May 24, 2024

Chief Clerk Linsay Hale
Wisconsin State Senate
P.O. Box 7882
Madison, WI 53707-7882

Chief Clerk Edward Blazel
Wisconsin State Assembly
17 West Main Street, Room 401
Madison, WI 53703

Re: Wind Turbine Siting-Health Review and Wind Siting Policy Update Pursuant to Wis. Stat. § 196.378(4g)(e).

Dear Chief Hale and Chief Blazel:

Enclosed for your review is the 2024 Report of the Wind Siting Council. This report is a summary of developments in the scientific literature regarding potential adverse health effects associated with the operation of wind energy systems, and also includes state and national policy developments regarding wind siting policy. The council also offers subsequent recommendations to be considered for legislation. On behalf of the Council, I wish to thank you for the opportunity to provide this report to the legislature.

Sincerely,

/s/

Jennifer Giegerich
Wind Siting Council Chairperson

Enclosure

<u>Wisconsin</u>
<u>Wind Siting Council</u>

Wind Turbine Siting-Health Review

and

Wind Siting Policy Update

May, 2024

Contents

Appendices

1.0 EXECUTIVE SUMMARY

The Wind Siting Council offers this report to the Wisconsin State Legislature for its consideration with a copy given to the Public Service Commission of Wisconsin.

2009 Wisconsin Act 40 (Act 40) took effect on October 15, 2009. Act 40 created a policy framework to allow uniform local regulation of wind energy systems in Wisconsin. Wisconsin Statutes § 196.378(4g), created by Act 40, directed the Public Service Commission of Wisconsin (Commission or PSC) to promulgate rules to specify maximum restrictions that a municipality can impose on installation and use of wind energy systems throughout the state of Wisconsin. Act 40 also created Wis. Stat. § 15.797 which directed the Commission to appoint a Wind Siting Council (Council) to provide advice and counsel during the rulemaking process. Furthermore, Wis. Stat. § 196.378(4g)(e) directs the Council to provide a report on pertinent peer-reviewed literature of the effects of wind energy systems on human health to the Commission and the Wisconsin State Legislature, every five years. Wisconsin Stat. § 196.378(4g)(e) also requires the Council to study state and national regulatory developments regarding wind siting. The report may include recommendations for legislation. This report provides this literature review and also describes current policy trends with regards to wind energy system siting. This report also has attached several appendices including a minority report[1] from members of the Council.

As required by Wis. Stat. § 15.797(1)(b), the Commission appoints a Council of 15 members[2] representing stakeholder categories with interests in or related to wind projects. The issues surrounding wind siting are complex and involve many competing policy priorities including protecting health and safety, complying with regulatory mandates, protecting the environment, preserving local government control, considering impacts to private property, and providing a reliable and affordable supply of energy. The make-up of the Council reflects these diverse interests. Each member of the seven stakeholder groups represented on the Council has their own unique view about how to balance these priorities.

The Council understands that the diversity of its membership and the volume of research on wind health and siting issues on all sides of the debate presents challenges. The Council agrees that the protection of public health and safety are paramount. Accordingly, the Council agreed prior to its investigation and preparation of this report to review scientific literature with the awareness that not all scientific documents are of equivalent rigor or impact. Accordingly, more weight was given to some types of literature over others.[3]

Pertinent literature included empirical research, reviews, and opinion articles that were gleaned from peer-reviewed scientific journals and reports from governmental entities. The scope of literature that was used for the wind-health review was also generally restricted to literature that

---

[1] See Appendix E for the minority report.
[2] See Appendix A for a description of Council member stakeholder groups and membership.
[3] See Appendix C for a detailed description of literature criteria.

specifically focused on the effects of wind energy systems on human health or well-being. As part of the Council's work while developing its 2010 wind siting recommendations that led to the creation of the Commission's administrative rules relating to wind energy systems, Wis. Admin. Code ch. PSC 128 (PSC 128), the Council provided an exhaustive and then up-to-date review of pertinent wind-health scientific literature.[4] The first Council report covered new information that was published in the scientific literature from 2011 to 2014.[5] The Council did not meet in 2019 to complete a report for that year, but began meeting again in 2022 to prepare for the 2024 report. This report covers new information not included in the first two reviews of pertinent wind-health scientific literature and focuses on more recent literature.

To prepare this report, Council members collected literature related to the effects of wind energy systems on human health. Commission staff also conducted a formal literature review of articles discussing state and national (including international) siting policies. The Council set itself a deadline for submittal of articles and research to be considered for the report of September 15, 2023. These efforts identified over 51 peer-reviewed publications on wind-health issues and 8 governmental policy or siting reports.[6]

The Council's conclusions and recommendations are detailed below.

1.1 Summary of Key Findings from Wind-health Literature

The Wind Siting Council is tasked with surveying peer-reviewed scientific research regarding the health impacts of wind energy systems and studying state and national regulatory developments regarding the siting of wind energy systems. The Council may make recommendations based on the health research and on regulatory developments.

The Council's thorough review of 59 peer-reviewed literature and studies conducted since the last Wind Siting Council Report in 2014 did not produce new evidence of direct adverse health effects from wind energy systems. If anything, recent research has identified numerous health benefits that result from replacing fossil fuel power plants with emission-free wind energy.

- Of the 59 articles cited in the report, only three studies suggest potential negative health impacts from wind turbines. However, after a thorough review of these studies, reasonable arguments were found to question the legitimacy of their conclusions.
- Of the 59 articles cited in the report, seven studies concluded there are significant positive health benefits to be realized from wind turbine facilities.

