OLLSON
Environmental Health Management

February 12, 2018

Codington County Planning Commission
1910 West Kemp Avenue
Watertown, SD 57201-3048

RE: Discussion of Possible Changes to Chapter 5.22 (Wind Energy Systems) of the Codington County Zoning Ordinance

Commission Members:

Ollson Environmental Health Management (OEHM) was retained by NextEra Energy Resources (NEER) to review possible changes to the Chapter 5.22*. Wind Energy System (WES)* of the *Codington County Zoning Ordinance* with respect to protection of public health and safety. OEHM was provided with a copy of the proposed changes that the Planning Commission will be considering on February 14, 2018.

It is OEHM's understanding that NEER has been pursuing the Crowned Ridge wind turbine project in Codington County for several years under the existing ordinance. This report provides the Board an overview of the science supporting proper siting of wind turbines for the protection of public health. In addition, review and comments on the existing and proposed changes to the ordinance have been provided. Dr. Christopher Ollson of OEHM will be attending the upcoming Commissioners meeting.

In summary, over the past decade there has been considerable research conducted around the world evaluating health concerns of those living in proximity to wind turbines. This independent research by university professors, consultants and government medical agencies has taken place in many different countries on a variety of models of turbines that have been in communities for numerous years. Based on scientific principles, and the collective findings of over 80 scientific articles, OEHM believes that the minor changes to the WES ordinance should be considered.

1 Qualifications of Dr. Christopher Ollson of OEHM

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

Dr. Ollson's formal education includes:

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

In addition to his consulting practice he holds an appointment of Adjunct Professor in the School of the Environment at the University of Toronto. In 2013, he was appointed to the Governing

Council, and was Vice-Chair of the Academic Affairs Committee, of the University of Toronto Scarborough until 2016. Dr. Ollson teaches a graduate course at the University of Toronto in Environmental Risk Analysis and co-supervises doctoral students.

Approximately one third to half of Dr. Ollson's practice on an annual basis has been devoted to better understanding the relationship between people, animals and wind energy. For almost a decade, he has been engaged by a number of private companies to review the potential health effects that may be associated with living in proximity to wind turbines as part of their preparation of planning and permitting documentation. Since 2014, he has provided expert advice on wind turbines, health and proper siting requirements for the Vermont Public Services Department. This led to the development of a research team at his former employer (Intrinsik), which included three Doctoral level staff, one Environmental Physician, and one Doctoral Candidate. These research efforts were first published in a peer-reviewed scientific article entitled:

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

Environmental Health is an open access journal (meaning anyone can obtain a copy for free) and has an impact factor of 3.37, meaning that articles published in this journal are often cited in other peer reviewed scientific papers. After its publication in September 2011 the journal quickly identified the article as "highly accessed", it has been viewed over 49,000 times and cited in more than 30 other scientific articles.

Subsequently, the research team published the following five articles in peer-reviewed scientific journals:

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

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

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

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

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

Dr. Ollson's research has been presented at numerous international scientific conferences.

Dr. Ollson 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. The following are the proceedings where he was formally qualified to give expert opinion evidence on health effects and wind turbines:

- North Dakota Public Services Commission
  - Brady Wind Energy Center (March 2016) NextEra
  - Brady II Wind Energy Center (June 2016) NextEra
  - Oliver III Wind Energy Center (June 2016) NextEra
- Perquimins and Chowan Counties, North Carolina, CUP Hearings for Timbermill Wind (September, 2016) Apex
- Clinton County Planning and Zoning Commission, Missouri, County Ordinance Changes (June and August, 2016) NextEra
- Queen's Bench of Saskatchewan in McKinnon v. Martin (2010) Red Lily Wind
- Ontario Environmental Review Tribunals – Appeal of Company Renewable Energy Approvals
  - Erickson v. MOE (2011) Suncor
  - Monture v. MOE (2012) Samsung
  - Moseley v. MOE (2014) Capstone
  - Lambton County v. MOE Suncor
  - EOCA v MOE (2015) ProWind
- Alberta Utilities Commission (AUC):
  - Proceeding No. 3329, Grizzly Bear Creek Wind Project (March 2016) BluEarth
  - Proceeding No. 1955, Bull Creek Wind Project (October 2013) E.On. Renewable

Dr. Ollson has appeared before numerous County Planning & Zoning and County Commissions to provide an overview of potential health concerns during their deliberations on review of WES ordinances and granting Conditional/Special Use Permits for wind generating facilities. Dr. Ollson appeared in 2017 before the Codington County Planning Commission and addressed concerns related to APEX's Dakota Range Wind Farm that was approved by the Commission.

