of influence which has to be considered. This can lead to considerable differences in energy production losses by a shadow flicker control module.*

Across North America many jurisdictions have successfully adopted shadow flicker restrictions based on the "Adjusted/Actual/Realistic/Expected" scenario (Assessment Case B). The following are some examples of state-wide legislation.

North Dakota

The North Dakota Public Service Commission requires effects from the impact upon light-sensitive land uses to be managed and maintained at an acceptable minimum (N.D. Admin. Code §69-06-08-01(5)(c)(3)). The North Dakota Public Service Commission has recognized the 30-hour per year standard and evaluates actual shadow flicker impacts pursuant to this standard. Justification, similar to what is contained in this report, for continued use of this standard has been provided to the ND PSC during several recent wind project applications and hearings.

Connecticut

Similarly, the Regulations of Connecticut State Agencies Section 16-50j-95, part (c) requires:

Shadow flicker shall not occur more than 30 total annual hours cumulative at any off-site occupied structure location from each of the proposed wind turbine locations and any alternative wind turbine locations at the proposed site and any alternative sites.

12 Physical Health and Safety Considerations for Determining Appropriate Setback Distances

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

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

Ice Throw

In 2007, Garrad Hassan Canada Inc. was commissioned by the Canadian Wind Energy Association (CanWEA) to undertake a probabilistic risk evaluation of the likelihood of ice fragment throw from wind turbines would strike a member of the public. They used a hypothetical wind turbines, similar to those commonly in operation. They examined meteorological conditions in Ontario, Canada, which are similar to winter environment in South Dakota. Three scenarios were examined – Scenario A House, Scenario B Road and Scenario C Individual. Their findings are provided in Table 6.

Table 10. Ice Throw Strike Probabilities (Garrad Hassan, 2007)

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

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

The results indicate an extremely low probability that an individual or vehicle would ever be struck. They are far less than risks that people face in everyday life (e.g., driving a car, being struck by lightning, or being in an airplane crash).

Blade Failure

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

> *For example, using the one fatality per impact assumption, the fatality risk for the 5.5 MW turbine at a 1.1x tip height setback is 1 fatality per 12 million years for 1 vehicle/mile traffic density, and 1 fatality per 1.1 million years for 10 vehicles/mile. Similarly, the results for the*

> *1.5 MW and 3.4 MW turbines at a 1.1x tip height setback are well below 1 fatality per 100,000 years for 1 vehicle/mile and 10 vehicles/mile traffic densities. This indicates that, from an engineering safety perspective, the 1.1x tip height setback produces a satisfactory level of risk mitigation for rural roadways.*
>
> *Results for these example turbines show that the typical setback of 1.1x tip height is generally sufficient at reducing risk to extremely low levels (between 1 impact in 1 million years and 1 impact in 10 million years) for roads in rural areas which tend to be lightly traveled.*

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

Tower Collapse

Tower collapse is a very rare event, although it is acknowledged that it can occur. When wind turbine tower fail, they tend to collapse within a distance equal or less to their total height. The proposed changes require wind turbines be placed 1.1 times Turbine Height from edge of the Right-of-Way from roads and property lines. This safety distance ensures that in the unlikely event of a tower collapse that the wind turbine will impact only the participating parcel of land and not interfere, or affect, roads or neighboring properties.

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Testimony of
Alan Claus Anderson
Chair, Polsinelli Energy Practice Group
Adjunct Professor of Law, University of Kansas Law School of Law

Before the Yankton County Commission

June 6, 2024

Commissioners,

My name is Alan Claus Anderson and I am an attorney and the Chair of the Energy Practice Group at Polsinelli, an AmLaw 100 law firm with more than 1,000 attorneys serving clients in numerous industries, including a robust roster of attorneys working in and around the energy and transmission sector. I am also an adjunct Professor of Law at the University of Kansas School of Law where I teach Renewable Energy Law Practice and Policy. Thank you for allowing me to appear before you today to discuss the vital role that renewable energy, and specifically wind generation, plays as part of our national energy grid and to address common misconceptions that often arise when wind development is proposed in a community such as yours.

A. Introduction

Polsinelli is an AM Law 100 law firm with 23 offices across the United States. We are fortunate to work for clients in all areas of energy production and transmission, from oil, gas, and coal to renewable energies such as wind and solar. I also study and teach renewable energy law at the University of Kansas School of Law, with a particular emphasis on the impacts of both good and bad policy. In my professional capacity, I am commonly asked to testify in front of legislative and policy-setting bodies at both state, county, and local levels on the mechanics of the U.S. energy grid and marketplace, the economic impacts of renewable energy generation on local communities, and the potential impacts of proposed state and local policy decisions pertaining to renewable energy generation.

B. Overview

Hosting a renewable generation project in a community is a significant opportunity that requires thoughtful planning and coordination with local governments. Over several decades, County officials across the United States have undertaken an education process about the unique benefits and questions that arise when a wind project is proposed in their community. The good news for your community is that you have the benefit of that experience and have a significant well of information to draw upon to answer questions that are being raised. However, with the internet comes a wave of information both valid and invalid, and so the difficulty lies in identifying misinformation and finding reliable, peer-reviewed, and properly sourced research to address any questions you may have.