---

[4] The Council's 2010 report contained both general conclusions and siting recommendations as well as a minority, dissenting appendix.

[5] The Council's 2014 report contained two dissenting minority reports.

[6] The Council agreed to offer greater weight to peer-reviewed literature on wind-health issues, as mandated by Wis. Stat. § 196.378(4g)(e). As such, the Council's conclusions are based upon the peer-reviewed literature. Full citation of all articles included in this review is provided in Appendix D.

- Of the 59 articles cited in the report, twelve studies identified annoyance as the primary impact of wind turbine facilities.

Based upon literature that was accepted by the council for inclusion in the report, it is reasonable to conclude that most individuals living near wind energy systems do not experience detectable health effects directly caused by the wind turbines.

1.2 Summary of Key Policy Recommendations

The Council reviewed the policies enacted at the state level[7] that address wind siting rules similar to PSC 128. This review found that 19 states have 'no state specifications indicated' when looking for state-level rules or recommendations for wind energy system siting[8]. An additional six states[9] have provided recommendations for wind energy siting, but not requirements or rules at the state level. These states largely leave wind energy system siting to local jurisdictions. The WSC did not review county level ordinances within states or wind siting policy from other countries.

The WSC review of state policy and peer-reviewed literature did not identify significant areas of research or siting policy that would prompt revisions to wind siting legislation in Wisconsin. Current wind siting and permitting processes are intended to balance human health and community concerns with a stable and consistently applied regulatory framework.

2.0 THE COUNCIL AT WORK

2.1 Wind Siting Council Membership

Recognizing that there are many complex, diverse, and sometimes controversial issues involved in wind turbine siting, the Legislature prescribed a very diverse and explicit membership to the Council. Wisconsin Stat. § 15.797(1)(b) directs the Commission to appoint a Wind Siting Council of up to 15 members to, among other things, advise the Commission in its rulemaking process, provide pertinent information regarding wind siting policy, and survey the wind-health literature.

2.2 Wind-health Report Drafting

The Council first met to discuss the drafting of this wind-health review and policy update in mid-November, 2022. At that meeting, the Council elected officers and developed a tentative timeline and framework for report drafting. At the next meeting in late November, 2022, the council agreed upon the types of literature that would be considered in its survey and on the work plan for report drafting. This included timelines for the compilation of a literature list.

---

[7] See Appendix F for a table containing this review.

[8] Alabama, Alaska, Arizona, Arkansas, Georgia, Florida, Idaho, Iowa, Kansas, Louisiana, Maryland, Mississippi, Missouri, New Mexico, South Carolina, Texas, Virginia, Washington D.C., West Virginia.

[9] Indiana, Maine, Massachusetts, Pennsylvania, Rhode Island, South Dakota.

Council members also agreed to have Commission staff assist them in drafting this report. By the end of September, 2023, Council members had submitted the literature they wished to be included in the report and Commission staff had conducted a formalized wind-health literature review.

Commission staff began drafting the report as literature was discussed and agreed upon by the Council for inclusion. The Council's review of draft language occurred concurrently with report drafting and continued through multiple iterations of discussion and revision. In May of 2024, the Council voted to adopt this wind-health report, including the dissenting minority report that is attached as Appendix E.

2.3 Wind-policy Update Drafting

Along with submitting literature for the wind-health section of the report, the Council was asked to provide to Commission staff any documents they would like to consider for the wind siting policy update. Policy papers included those that studied local, state, national, and international siting and policy decisions. The Council accepted eight papers on policy items. Commission staff further surveyed all American states' policies to evaluate national policy trends.

3.0 COUNCIL REVIEW OF WIND TURBINE-HEALTH LITERATURE

3.1 Survey of Peer-reviewed literature

The first large utility-scale wind turbines in Wisconsin went online in the late 1990s. From the outset of this newly implemented technology, there was considerable debate in different political subdivisions regarding the siting of wind turbines. As wind energy systems increased in size and capacity, some of this debate turned to the possible impacts that turbine operations may have on human health. Concerns about potential adverse health effects led to a formal regulatory framework in 2009 with the passage of Act 40 and creation of Wis. Stat. § 196.378(4g) which requires the Council to, among other things, provide recommendations on wind turbine siting criteria for rulemaking purposes and survey current, peer-reviewed literature on health impacts. As part of its recommendations to the Commission regarding wind siting rules, the Council completed its initial survey of the wind-health literature in 2010. The majority of the members concluded that given appropriate siting measures, including 50/45 dBA day/night noise limits, 1,250-foot wind turbine setback, and less than 30 hours of shadow flicker per year for non-participating residences, it is reasonable to conclude that adverse health effects would be unlikely to occur. These conclusions were codified in PSC 128 which describes the wind siting rules that the Commission considers when reviewing wind energy projects and the siting criteria that local governments may not be more restrictive than when developing local rules.

With over 479[10] utility-scale wind turbines installed throughout Wisconsin, some members of the public have continued to express concerns over potential adverse human health effects attributed to wind turbines. When wind energy systems were initially being proposed, the potential adverse health effect causes that people were concerned with included noise, shadow flicker, electromagnetic fields (EMF), stray-voltage, ice-throw, and physical collapse of the turbine. As wind energy has expanded, the most common issue that is now being studied with regard to impacts on individuals residing in close proximity to wind turbines is noise generated by the moving blades.