2 Proposed Changes to the Codington County WES Ordinance

OEHM is familiar with changes to the Chapter 5.22*. Wind Energy System (WES)* of the Codington County *Zoning Ordinance*.

As with any energy facility it is important that proper setbacks and guidelines are in place for wind turbines to ensure public health and safety. Table 1 is provides the list of set back requirements listed in the proposed changes to the *WES Ordinance,* and recommendations by OEHM. The suitability of these setbacks will be discussed in each of the following sections.

Table 1. List of Setback Requirements and Disturbances

Distance from a…	**Vertical Height of Tower 75' to 500'**	**Vertical Height of Tower Over 500'**	**OEHM Recommendations**
Residence, business and public building	550'	550' plus 2.5' feet for each additional vertical foot more than 500' in height	Sufficient to protect public health.
Non-Participating occupied residence, business, church, or school	1000'	1,000' plus 2.5' feet for each additional vertical foot more than 500' in height	May want to consider distance from existing non-participating residences, business and public buildings shall be not less than one thousand four hundred (1,400) feet. For purposes of this section only, the term "business" does not include agricultural uses.[1] An addition of 2.5' for each additional vertical foot more than 500' is also agreeable.
Distance from Centerline of Public Road	110% of the height of the wind turbine		May want to consider the setback to the edge of the road right-of-way instead of centerline.
Distance from Property Line	110% of the height of the wind turbine		Sufficient to protect public health but should consider from a non-participant property line.
Noise	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.		Sufficient to protect public health. Will likely result in a setback greater than 1000' to non participants. Most jurisdictions set sound level at homes.
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.		Recommend changing 30 hour requirement to non participants only.

Note 1. It is OEHM's understanding that 1,400 is NEER's minimum design setback standard from occupied dwelling now used across all projects. Therefore, OEHM was asked by NEER to evaluate whether this standard would be protective of public health and safety.

3 Health Research on Living in Proximity to Wind Turbines

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

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

This letter serves to provide background on issues that are contained in the possible changes to the *Codington County WES Oridinance* to protect public health and safety, including:

- Audible noise
- Shadow Flicker
- Setback Distances – sound and public safety

3.1 Peer-Reviewed Health Literature for Consideration by Codington County Audible Noise

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

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

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

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

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

Health Canada's public brochure contains the following statement:

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

This research will be discussed as appropriate throughout this report.

3.2 Audible Sound (Noise)

The audible sound (noise) from the wind turbines is limited no greater than 50 dBA at the property line of existing non participating residences, businesses, and buildings owned and/or maintained by a governmental entity. With any sound source sleep is the critical health endpoint that needs to be protected at residences. By setting the acceptable sound level at the property, instead of the house, Codington County has taken a very conservative approach. 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 if the proposed changes to the WES Ordinance is protective of health.

3.2.1 Sleep

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

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

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

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

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

The following excerpt from the paper discusses the study objective:

> *The current study was designed to objectively measure sleep in relation to WTN exposure using actigraphy, which has emerged as a widely accepted tool for tracking sleep and wake behavior. The objective measures of sleep, when considered together with self-report, provide a more comprehensive evaluation of the potential effect that WTN may have on sleep.*

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

From the conclusions of the paper:

> *The potential association between WTN levels and sleep quality was assessed over the previous 30 days using the PSQI, the previous year using percentage highly sleep disturbed, together with an assessment of diagnosed sleep disorders. These self-reported measures were considered in addition to several objective measures including total sleep time, sleep onset latency, awakenings, and sleep efficiency. In all cases, in the final analysis there was no consistent pattern observed between any of the self-reported or actigraphy-measured endpoints and WTN levels up to 46 dB(A) [at homes as close as 820 ft]. Given the lack of an association between WTN levels and sleep, it should be considered that the study design may not have been sensitive enough to reveal effects on sleep. However, in the current study it was demonstrated that the factors that influence sleep quality (e.g. age, body mass index, caffeine, health conditions) were related to one or more self-reported and objective measures of sleep. This demonstrated sensitivity, together with the observation that there was consistency between multiple measures of self-reported sleep disturbance and among some of the self reported and actigraphy measures, lends strength to the robustness of the conclusion that WTN levels up to 46 dB(A) [at homes as close as 820 ft] had no statistically significant effect on any measure of sleep quality.*

Given the breadth of the study, the number of participants and consistency with past credible, peer-reviewed studies on whether living in proximity to wind turbines impacts sleep OEHM believes that this is a critical study.