Recognizing that challenge, I am here today to provide an overview of several topics that have arisen before this body recently. Specifically, I will address the importance and institutional protections given to property rights in the United States, provide a high-level overview of the mechanics of the electrical grid and energy marketplace in the United States, and provide a summary of the significant research that has been conducted on the potential impacts of wind generation projects on neighboring property values.

C. Renewable Siting Decisions Are Often A Question of Property Rights

Before we discuss the energy issues that underpin our electricity grid, it is helpful to frame the impact that any potential land use decisions may have on private property rights. One of the most fundamental protections provided by the framers of our Constitution is a right for U.S. citizens to determine how their private property may best be used. In socialist or communist countries, the government restricts and controls how property is used in the marketplace with little control given to individuals.

> ***"One of the most fundamental requirements of a capitalist economic system—and one of the most misunderstood concepts—is a strong system of property rights." Professor Armen Alchian, emeritus professor of economics at UCLA, The Concise Encyclopedia of Economics, 2008.***

Governments with a robust system of private property rights allow private landowners to generally make the decision as to how they will use their property in a free market economic system. A landowner's use of their property is how that landowner takes part in the free market economy. Professor Alchian at UCLA reminds us that, "one of the most fundamental requirements of a capitalist economic system—and one of the most misunderstood concepts—is a strong system of property rights."

Restrictions on the use of private property inherently take away a land use from a landowner, with such taking causing some level of economic harm to that impacted landowner. There are good reasons for creating land use regulations that protect the health and safety of the community, but when a government takes away economic use of a landowner's property beyond what is needed it is a taking of that economic use by the government and impacts our free-market capitalist system.

Private property rights have been critical since the founding of the United States of America and as part of South Dakota's entry as a state. The Fourteenth Amendment of the United States Constitution provides that ***no state shall "deprive any person*** of life, liberty, or ***property, without due process of law***…." Similarly, Section 2 of Article 6 of the South Dakota Bill of Rights provides that "***No person shall be deprived of*** life, liberty or ***property without due process of law***." Both our country and South Dakota were founded on the principle that protection of private property rights must be foremost in our beliefs.

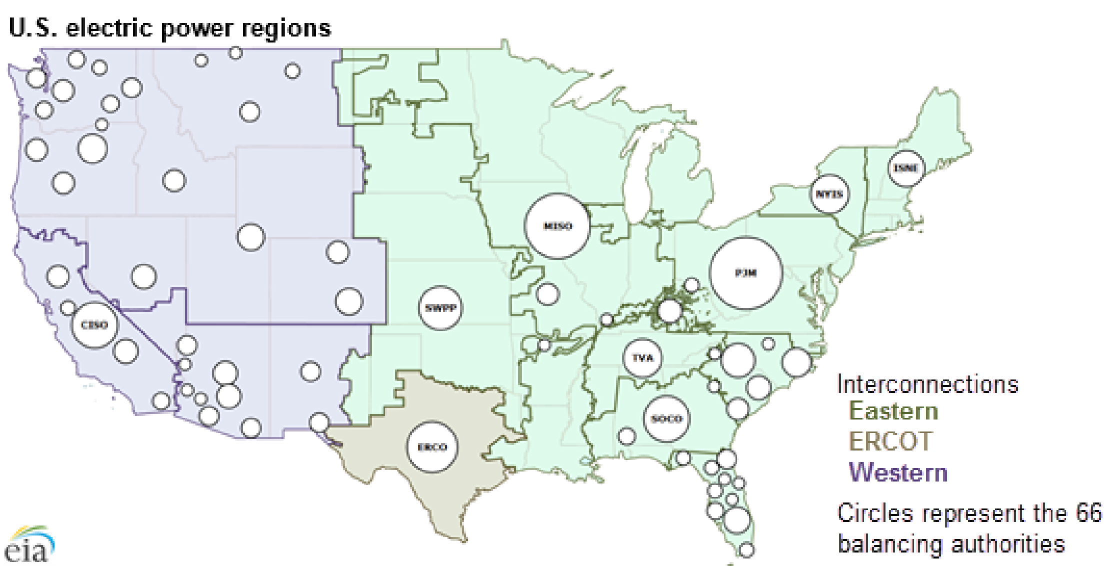
Excessive restrictions on private property take away property rights just as a physical taking does. For example, excessive setbacks for wind turbines that do not add additional health and safety protections would take away the ability of landowners to use their property for wind energy generation. As a deliberative body, such as the Yankton County Commission, reviews draft restrictions on wind energy, it must do so with an understanding that its decisions will either evidence a belief in a strong system of private property rights or a system where the government dictates its citizens use of their private property in the free market.