In this literature and policy review, the Council surveyed scientific research, analysis, and opinions on the issue of wind energy systems and health that have been published since its 2014 report. The Council conducted this survey using the operational definition of health as "a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity."[11] In addition to literature that was identified by Council members, Commission staff also conducted a search of literature published between the years 2014 and September 2023 and made this list of literature available to the Council members to review for consideration. Commission staff searched for relevant literature by using Google Scholar and a range of search terms including: wind turbines or wind energy or wind farms and health, effect, impact, noise, and concern. In addition, three students from UW-Madison[12] enrolled in an Energy Analysis and Policy capstone project conducted a review of literature with the same criteria used by the Council, categorized the literature by type and identified topics/tags, and provided brief summaries of the articles. The UW Students also wrote up a meta-analysis of the literature reviewed. The work the UW Students did locating and organizing the peer-reviewed scientific literature on topics relating to wind energy systems and health or policy was of great use in identifying and organizing the amounts of literature available for this report.

3.1.1 Empirical Research

One of the most powerful measures to assess potential adverse health effects caused by utility-scale wind turbines are the results from epidemiological studies. The Council identified 16 cross-sectional, survey-based studies. These types of studies are common because they are easy to conduct, inexpensive, and can determine baseline prevalence of impacts across communities. They are, however, limited because they are not experimental and therefore cannot clearly demonstrate cause and effect. They are also limited in that they are subject to bias, discussed below, and they are a snapshot and are not able to establish trends. The Council's review of the wind-health literature revealed 20 publications on cross-sectional surveys of individuals living near wind farms, related to health.[13] Of these publications, the topic with most discussion was

---

[10] Turbine numbers from the USGS' US Wind Turbine Database online map https://eerscmap.usgs.gov/uswtdb/
[11] World Health Organization definition of health, available at https://www.who.int/about/governance/constitution
[12] Elizabeth Jurado, Kaitryn Olson, and Samantha Jurvich
[13] Blanes-Vidal & Schwartz, 2016, Hübner et al., 2019, Botterill & Cockfield, 2016, Radum et al., 2022, Pawlaczyk-Luszczynska et al., 2018, Qu & Tsuchiya, 2021, Turunen et al., 2021 (a), Haac et al., 2022, Jalali et al., 2016 (a), Fast & Mabee, 2015, Elmallah & Rand, 2022, Jalali et al., 2016 (b), Michaud et al., 2016 (a), Michaud et

wind turbine noise[14], with specific interest in infrasound.[15] Many studies describe results that suggest trends of increased annoyance and sleep disturbance due to wind turbine noise, but not all studies had statistically significant relationships. Several studies that assessed attitudes found that symptoms reported often correlated with perceived fairness of planning of the project or relationship with developer.[16] Another repeated finding was that wind turbine noise can often be masked in urban environments by other environmental noise such as road traffic.[17] Another annoyance factor that was investigated was shadow flicker.[18] The surveys that assessed shadow flicker found similar results to those that assessed wind turbine noise, and concluded that noise limits could serve as a proxy for shadow flicker exposure.[19] Several studies occurred outside of the US, often in Canada[20] or European countries such as Finland or Poland.[21]

Caution may be warranted when reviewing these surveys as they can be subject to different, and sometimes overlapping, biases due to study design. These include observation, confirmation, and selection bias. Observational bias results when authors limit the scope of a study to a particular area or issue, in particular an area or issue where results are expected to be found while disregarding other information. This bias makes a positive result more likely than if a randomized sample was surveyed. Confirmation bias encompasses a range of effects that can be described broadly as a tendency to draw conclusions that are in keeping with pre-established beliefs. It can arise through the way data is collected, such as disregarding evidence that would be in conflict with anticipated results. Selection bias has to do primarily with failure to select study subjects that accurately represent the population or by allowing subject self-selection. For instance, performing a survey through an open, online means may select for those individuals motivated to participate rather than a representative cross section of a population.

In addition to these biases in research design, there is also personal bias. As with any contentious field of academic study, some authors of the articles cited in this report may have interests in one area of argument. For instance, some authors reach the conclusion that wind turbines cause adverse health impacts by relying on evidence that other authors deem unreliable. The source of funding for some of the articles cited herein may also be from organizations that

---

al., 2016 (b), Feder et al., 2015, Barry et al., 2018, Maijala et al., 2020, Turunen et al., 2021 (b), Baxter et al., 2013, Gaßner et al., 2022

[14] Blanes-Vidal & Schwartz, 2016, Hübner et al., 2019, Radun et al., 2022, , Pawlaczyk-Luszczynska et al., 2018, Qu & Tsuchiya, 2021, Turunen et al., 2021 (a), Jalali et al., 2016 (a), Jalali et al., 2016 (b), Michaud et al., 2016 (a), Michaud et al., 2016 (b), Feder et al., 2015, Barry et al., 2018, Maijala et al., 2020, Turunen et al., 2021 (b)

[15] Turunen et al., 2021 (a), Turunen et al., 2021 (b), Maijala et al., 2020

[16] Hübner et al., 2019, Botterill & Cockfield, 2016, Jalali et al., 2016(a), Jalali et al., 2016 (b), Fast & Mabee, 2015, Elmallah & Rand, 2022

[17] Hübner et al., 2019, Qu & Tsuchiya, 2021

[18] Haac et al., 2022

[19] Haac et al., 2022

[20] Jalali et al., 2016 (a), Jalali et al., 2016 (b), Michaud et al., 2016 (a), Michaud et al., 2016 (b), Feder et al., 2015, Barry et al., 2018, Fast & Mabee, 2015

[21] Pawlaczyk-Luszczynska et al., 2018, Qu & Tsuchiya, 2021, Turunen et al., 2021 (a), Turunen et al., 2021 (b), Maijala et al., 2020, Blanes-Vidal & Schwartz, 2016, Hübner et al., 2019, Radun et al., 2022

support or oppose wind energy. This may or may not influence the authors' perspectives on the wind-health issue. What is clear is that the majority of the articles cited in this report are peer-reviewed and that, regardless of the opinions of the article authors, outside experts have opined that the articles offer some degree of independence and important scientific information.