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

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

Prior to the Health Canada Study (2014), perhaps the most compelling research into wind sound awakenings was conducted by Bakker et al. (2012). This research reported the number or percentage of awakenings with those living in proximity to wind turbines in a rural setting. As can be seen from Table 7 from the Bakker paper, more people in rural environments are awakened by people/animal sound and traffic/mechanical sounds, than by the proximate wind turbines. In this study, people living in close proximity to wind turbines reported being awoken more by people/animal noise (11.7%) and rural traffic/mechanical noise (12.5%), than by turbine noise (6.0%). Sound levels in this study were as high as 54 dBA.

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

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

From Michaud et al., 2016:

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

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

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

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

> *The result of this study based on advanced sleep recording methodology together with extensive noise measurements in an ecologically valid setting cautiously suggests that there are no major changes in the sleep of participants who host new industrial WTs in their community. Further studies with a larger sample size and including comprehensive single-event analyses are warranted.*

These findings are consistent with the previous reported studies.

Conclusion on Wind Turbine Noise and Sleep

The recent published findings reveal that there is no association between exterior wind turbine sound levels and impact on sleep for residences as close as 820 ft. Therefore, OEHM believes that the Codington County WES Ordinance of 50 dBA at the property line of nonparticipants is conservative and more than sufficient to protect residents and should not affect the sleep of those living in proximity wind projects.

3.2.2 Other Potential Health Concerns Living in Proximity to Wind Turbines

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

There are numerous peer-reviewed studies that have explicitly examined the relationship between levels of wind turbine noise and various self-reported indicators of human health and well-being (e.g., Health Canada 2014 and associated publications; Bakker et al. 2012; Janssen et al. 2011; Pedersen 2011; Pedersen and Persson Waye 2004; 2007). These studies have researched a wide range of wind turbine models, manufacturers, heights and noise levels. They were conducted over several years, in some cases over 10 years, after wind turbines became operational. The study of wind turbine health concerns began in Europe in the early 2000s and most recently examined in Canada.

It is important to understand that from a health perspective it is not the height of the turbines, or the noise output at their hub, that is the important. Rather, it is the resulting sound level at people's homes that is critical to ensure the protection of public health. Simply put, whether a developer selects a 500-foot wind turbine, or smaller model, the requirement to meet the 50 dB sound level at nonparticipating property lines remains the same. OEHM understands that Codington County is proposing an additional 2.5 foot setback to nonparticipants for turbines greater than 500'. Such a measure would increase setbacks as tower height increases.

In general, peer reviewed studies do not support a correlation between wind turbine noise exposure and any other response other than some annoyance (McCunney et al., 2014). For example, various studies based on the results of two surveys performed in Sweden and one in the Netherlands (1755 respondents overall), found that no measured variable (e.g., self-reported evaluations of high blood pressure, cardiovascular disease, tinnitus, headache, sleep interruption, diabetes, tiredness, and reports of feeling tense, stressed, or irritable) other than annoyance was directly related to wind turbine noise for all three datasets (Pedersen, 2011) at noise levels below 45 dBA.

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

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

Health Canada reported that:

> *"The results from the current study did not show any statistically significant increase in the self-reported prevalence of chronic pain, asthma, arthritis, high blood pressure, bronchitis, emphysema, chronic obstructive pulmonary disease (COPD), diabetes, heart disease, migraines/headaches, dizziness, or tinnitus in relation to WTN exposure up to*

46 dBA [at homes as close as 820 ft]. In other words, individuals with these conditions were equally distributed among WTN exposure categories."