D. Renewable Generation is An Important Component of a Robust Electrical Grid

Electricity is simultaneously one of the most fundamental, and one of the most misunderstood, facets of our modern lives. Over the last century, our nation has developed a vast, complex, and interconnected system, impacting multiple layers of regulators, regulations, technical and engineering obstacles, and geographic barriers, all with the simple goal of allowing us to flip a switch and turn on a light. The internet is full of inaccuracies and oversimplifications of how this system operates leading to frequent misunderstandings from lay people, particularly when it comes to how renewable generation fits into this puzzle. With that in mind, we feel it would be beneficial to provide a brief overview of the U.S. energy marketplace and the significant role that renewable generation plays, both nationally and for the State of South Dakota.

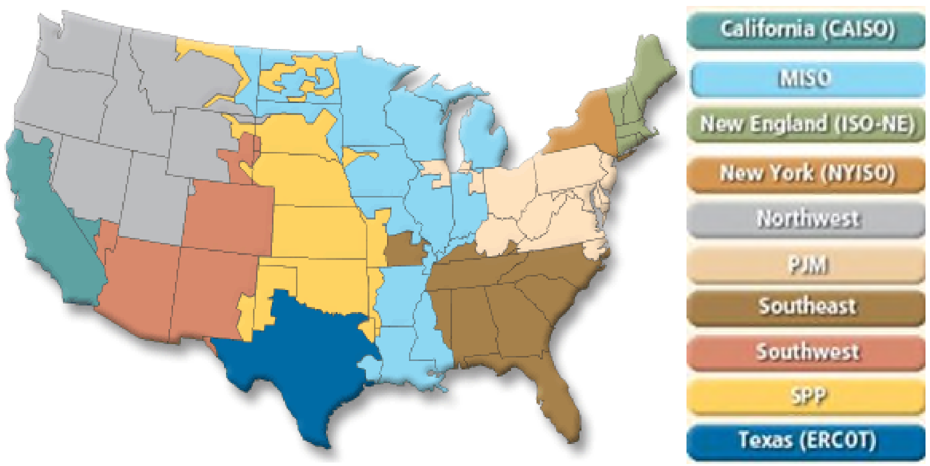
Overview of the United States Grid Infrastructure

At the highest level, the United States grid is divided into three main "interconnections," which operate as largely independent systems of generation and transmission infrastructure with only a limited ability to transfer power through "seams" between the three regions.

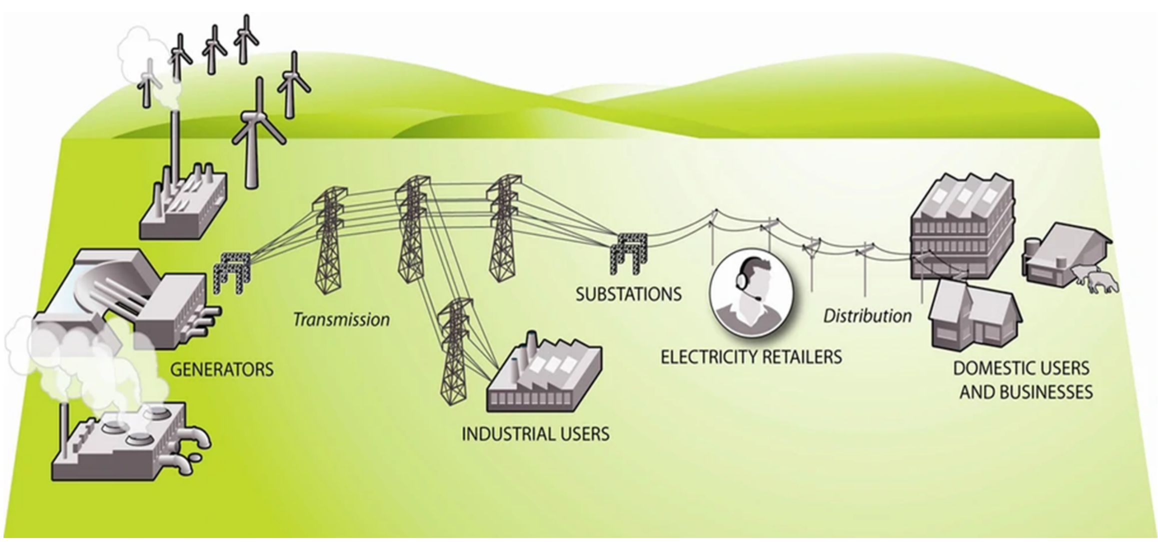


Source: U.S. Energy Information Administration, https://www.eia.gov/todayinenergy/detail.php?id=27152

Each of these regions is then further divided into individual grid operating authorities that have the responsibility to oversee the management of the grid and the balance of supply and demand within a specific region. These authorities are typically either are public utilities or larger quasi-governmental entities known as Regional Transmission Organizations or "RTOs." RTOs are member-operated non-profit entities, often led by the applicable member public utilities and energy generators within a region who band together to ensure reliability and manage supply and demand within a region.