While cross-sectional, survey-based studies are the most common type of research study when it comes to wind acceptance and self-reported health outcomes, other forms of empirical research, including longitudinal and experimental studies, are growing in number. Longitudinal studies are similar to cross-sectional studies in that the studies tend to be observational in nature, with quantitative or qualitative data being collected on various outcomes, without any variable manipulation. In contrast, longitudinal studies use continuous or repeated measurements of individuals over a period of time. These types of studies have the advantages of trying to identify events or shifts that can cause a change in the person over time, but they can be difficult to conduct due to individuals leaving the study and time or financial constraints. These types of studies have appeared more and more as research within the wind-health landscape has developed and matured. The Council's review of the wind-health literature revealed two publications on longitudinal studies of individuals living near wind farms, related to health.[22]

Experimental studies, unlike cross-sectional research, are not purely observational and are designed to capture a cause-effect relationship. These types of studies work well for research that has a well-defined set of variables that can be manipulated and compared to a control group. Based upon the study's protocol, the study should be able to be replicated in another, similar group of people with similar results, giving the study high validity. These types of research studies are highly resource intensive, and often there are ethical concerns when human health is involved. The relatability of a lab conducted study to a 'real-world' environment is another criticism that is often raised. There were multiple papers that technically exist under the category of experimental research but are very different than human observation studies or even physical measurement-based studies.[23] This second type of experimental literature is based in modeling frameworks, exploring various theoretical conclusions through scenario-based variable manipulation. The Council's review of the wind-health literature revealed 15 publications on experimental studies of individuals living near wind farms, related to health.[24]

One of the notable types of experimental research was investigating the impact of wind turbine noise on various aspects of sleep.[25] All sleep studies were conducted in laboratory environments with mimicked or recorded wind turbine noise, and various physiological measures of sleep were measured. Little physiological evidence was found to show any impact of wind turbine noise on

[22] Pohl and Hübner, 2018, Poulsen et al., 2018
[23] Buonocore et al., 2015, Buonocore et al., 2019, Siler-Evans et al., 2013, Millstein et al., 2017, Deignan & Hoffman-Goetz, 2015, Lerner, 2021
[24] Maffei et al., 2015, Malecki et al., 2023, Berger et al., 2015, Chiu et al., 2021, Smith et al., 2020, Liebach et al., 2021, Tonin et al., 2016, Crichton et al., 2013, Marshall et al., 2023, Buonocore et al., 2015, Buonocore et al., 2019, Siler-Evans et al., 2013, Millstein et al., 2017, Deignan & Hoffman-Goetz, 2015, Lerner, 2021
[25] Smith et al., 2020, Liebach et al., 2021, Marshall et al., 2023

sleep or sleep latency, however one study specifically notes that they tested younger participants in an urban environment[26] which may have biased results. Other contributions of experimental studies included investigations into heart rate variability[27], audible noise recognition[28], and infrasound exposure.[29] Multiple experimental studies found evidence to suggest preconceived ideas about wind turbine noise and infrasound can influence perceived symptoms after exposure.[30]

All of the modeling-based, experimental work investigated the ability to quantify potential benefits of renewable energy deployment across the United States at some scale.[31] Benefits quantified included monetary benefits derived from emissions displacement or climate change minimization, as well as health benefits like premature death avoidance. All of the papers of this type evaluated types of benefits across regional scales of the U.S., with some papers explicitly concluding that emission reduction benefits as a result of renewable energy deployment were generally highest in the mid- to upper-Midwest region.[32]

3.1.1.1 Surveys with Large Sample Sizes

3.1.1.1.1 Health Canada Study

Health Canada is the Canadian federal agency responsible for national public health. In response to public concern regarding potential health impacts from wind turbines, Health Canada, in partnership with Statistics Canada, undertook a $2.1 million Canadian Dollar epidemiological study to evaluate the health of people living up to 10 kilometers (km) (6.2 miles) from wind turbine installations. The study took place in communities in southern Ontario and Prince Edward Island during 2013. The study consisted of three main parts:

1. An in-person questionnaire, given to randomly selected adult participants living at various distances from the wind turbines. The study found 1,570 eligible households in the study areas, of which 1,238 households participated (78.9 percent).
2. A collection of physical health measures that assessed stress levels using hair cortisol, blood pressure, sleep actimetry[33] (over seven days) and resting heart rate. This goal of obtaining objective measures of health sets the Health Canada study apart from many other studies on this subject, which rely only on self-reported health effects.[34]

---

[26] Liebach et al., 2021
[27] Chiu et al., 2021
[28] Berger et al., 2015, Maffei et al., 2015
[29] Malecki et al., 2023, Tonin et al., 2016, Crichton et al., 2013
[30] Smith et al., 2020, Maffei et al., 2015, Crichton et al., 2013, Tonin et al., 2016
[31] Buonocore et al., 2015, Buonocore et al., 2019, Siler-Evans et al., 2013, Millstein et al., 2017
[32] Siler-Evans et al., 2013, Buonocore et al., 2019
[33] Small watch-like devices were worn by participants to provide an objective measurement of sleep over a 7-day period.
[34] The Health Canada study did find that the objectively measured health outcomes were consistent and statistically related to corresponding self-reported results in their study.