This resulted in the overall conclusion of the paper that:

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

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

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

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

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

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

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

Overall, annoyance levels associated with wind turbine sound are low and consistent with other levels of noise related annoyance. Most notable was that only 9% of the annoyance from wind turbines could be correlated to the sound. Regardless of the presence of some annoyance, the previous Health Canada research (Michaud et al. 2016a), demonstrated there was no association between self-reported health conditions and sound levels.

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

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

In the Concluding Remarks the authors report:

The results provide no evidence that self-reported or objectively measured stress reactions are significantly influenced by exposure to increasing levels of WTN up to 46

> *dB [at homes as close as 820 ft]. There is an added level of confidence in the findings as this is the first study to date to investigate the potential stress impacts associated with WTN exposure using a combination of self-reported and objectively measured endpoints.*

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

3.2.3 Summary

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

- Adverse health effects have not been attributed to properly sited wind turbine projects;
- People tend to notice sound from wind turbines almost linearly with increasing sound pressure level (in other words, the louder the wind turbine at ground level the more people notice them);
- A proportion (typically less than 10%) of people that notice sound from wind turbines find it annoying (annoyance is not a medical condition);
- Noise-related annoyance can be within the range of existing levels of community noise related annoyance (e.g., rail, road and air traffic; animal noise);
- Annoyance is not only related to wind turbine noise but more strongly to subjective factors like attitude, visual cue, stress and expectations; and
- People who economically benefit from wind turbines often experience higher sound levels outside their homes than non-participants and have significantly decreased levels of annoyance compared to individuals that received no economic benefit.

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

Noise-related annoyance from these more common sources is prevalent in many communities. For instance, results of national surveys in Canada and the U.K. by Michaud et al. (2005) and Grimwood et al. (2002), respectively, suggested that annoyance from noise (predominantly traffic noise) may impact approximately 8% of the general population. Even in small communities in Canada (i.e., <5000 residents) where traffic is relatively light compared to urban centers, Michaud et al. (2005) reported that 11% of respondents were moderately to extremely annoyed by traffic noise. This same trend was noted in the Bakker *et al.*, 2012 study in the Netherlands where people living in close proximity to wind turbines reported being awoken more by people/animal noise (11.7%), rural traffic/mechanical noise (12.5%) than turbine noise (6.0%).

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

> *1. Measurements of low-frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels*

of infrasound at customary distances to homes are typically well below audibility thresholds.

2. No cohort or case–control studies were located in this updated review of the peer-reviewed literature. Nevertheless, among the cross-sectional studies of better quality, no clear or consistent association is seen between wind turbine noise and any reported disease or other indicator of harm to human health.

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

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

Therefore, the proposed changes to the Codington County WES Ordinance will ensure the protection of public health. Further details on setback requirements are provided below.

3.3 Shadow Flicker

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

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

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

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

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

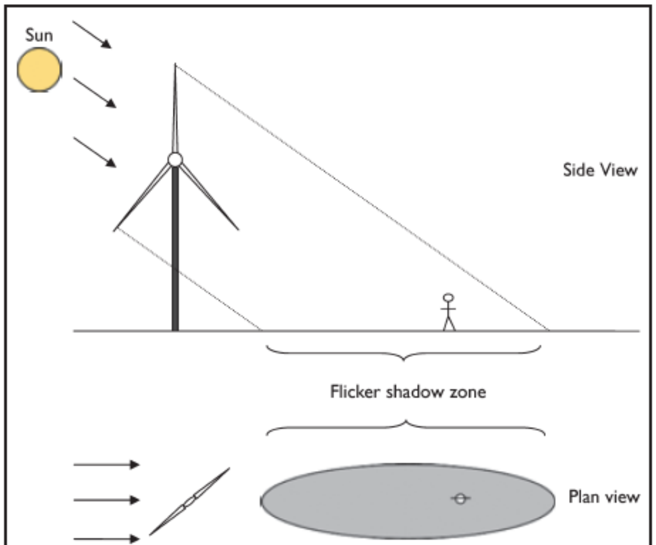

Figure 1.
Generalized geometry for turbine flicker, showing an observer in the shadow area. Note the main analysis assumes the observer and turbine blades are directly facing each other.
Epilepsia © ILAE

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

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

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

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

Modern turbines commonly spin at rates well below this threshold and are typically below 20 rpm. For example, the General Electric (GE) turbines has a maximum rotational speed of 18.5 rpm. Therefore, shadow flicker from these wind turbines is not at a flash frequency that could trigger seizures and not a concern.