While there is limited connection between the three national interconnects, energy generation is coordinated throughout the RTOs to create greater reliability and market efficiency. South Dakota is predominantly located within the Eastern Interconnect, and further within an RTO known as the Southwest Power Pool ("SPP"). As such, electricity generated in South Dakota (for example by a public utility or a renewable generator) will be transmitted onto an electrical grid that is managed by SPP. The local utility or renewable developer, as a member of SPP, reports their generation supply and electrical demand to SPP and that power is then dispatched appropriately across SPP's 14 state footprint.

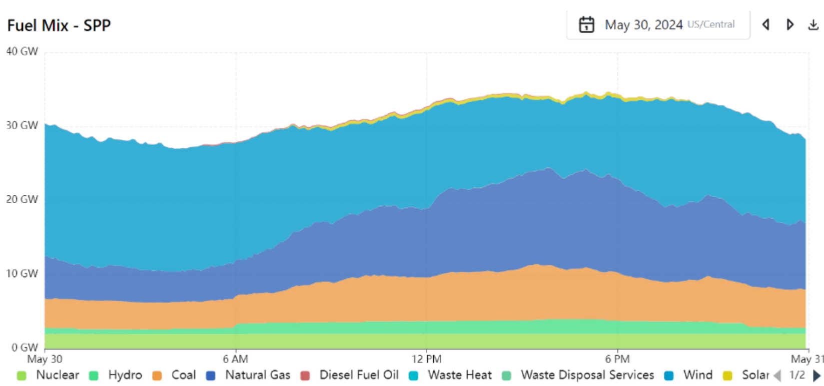


One of the biggest advantages of an RTO system is that supply and demand fluctuations are dispersed among a much larger geographic area, with a larger pool of participants that can be called upon to balance the system. This balancing over a larger geographic area, and amongst diverse sources of generation, creates far greater reliability and market efficiency. For example, a local South Dakota utility can purchase power generated by a wind project in Oklahoma through the SPP market to help meet demand requirements on a particularly hot summer day. Similarly, reliable wind power generated in South Dakota can be utilized to help balance out coal and natural gas generation in northern Texas during uncommonly severe winter events.

It must be noted that there is often misinformation about the role of the RTO and its interplay with the local utility's generation. The RTO does not favor any source of generation, such as renewable energy. The RTO is simply the manager of the grid and the body by which the wholesale market of electricity is maintained. The local utility can choose to run a its generation at full capacity and favor its own generation regardless of what electricity may otherwise be available on the wholesale market. However, and as you will see in the discussion of electricity generation pricing, doing so may not be in the best interests of the ratepayers.

<u>Generation Source Accreditation</u>

For the RTO to manage the grid and balance supply and demand across a wide region, it must understand when and how much electricity will be generated by each generation source. In these calculations, the RTO understands that some generation will generally run at a consistent capacity with limited ability to fluctuate ("baseload generation"), some sources are available to ramp up and down quickly when needed ("dispatchable generation"), and other sources are available under certain conditions ("intermittent generation").[1]



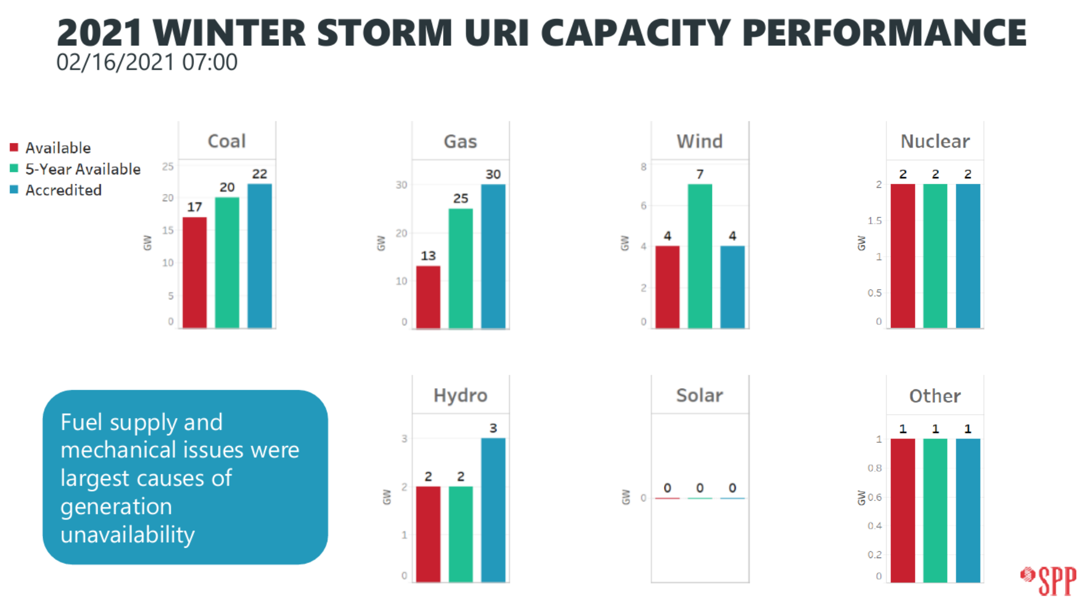
Many try to simplify or misstate the role of each of these sources of generation, but each serves an important purpose for the RTO to meet variable demand (i.e., more electricity may be needed during a winter storm in the middle of the day than during a cool fall night). Baseload generation provides a critical foundation of electrical generation that is available all the time, but it cannot quickly ramp up and down to satisfy fluctuations in demand that occur throughout the day or from season to season. Because electricity generated must not be greater than demand, and while

[1] GridStatus.io, Fuel Mix-SPP, May 30, 2024, https://www.gridstatus.io/graph/fuel-mix?iso=spp&date=2024-05-30, accessed at: 5/31/24.

baseload generation is critical to a reliable grid, it therefore cannot meet moments of peak demand. To help fill the demand peaks, we must look to dispatchable and intermittent generation.