3. More than 4,000 hours of wind turbine noise (WTN) measurements were conducted to support the modeled calculations of WTN levels at homes in the study.

The study aimed to compare all households located within 600 meters of a wind turbine in the study area, with others between 600 meters and 10 km randomly selected. One randomly selected adult in each household was selected to participate in the study. Details of house construction, including the dimensions of the participants' bedrooms were obtained during the survey to assist with sound level modeling.

Calculated outdoor A-weighted WTN levels for the homes participating in the study reached 46 A-weighted decibels (dBA) for wind speeds of 8 meters/second. Use of A-weighted scales in evaluating noise is a common method of measuring environmental noise and assessing potential noise health effects. It is meant to represent the noise filtering process of the human ear, putting less importance on frequencies to which human ears are less sensitive. Other ways of assessing noise could use different weighted scales, and some argue that using A-weighted scales underrepresents low frequency sounds. The Health Canada study also calculated C-weighted sound levels to attempt to better assess the low frequency levels, but found A and C weighted levels were so close as to provide the same information. The calculated WTN levels are likely to be representative of yearly averages with an uncertainty of about ±5 dB.

No evidence was found to support an association between WTN and self-reported sleep quality, self-reported illnesses such as migraines, tinnitus, heart disease[35] or self-reported stress[36] or quality of life. A statistically significant association was found between self-reported annoyance towards several wind turbine features and increasing levels of WTN[37]. The statistically significant increase in annoyance was found when modeled WTN levels exceeded 35 dBA. Where modeled WTN levels were equal to or greater than 40 dBA, 16.5 percent of participants in Ontario and 6.3 percent of participants in Prince Edward Island reported high levels of annoyance. Annoyance was significantly lower among the 110 participants that received personal benefits, such as rental payments, from the wind energy systems. The Health Canada study results do not support an association between exposure to WTN up to 46 dBA and sleep disruption as measured through actimetry.

An article[38] published by the panel of the study described in greater detail the World Health Organization Quality of Life[39] questionnaire (WHOQOL-BREF) used in the Health Canada study, as well as the results seen using univariate analyses and multiple linear regression models. It found that lower scores, indicating less satisfaction with quality of life, on the physical and

---

[35] Michaud et al., 2016 (a)
[36] Michaud et al., 2016 (b)
[37] Michaud et al., 2016 (a)
[38] Feder et al., 2015
[39] The World Health Organization defines Quality of Life (QOL) as a broad multidimensional concept that includes subjective evaluations of both positive and negative aspects of life. Physical domains of health are joined with social, psychological, and environmental domains to create a complex series of measurements. Evaluated items are ranked from a low of 1 to a high of 5.

environment domains of the questionnaire were observed among participants that reported high visual annoyance towards wind turbines. Higher scores, indicating more satisfaction with quality of life, on the physical domain of the questionnaire were seen in participants that received a personal benefit from wind turbines (such as rental payments). Overall, the analysis of the study results do not support an association between exposure to WTN up to 46 dBA (modeled) and quality of life assessed.

An article written by Krogh et al. finds that the Health Canada Study is limited in certain conclusions. Krogh et al. suggests that turbine noise calculations may have been influenced by a divergence between wind turbine calculated noise models and actual full spectrum noise. Calculated models of WTN such as the A-weighed noise levels in the Health Canada Study, do not always reflect the actual noise levels inside the home environment. Krogh et al. references a study by Iannace that argues that wind speed conditions and placement of turbines can influence sound levels not reflected in the A-weighting system. The lack of actual noise measurements may have impacted the analysis of self-reported findings interviews and objective health measure data in the Health Canada study.

Additionally, this article argues that the Health Canada Study's analysis of cortisol levels may have been influenced by inaudible infra and low frequency sound that were not accounted for in the study. Krogh referenced research performed by Persson Waye et al. that indicates cortisol responses differ based on the type of noise, making low frequency noise calculated through actual noise measurements an important variable omitted in the Health Canada report. The high number of excluded hair cortisol samples and the failure to supplement hair cortisol samples with saliva cortisol samples also could present a weakness in study methodology. Krogh recommends that, to measure peak stress successfully, wind turbine investigations should use a study group to correlate subjective and objective measurements of noise (inside and outside homes), wind speed, operational status, and direction at the hub.

Finally, Krogh et al. finds that the unavailability of raw (uninterpreted) data is a weakness that limits researchers to commenting only on interpreted data instead of enabling additional contributions to the research based on raw data sets. Ultimately, the Krogh et al. article argues that the Health Canada overlooks important factors governing health impacts. The authors agree with the Health Canada Study that results "are not definitive on their own" and that results are not generalizable beyond the study areas of Ontario and Prince Edward Island, Canada. It should be noted that the Krogh et al. article was published by a low-impact journal, potentially impacting its credibility.

Researchers on the Health Canada study provided a response to questions raised by Krogh and others about the methodology and conclusions of the Health Canada study.[40] This included a restatement that the study, although of a large population size and with a good response rate,

[40] Michaud, et al., 2018 (a)

cannot be used to determine causal relationships, and that the findings are representative of areas where long-term outdoor WTN levels do not exceed 46 dBA (63 dBC) for individuals between 18 and 79 years of age. The researchers stated that the available data did not provide evidence to support an association between WTN levels up to 46 dBA and any of the self-reported or objectively measured health outcomes apart from an increase in the prevalence of long-term high annoyance toward wind turbine features. The researchers stated that the data to analyze these findings is available to interested parties apart from data that could be used to reveal the identity of study participants or that considered to be confidential business information.