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

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

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

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

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

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

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

Therefore, there is nothing in the scientific literature that suggests that shadow flicker should be limited to protect health.

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

The origins of this industry 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 nuisance of local residents. This level is often cited as being below one that would result in 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.

Eliminating shadow flicker at non-participating homes does not afford any additional protection for health. Therefore, OEHM agrees with the recommendation of the Commission to adopt a no more than 30 hours of shadow flicker a year at non-participating residences. To put this in perspective it represents less than 0.5% of the daylight hours a year. OEHM believes the Commission should consider limiting this restriction to on nonparticipants.

3.4 Physical Health and Safety

Public health and safety with respect to wind projects are also governed by setback and safety distances. The *proposed changes to the Codington County WES Ordinance* are consistent with other jurisdictions and with for example a major manufacture of wind turbines - GE Power & Water setback considerations (GE Power & Water, 2013) (Table 2).

All of these setbacks were developed to ensure protection of public health and safety.

The following describes the suitability of the proposed changes to the *Codington County WES Ordinance* for projection 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.

Table 2. GE Setback Considerations

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

All turbine sites (blade failure/ice throw):
1.5 x (hub height + rotor diameter)
	- Public use areas
	- Residences
	- Office buildings
	- Public buildings
	- Parking lots
	- Public roads
	  - Moderately or heavily traveled roads if icing is likely
	  - Heavily traveled roads 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 - Public roads - Private roads - Railroads - 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

3.4.1 Ice Throw

In 2007, Garrad Hassan Canada Inc. was commissioned by the Canadian Wind Energy Association (CanWEA) to undertake a probabilistic risk evaluation of the likelihood of ice fragment throw from wind turbines would strike a member of the public. They used a hypothetic 2.0 MW turbine with the same hub height (80 m) as common modern wind turbines. They examined meteorological conditions in Ontario, Canada, which are similar to winter environment in South Dakota. Three scenarios were examined – Scenario A House, Scenario B Road and Scenario C Individual. The setback distances they used were consistent or less than those found in the proposed changes to the Codington County WES Ordinance . Their findings are provided in Table 3.

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

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

The results indicate an extremely low probability that an individual or vehicle would ever be struck. Therefore, setback distances considered in the proposed changes to the Codington County WES Ordinance and the GE recommended setbacks are more than sufficient to protect public health and safety from risk of ice throw.

3.4.2 Blade Failure

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

In 2013, MMI Engineering Ltd undertook a study titled "Study and development of a methodology for the estimation of the risk and harm to persons from wind turbines" for the United Kingdom government. They studied a 2.3 MW wind turbine with a hub height of 80 m, similar to that of modern wind turbines. Through their probabilistic assessment they determined that risk of fatality from wind turbine blade fragment throw is low in comparison to other societal risks. It was roughly equivalent to the risk of fatality from taking two aircraft flights a year or being struck by lightening.

Given the very low probability of risk of fatality or injury from blade failure the proposed changes to the *Codington County WES Ordinance* and the GE recommended setbacks are deemed sufficient to protect public health and safety.

3.4.3 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 centerline of 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. The proposed changes are consistent with safety setbacks found across most counties and states. However, it is recommended that the proposed changes include a distance of 110% setback to the road right-of-way and not centerline. It is also recommended that it be altered to 110% setback to nonparticipating property lines.

3.4.4 Conclusions on Setback Distances

The proposed changes to setback distances are sufficient to protect public health and safety. Some minor modifications could be considered.

4 Conclusions

Over the past decade there has been considerable research conducted around the world on the potential for wind turbines to adversely impact health. This independent research by university professors, consultants and government medical agencies has taken place in many different countries on a variety of models of turbines that have been in the community for a number of years. Based on scientific principles, and the collective findings of over 80 scientific articles, OEHM believes that the existing Codington County WES Ordinance will continue to be protective of health. However, the proposed changes are reasonable and the Commission could consider slight modification to the distance setback from homes to non-participating homes to 1,400 ft, and limiting shadow flicker no more than 30 hours at non-participating homes.

Overall, OEHM believes that the proposed changes to the Codington County WES Ordinance are sufficient and only minor if any modifications are recommended for the protection of public health.

Sincerely,

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