From an RTOs' perspective, it is vital that each component of this system is that individual generation units perform as expected. For planning purposes, to manage the different profiles of each of these types of generation (baseload, dispatchable, and intermittent) the RTO assigns an "accredited capacity" for each source. In other words, the RTO knows that intermittent generation does not operate all the time, so it rates that capacity according to what it can expect it to provide to the grid at any given moment. Fossil fuel generation similarly does not operate all the time, but it is expected to run at a high percentage of time. While this generation is more expensive than intermittent generation, it is an important part of the grid as it can provide reliability.

If a generator fails to provide the amount of energy that the RTO expects, then an imbalance can occur that could lead to reliability problems and brownouts. An example of this dilemma occurred in February 2021 with Winter Storm Uri. Natural gas pipelines and coal piles across the Midwest froze, significantly hindering the operation of coal and gas-fired generation. As a result, those units were derated and operated at less than full capacity, causing imbalances in energy supply at a time when customers were heating their homes.[2] The wind, however, kept blowing and wind generation continued to operate largely as expected throughout the severe weather event, which in turn provided a reliable pool of electricity that SPP dispatched to the areas that needed it most. The following table from SPP breaks down the supply of energy provided from each generation type during the event, with red showing the amount that was actually available, blue showing the amount that SPP expected (known as the "accredited" amount), and green showing the amount of energy actually supplied over a 5-year period.



Source: Suskie, Paul, Southwest Power Pool, presentation to the Kansas Special Committee on Energy and Utilities, "SPP Resource Adequacy Overview"

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[2] See Environment Texas Research & Policy Center, "The Texas Frees: Timeline of event", https://environmentamerica.org/texas/center/articles/the-texas-freeze-timeline-of-events/

In response to situations like Winter Storm Uri, SPP has begun undertaking a process to reevaluate its planning criteria for generation sources.[3] As described above, "accreditation" is how SPP determines the amount of energy that a specific generator will provide when it is called upon. Historically, SPP would apply generation capability testing, looking largely at short testing durations during summer months and defining a maximum capability that it could expect to provide under most conditions. Under the new "Performance Based Accreditation" model, SPP is beginning to differentiate individual generators according to their reliability performance, correcting an overcounting of capacity that was predominantly seen in coal and natural gas generation. This new accreditation standard will be rolled out in phases between 2024 and 2027.

To be clear, a robust generation system requires a variety of generation types, including coal, natural gas, nuclear, wind, solar, and other sources of generation. Both traditional and renewable fuels serve important roles in maintaining the reliability of our grid and to provide low-cost power. Recent experience has demonstrated that renewables sources like wind and solar provide a vital counterpoint to traditional fuel sources and can help maintain grid stability during times when traditional sources may fail to perform as expected.

E. Renewable Energy is Low-Cost Generation With and Without Subsidies

Another commonly misstated aspect of renewable energy's place in the marketplace relates to pricing. It is not unusual to hear lay commentators make claims that renewable energy is a higher cost option than coal or natural gas, or that renewable energy would not be viable without assistance from federal subsidies. The truth is that these claims are both outdated and incorrect. First, all sources of electricity generation have subsidies and, in fact, if all tax incentives were removed from all sources of electricity generation, renewables benefit even more. For example, oil and gas have subsidies such as the intangible drilling cost deduction that accounts for an up to 80%+ tax deduction in the first year and has been in place since 1913.