In 2018, a group of researchers[41] used the data from the Health Canada study to measure the association between wind turbine distance and human health. The study took issue with using modeled A-weighted wind turbine sound pressure levels in the study to indicate that wind turbine noise is not associated with any adverse outcomes except for annoyance. The researchers modeled distance as a continuous variable and logarithmically transformed to normalize the distribution. After this was done, their results suggested that proximity to wind turbines were inversely associated with environment and physical quality of life scores. The results also indicated that wind turbine proximity was associated with annoyance. In response[42] to this study, the Health Canada researchers indicated that the reanalysis using logarithmically transformed distance as the alternate exposure to investigate the association between wind turbines and human health was incorrect. The researchers stated that it is the response variables and not the distance variable that should be transformed. When distance is not logarithmically transformed, the researchers show that there is no apparent statistical association between the distance to wind turbines and any of the quality-of-life domains explored in the Health Canada Study.

Also in 2018, researchers released an article[43] that further assessed the relationship between annoyance and measures of health by reviewing data collected in Health Canada's Community Noise and Health Study. An aggregate annoyance construct was generated across five wind turbine features: noise, shadow flickers, blinking lights, visual impacts, and vibrations. These five features were each assigned an annoyance level between 0-4 with the aggregate annoyance score ranging from 0-20. The researchers found that the aggregate annoyance level of individuals was related to self-reported health effects. For instance, those who indicated that they had a health condition such as chronic pain, poor sleep, tinnitus, dizziness, or headaches would have an aggregate annoyance score between 2.53 to 3.72 while those who did not report those conditions would have an annoyance score between 0.96 and 1.41. Those who had statistically the highest annoyance score were those who reported that someone in their household had filed a formal complaint about wind turbine noise (8.02) compared to those who had not filed a complaint (1.39).

---

[41] Barry, et al., 2018
[42] Michaud, et al., 2018 (b)
[43] Michaud, D., Marro, L., and McNamee, J., 2018.

3.1.1.1.2 Population surveys (not topic-specific)

A study[44] of residences in rural Denmark conducted a masked mail survey of 1,120 households with 454 responses from residents living within 167m (548 ft.) and 8,983m (5.6 miles) of wind turbines, all of which were operating for at least 12 months during the 2 years prior to the study. The median and mean distance to the closest turbine for respondents was 1,712m (5,617 feet) and 2,052m (6,732 feet) respectively. The survey requested general socio-demographic data and lifestyle data followed by an open-ended questionnaire, a section on environmental stressors, and a third part on physical symptoms and health. Five individuals responded in the open-ended question that one of the main disadvantages of living in the countryside was the presence of wind turbines. The study found a significant association between residential proximity to wind turbines and wind turbine noise (WTN) annoyance. There was not an association with those levels of annoyance and other health effects or symptoms.

Another study[45] combined survey data from one cross-sectional US survey and three European surveys (two cross-sectional, one longitudinal) to evaluate annoyance and stress impacts of wind turbines on nearby residents. The datasets were reduced as necessary for comparison resulting in a total sample size of 2,470 respondents residing within 4.8 km (3 miles) of a wind turbine (US sample n = 1,441; European sample n = 1,029). All surveys used a standardized questionnaire in which responses were used to assess levels of annoyance related to specific wind turbine impacts including noise, shadow flicker, lighting, and landscape change using the Annoyance Stress-Scale (AS-Scale). The AS-Scale combines singular annoyance factors like noise and shadow flicker to create a more precise wind turbine impact indicator. The study's findings provided evidence that wind turbine annoyance and related stress effects are not a wide-ranging issue, and annoyance levels in the US towards shadow flicker, lighting, and landscape changes were, on average, slightly lower than the European levels. Overall, annoyance levels were comparable to those levels reported about traffic noise.

Research conducted in Australia[46] utilized a two-phase approach, consisting of a questionnaire and targeted interviews, to explore people's feelings and relationships with wind turbines appertaining to visual aesthetics and perceived health impacts. The study examined a subset of 189 responses from the 2011 Senate Inquiry that was sent to the general public in Australia with the purpose of exploring opinions on the impact of wind turbines on health and noise. In tandem, a set of interviews were conducted with residents in four Australian communities that host wind turbines. Interviewees were initially recruited through identification of people from the Senate Inquiry, and additional interviews were conducted with a variety of people spanning from those directly involved in wind turbine siting debate, to those who expressed interest in participating in an interview. The questions asked in the interviews were open ended in nature to allow participants to express a range on feelings towards wind turbines without participants feeling as though the inquiry had a pre-disposition of support or opposition. Results from the

---

[44] Blanes-Vidal and Schwartz, 2016
[45] Hübner et al., 2019
[46] Botterill and Cockfield, 2016

survey review and interviews revealed a range of feelings and opinions, with some support for potential benefits of turbines including tourism and aesthetic appeal. For those that were opposed to wind, the most common reason cited was health concern. Among those that were opposed due to health concerns, there were some participants that indicated they were in support of the wind turbines until they had personally experienced health concerns or were impacted by noise. Additionally, those that were opposed often stated that the development process excluded the host community's thoughts and opinions.