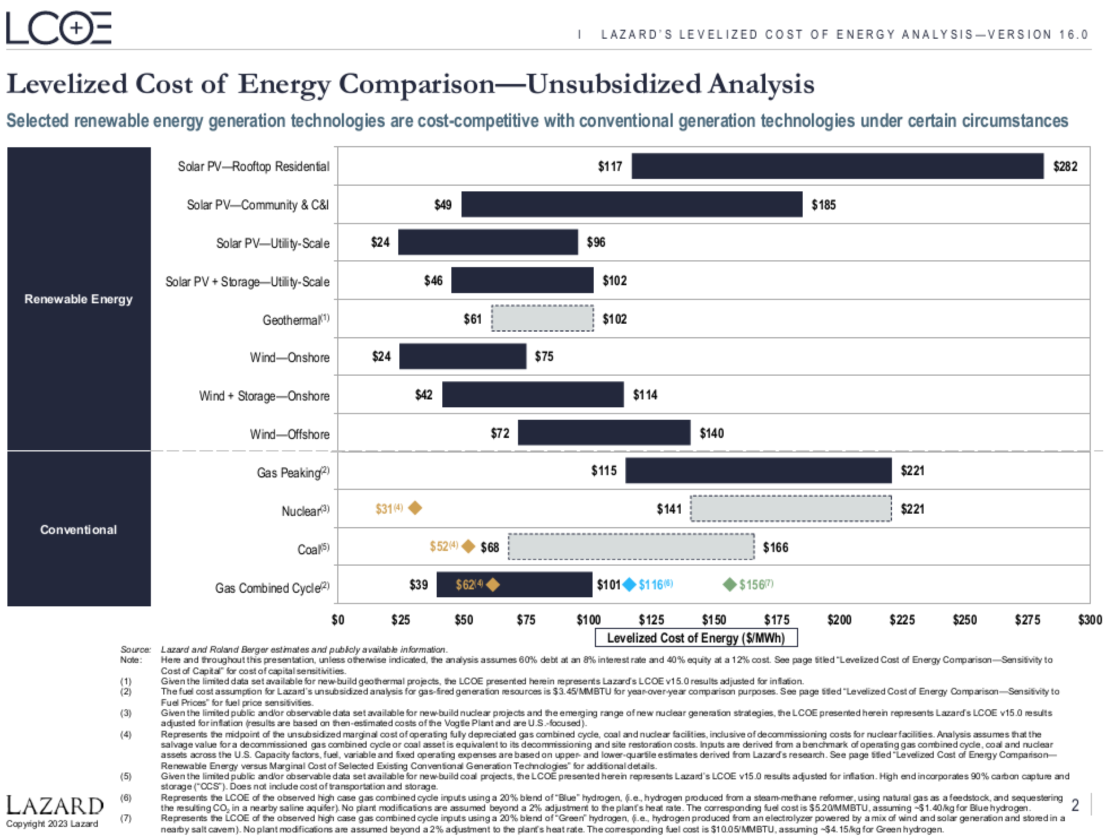
Fortunately, and as discussed below, studies have shown that renewable generation, specifically wind and solar, are most often the lowest cost option for generation and, thanks to the large volume and expansive geographic scope of the RTOs, are often being seen as a reliable substitute for baseload generation. These studies aside, the reality of the free market also demonstrates the point clearly, as utilities across the United States are responding to the market pricing and adding significant amounts wind and solar generation due to the benefit to ratepayers. Utilities in South Dakota and the SPP have no clean energy or green agenda, but they do favor low cost and reliable energy.

Current market research clearly shows the favorable cost comparisons of wind generation versus coal and natural gas. Lazards, one of the world's leading financial advisory and asset management firms, releases an annual study that analyzes the levelized costs of energy ("LCOE") from each of the various generation technologies, meaning the cost of each source of generation if tax incentives were removed. More specifically, the Lazard Power, Energy & Infrastructure

[3] Suskie, Paul, Southwest Power Pool, presentation to the Kansas Special Committee on Energy and Utilities, "SPP Resource Adequacy Overview"

group calculates the cost of each type of generation and fuel source on a $/MWh basis, removing the impact of U.S. federal tax subsidies.