3.1.1.1.3 Noise

A study[47] in Finland examined reactions to wind turbine noise and compared reactions to road traffic noise. The noise-level allowances[48] for wind energy systems in Finland are 45 dB (day) and 40 dB (night), and the researchers stated that turbines generally adhere to the 40 dB limit overall rather than have higher amounts of noise during the day. In 2018, the researchers sent questionnaires to 3,058 addresses and received responses from 684 households (22 percent response rate). The questionnaires masked the intent of studying WTN, by also mentioning road noise an almost equal amount of time. Of the 684 households, 121 lived in a control area (not near wind turbines). Researchers modeled noise from both wind turbines and traffic, and respondents living in areas near wind turbines had modeled noise levels ranging from 17 – 40 dBA. Responses that indicated annoyance were highest in were category 30-40 dBA (the study had 10 respondents for sound levels >35 dBA). The researchers concluded that the only health effect from wind turbine noise is annoyance, and there is no conclusive effect of wind-turbine noise on self-reported health. They also found that, for traffic noise, there is an association with a higher probability of self-reported health effects and suggest that public health improves if road traffic noise exposure is reduced, especially when 55 dBA is exceeded in residential yards.

Another study[49] in Poland evaluated the perception and annoyance of noise from wind turbines in populated areas near ten windfarms in north, central, and southeast parts of Poland. The study surveyed 545 subjects, aged 13 to 88, living within 2-km or less to the nearest wind turbine. The survey that was used contained two parts, with part one inquiring about the house and level of satisfaction with the living environment, and part two was a physical health self-assessment. In the areas where respondents lived, A-weighted sound pressure levels (SPLs) were calculated and randomly verified with on-site measurements. Almost all respondents (93.4 percent) could see one or more WT from their dwelling or yard, furthermore 34 and 18 percent of respondents stated that they were annoyed or highly annoyed indoors respectively. There was a statistically significant decrease in negative assessments about WT when the noise levels decreased from > 45 dB to < 35 dB. Additionally, the percentage of respondents that indicated annoyance was strongly dependent upon their general attitude toward WTs. A-weighted SPLs, general attitudes towards WTs, noise sensitivity, terrain shapes, and road traffic noise were all found to be

---

[47] Radun et al., 2022

[48] Noise level allowances in Wisconsin and areas that conducted other studies on WTN and health, such as Canada, are higher than those in the Finnish study.

[49] Pawlaczyk-Luszczynska et al., 2018

important factors in evaluating annoyance levels. Overall, they did not identify a statistically significant relationship between the noise level and reported health effects.

A longitudinal field study[50] conducted in Lower Saxony, Germany examined attitudes towards WT and WTN over time to evaluate if WT annoyance changes over time. A group of 212 individuals living within proximity to a wind farm were surveyed from March through April 2012, with a questionnaire of 450 items. The study retained 133 individuals who participated in a follow-up questionnaire from February through March 2014. Overall, a marginal decrease in annoyance was observed decreasing from 9.9 percent being strongly annoyed in 2012, to 6.8 percent of residents being strongly annoyed in 2014. There was also a reduction in noise related symptoms from 10 percent of participants in 2012 to 7 percent in 2014. In addition, the number of average reported symptoms decreased from 12 to 3.

A study[51] in suburban-urban residential areas near three wind farms in the United Kingdom aimed to investigate the relationship between modeled exposure to WTN and noise perceptions, self-reported sleep disturbance, and perceived health impacts. Two variants of a questionnaire were used to sample residents: one to question noise perceptions, personal attitudes, and health problems related to WTs, the second to act as a control questionnaire with no specific reference to WTs other than as an option for environmental nuisance. A total of 2,971 individuals were sampled within 2-km of the nearest WT, 2,238 individuals received the WT specific survey, 733 individuals received the control survey. Noise maps were created for the areas sampled using A-weighted SPLs based on the ISO 9613-2 sound propagation standard. 359 participants responded to the survey: 262 for the WT specific survey, and 97 for the control survey. Only 16 percent (*n* = 59) of respondents noticed WTN, and of that, 41percent of respondents were not annoyed by the noise.

There was no significant relationship between general health responses or sleep disturbance associated with WTN, despite similar health conditions like nausea and headache being raised. A dose-response relationship was confirmed as probability for annoyance increased with modeled noise levels. Although, in urban environments, higher levels of urban noise may act as a mask to WTN specifically. Additionally, model results suggested a multitude of personal factors significantly influenced perception of WTN. Age and a negative attitude toward the environmental impact of WT were positively associated with annoyance, and higher educational qualifications produced a decreased probability of annoyance.

A study in Denmark investigated the impact of wind turbine noise levels on birth outcomes.[52] The study was designed to determine if any negative health impacts occur in children born near turbine areas and exposed to WTN. The study included all dwellings at distances within 20 wind turbine heights of a wind turbine and randomly selected 25 percent of all dwellings between 20 and 40 wind turbine heights from a WT. Noise at the residences was modeled by using weather

---

[50] Pohl and Hübner, 2018
[51] Qu & Tsuchiya, 2021
[52] Poulsen et al., 2018

data and classification of houses into six sound insulation classes based on building characteristics. The analysis included 143,684 live births with a mother living in these distance ranges between 1983 and 2013. The research collected information on gestational age, date of birth, and birth weight from the Danish Civil Registration System and the Danish Medical Birth Register. The adverse birth outcomes studied included preterm birth, term small for gestational age, and term low birth rate. The study found no associations between residential WTN and any of the three factors studied. The authors do note that the results should be interpreted cautiously, as very few cases were exposed to noise levels higher than 42 dB.