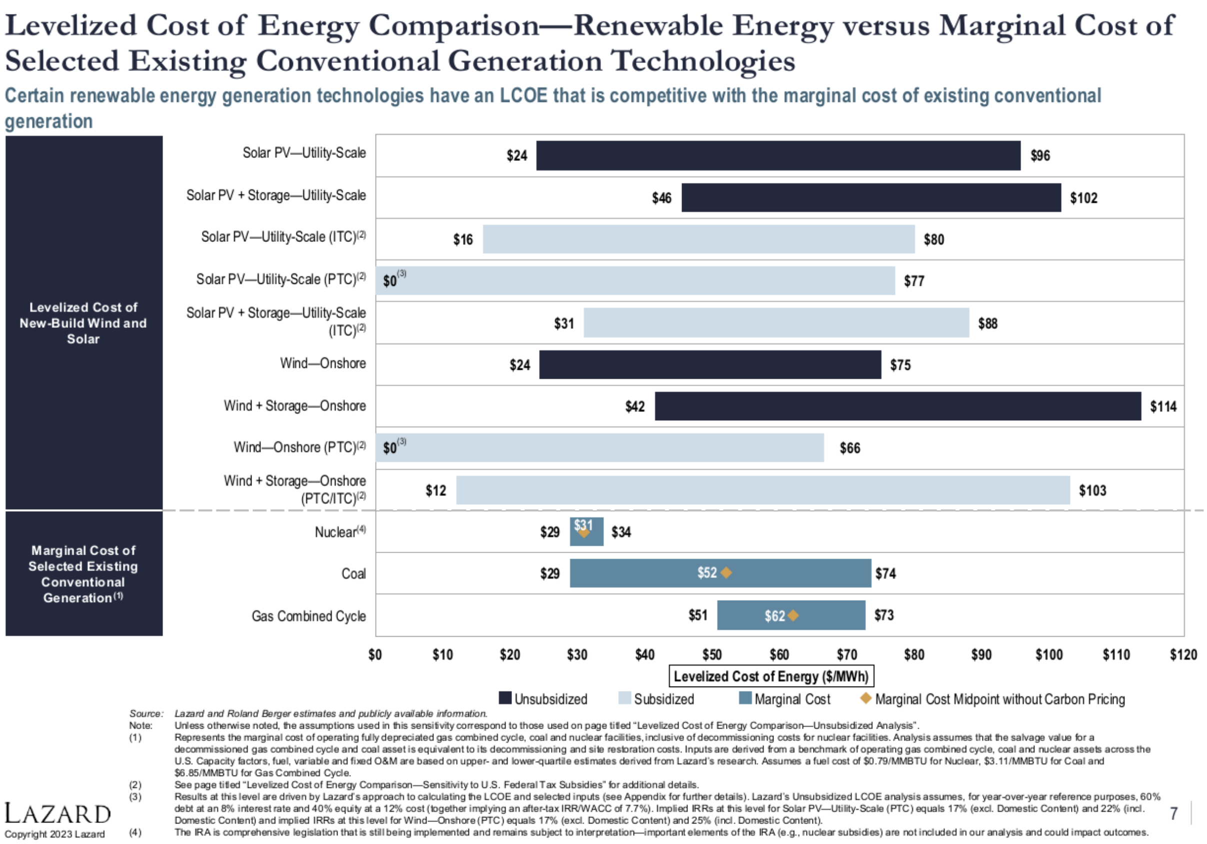
The Lazard report directly addresses the question of whether renewables require subsidies to be cost competitive with oil and gas generation by comparing the levelized cost of each source without subsidies. The results clearly demonstrate the value that renewable generation provides as compared to other sources.[4]



As you can see from the above chart, the levelized cost of onshore wind generation without subsidies ranges from $24-$75/MWh. The higher end of this range typically reflects projects that are located on the east coast or in areas where the wind resource is lower or projects are more geographically constrained, leading to a higher cost to output ratio. That is decidedly not the case in South Dakota, where a project would have access to an excellent wind resource and would be in the lower end of that scale. Compare this $24-$75/MWh range for wind to $68-$166/MWh for Coal and $39-$101/MWh for Gas Combined Cycle and you can clearly see that even without subsidies, wind generation is often the lowest cost source of electricity.

[4] Lazard's Levelized Cost of Energy Analysis—Version 16.0, April 12, 2023, available at: https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

The point is even more clearly emphasized when you compare the levelized cost, both with and without subsidies, of building new wind and solar generation as compared against continuing to operate existing coal and natural gas generation.[5]



Even accounting for the upfront cost of engineering and constructing new renewable projects, the pricing above clearly demonstrates the advantages of increasing our share of renewable generation as opposed to continuing to operate existing coal and natural gas. New onshore wind generation's cost ranges from $24-$75/MWh unsubsidized ($0-$66/MWh accounting for the federal Production Tax Credit) versus a range of $29-$74/MWh and $51-$73/MWh for coal and gas combined cycle, respectively. Simply put, it is often cheaper to build a new wind generation facility than to continue operating existing coal and natural gas facilities.

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[5] Lazard's Levelized Cost of Energy Analysis—Version 16.0, April 12, 2023, available at: https://www.lazard.com/research-insights/2023-levelized-cost-of-energyplus/

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F. Wind Does Not Materially Impact Neighboring Property Values

Any time a new large-scale development such as a wind project is proposed in an area, citizens and community leaders are naturally curious about the potential impact on the surrounding community. As a result, over the last few decades few topics have been more thoroughly studied than the potential economic impacts of wind developments on surrounding property values. The topic has been reviewed by independent third-party valuation experts, governmental research institutes, developers, and local governments utilizing samples of many thousands of property sales from all across the country in and around wind project footprints. Through all of these studies, an overwhelming consensus conclusion has emerged, finding that there is no long-term negative impact on surrounding property values, especially in rural communities. A sampling of the most material studies and conclusions is below.

> ***"If you're concerned about this impact on overall residential property value, that should not be a concern."***
> ***– Jeremy Hill, director of Wichita State University's Center for Economic Development & Business Research (2019). https://www.ksn.com/news/local/study-wind-farms-have-no-significant-impact-on-residential-property-values-in-kansas/***

- **Lawrence Berkley National Laboratory (2024)[6]**
  - Reviews home transactions across 34 states and 428 unique wind projects occurring between 2005 and 2020.
  - Concludes that impacts to property values are not apparent in home prices near projects in counties with fewer than 250,000 people.

- **Brunner, Eric J., PhD and Schwegman, David J. (2022)[7]**
  - Using data on the universe of commercial wind energy installations from 1995 to 2018, found that wind energy installation led to economically meaningful increases in county GDP per-capita, income per-capita, median household income, and median home values.
  - Found that county-wide home values increase after a wind energy project has begun operating.

- **Marous & Company (2022)[8]**
  - Conducted a survey of county assessors across 10 states in which wind farms are located (41 Iowa counties, 11 Minnesota counties, 20 Illinois counties, 5 Indiana

[6] Brunner, Eric, Ben Hoen, Joseph Rand, David Schwegman, "Commercial Wind Turbines and Residential Home Values: New Evidence from the Universe of Land-Based Wind Projects in the United States". Energy Policy. Accessed at: https://www.sciencedirect.com/science/article/pii/S0301421523004226?via%3Dihub.

[7] Brunner, Eric J., PhD and Schwegman, David J., "Commercial wind energy installations and local economic development: Evidence from U.S. counties, Energy Policy", Volume 165, 2022, 112993, ISSN 0301-4215. Accessed at: https://doi.org/10.1016/j.enpol.2022.112993.

[8] Marous & Company. 2022. Market Impact Analysis: Shenandoah Hills Wind Project, Fremont County and Page County, Iowa. March 6, 2022

counties, 7 Michigan counties, 3 Ohio counties, 6 New York counties, 21 Kansas counties, 8 South Dakota counties, and 5 West Virginia counties). T

- Found no market evidence to support a negative impact on residential property values because of the development of and the proximity to a wind farm. They also concluded that there were no reductions in assessed valuations.

- **University of California, Davis (2019)**[9]
  - The analysis found that studies on the topic of wind turbines and property values overwhelmingly find that wind turbines do not negatively impact property values at any point during their installment, including post-announcement, during construction and post-construction.

- **Wichita State University (2019)**[10]
  - Compared property value data between all rural Kansas counties with wind farms and all rural Kansas counties without wind farms
  - Concluded that counties with operating wind farms saw a slight increase in property value compared to counties without operating wind farms

- **University of Oklahoma (2018)**[11]
  - Reviewed 23,000 residential real estate records in five counties in Western Oklahoma, exploring the sale price of platted and unplatted properties before announcement, after announcement, and after turbine construction.
  - Found no significant decrease in property values for homes or unplatted property near wind farms. Among plots of unplatted land between 0.5 - 1 mile away from turbines, found the median sale price *increased*.

- **Lawrence Berkeley National Laboratory (2015)**[12]
  - Analyzed more than 50,000 home sales near 67 wind projects across nine states and 1,198 post-construction sales within 1 mile of a wind turbine.
  - Found "no statistical evidence that operating wind turbines have had any measurable impact on home sales prices."

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[9] Brinkley, Catherine and Leach, Andrew. 2019. "Energy next door: a meta-analysis of energy infrastructure impact on housing value." Energy Research and Social Science. Accessed at: https://www.sciencedirect.com/science/article/abs/pii/S2214629618300495

[10] Wichita State University, "Wind Project Effects on Kansas Counties' Property Values," Accessed at: https://www.greaterhutch.com/media/userfiles/subsite_24/files/Wind%20Power%20Property%20Value%20Analysis.pdf.

[11] Castleberry, Becca and Greene, John Scott. 2018. "Wind power and real estate prices in Oklahoma." International Journal of Housing Markets and Analysis. Accessed at: https://www.emerald.com/insight/content/doi/10.1108/IJHMA-02-2018-0010/full/html

[12] Hoen, Ben; Brown, Jason P.; Jackson, Thomas; Thayer, Mark; Wiser, Ryan; and Cappers, Peter. 2015. "Spatial Hedonic Analysis of the Effects of Us Wind Energy Facilities on Surrounding Property Values." The Journal of Real Estate Finance and Economics. Accessed at: https://link.springer.com/article/10.1007/s11146-014-9477-9

As these studies and many others clearly demonstrate, with several decades of data from tens of thousands of wind turbines operating across the United States, we do not need to speculate about potential impacts on property values. Acclaimed experts from a wide variety of independent institutions and governmental agencies have poured over tax records, sales data, and experiential reports and roundly concluded that there is no demonstrable impact on sales values in rural communities for residential property or agricultural properties that can be attributed to neighboring wind projects.

G. CONCLUSION

Any time significant development occurs in an area, it is good for local policymakers to seek quality information about how that development will integrate into the community. This task is made more difficult in an industry as complex as electrical generation, especially given the substantial amounts of speculation and misinformation that arise when an inherently non-political issue (energy infrastructure) becomes unnecessarily politicized. Fortunately, we do not have to speculate about the impact of a wind project, as we have decades of experience and data from communities just like Yankton County that have successfully hosted wind farms and experienced first-hand the benefits that it can bring.

As you consider policy changes related to wind projects, I would encourage you to seriously consider the source and veracity of the information put before you. Rely on peer-reviewed research, independent third parties, and the decades of experience from wind projects in similarly positioned counties. Look to experts in their fields instead of speculation, and remember that any additional burdens that you enact have a countering impact on property rights, materially harming a constituent's ability to utilize their property for a valid, legal, and socially beneficial purpose. With these principles in mind, I am confident you will implement good policy.

I appreciate the opportunity to speak with you today and look forward to addressing any questions you may have.