Another cross-sectional study[53] conducted in Finland explored prevalence of self-reported health concerns appertaining to broadband wind turbine noise in the vicinity of five wind energy systems. The selected areas for the study were in coastal Finland where wind turbines started operation between 2010 and 2016, and host three to sixteen wind turbines (depending on community) with power capacity of each ranging from 2.0 to 3.5 megawatts (MW). Researchers sent out masked questionnaires to residents by asking about other environmental noise factors to reduce selection bias. The distance from participants' residences and the closest wind turbine was used as a proxy for wind turbine exposure (≤ 2.5 km, > 2.5–5km, and > 5–10 km). In addition to the distance, sound pressure levels were modelled outside of the participants' residences according to the guidelines presented by the Ministry of the Environment in Finland, which utilizes ISO 9613-2 as a standard. Wind turbine SPLs outdoors could be reliably modelled only for the closest distance zone (less than 2.5 km/1.5 mile) from the turbines, where the yearly average was 34 dB and maximum 43 dB.

Questions included in the questionnaire were modified from a national survey which inquired about a list of symptoms or ailments the participant may have experienced in the previous month. Additionally, researchers asked the participants if they had certain diseases diagnosed by a doctor within the last calendar year. From the five selected areas, a total of 2,828 individuals were selected for the survey, and 1,411 persons responded to the inquiry resulting in a 50 percent response rate. The researchers asked for information on age, sex, marital status, education, work status, smoking habits, alcohol consumption, physical activity, body mass index, and presence of hearing problems to include within the statistical modeling as potential confounders. In result, 8 percent of the respondents that lived in the closest distance zone, defined as less than 2.5 km (1.5 mile) to the nearest wind turbine, reported being at least 'somewhat annoyed' by wind turbine noise outdoors and 5 percent reported similar annoyance levels indoors. Sleep disturbance due to wind turbine noise was reported by less than 4 percent of the respondents. When it came to various symptoms, ailments, and need for certain prescription medications, the prevalence was similar across distances. While annoyance in the closest distance zone was statistically higher, as anticipated, the prevalence of many self-reported symptoms was homogenously observed across distances to wind turbines. The reported health symptoms are very common in the general population and have multiple potential causes. Overall, the study results do not support a

[53] Turunen et al., 2021(a)

hypothesis that audible sound from wind turbines at the levels in the study could cause the self-reported health symptoms.

3.1.1.1.4 Noise - Infrasound

Several papers specifically discussed research into infrasound and potential health impacts associated with a government-sponsored study in Finland. Infrasound commonly refers to sound waves below 16 or 20 Hz, in a range where the human ear has poor sensitivity to detecting sound.[54] The Finnish government commissioned a multidisciplinary research project in relation to wind turbine infrasound with the results published in a lengthy report.[55] The report provided both a review of the literature on wind turbines and infrasound, as well as research done on infrasound levels near wind turbines, perception and reporting of health symptoms intuitively associated with infrasound, and whether infrasound from wind turbines could be detected in sound samples and related to reported symptoms. The report discussed characteristics of wind turbine sound, including infrasound, which does not decrease at night the way traffic noise often does, and that the low frequencies of infrasound do not attenuate or reduce the way other noise does over distance or when moving through natural or built structures.

One goal of the research was to examine sound levels down to 0.1 Hz in houses near wind turbines and characterize the sound, including both audible and inaudible infrasound. Research was conducted at several houses where wind turbine sound, including complaints about infrasound, were identified as problems, rather than selecting houses at random. Two houses were selected to take measurements inside, with microphones calibrated between 0.050 Hz and 20,000 Hz, and the wind turbine operators provided operational information to use during study evaluation to ensure measurements could be compared to when turbines were operational or not. For one house, the nearby turbines were 3.3 MW Vestas turbines with hub heights of 137 m (450 ft.) and the closest turbine was 1,585 m (5,200 ft) to the east. The second house was a similar distance from the closest turbine, which was a 3.0 MW Siemens turbine with a hub height of 143 m (470 ft.).

Researchers measured weather, sound, and vibration at each site and used specific infrasound microphones to capture full spectrum sound including that at the lowest frequencies. Sound was analyzed, including the depth of amplitude modulation, and used in statistical analysis to select samples for additional study work. Sound levels measured in the houses showed indoors infrasound sound levels ranged from 42 to 97 dB and A-weighted levels ranged from 29 to 55 dBA. As infrasound is considered below the area of human ear sensitivity, the SPL of sounds in those frequencies must be higher for detection to occur. The Finnish report provided a table of hearing threshold levels for low frequency sound (20-100 Hz) and infrasound, from research done by Toshio Watanabe and H. Møller in 1990, shown in Figure 1.

---

[54] Maijala et al., 2020
[55] Maijala et al., 2020

Figure 1. Hearing threshold levels for low frequency and infrasonic sound ranges.

Frequency, Hz	4	8	10	12.5	16	20	25	31.5	40	50	63	80	100
Level, dB	107	100	97	92	88	79	69	60	51	44	38	32	27

After the noise measurements, researchers sent a questionnaire to residents in four areas of Finland that appeared to have the most reports of health symptoms that the residents intuitively associated with infrasound. This was determined by emailing a survey to officials in 40 municipalities with wind turbines, asking for reports of symptoms. This approach – looking for areas with reported symptoms - allowed researchers to examine results in what could be considered a 'worst case scenario' for symptoms associated with infrasound. The survey found a total of five percent of respondents (70 individuals) reported symptoms they associated with wind turbine infrasound. Of those respondents, 47 percent also associated their symptoms with vibration or electromagnetic fields from the turbines. The study found that one third (23 respondents) of symptom-reporting respondents reported that they had visited a doctor due to the symptoms they suspected were the result of wind turbine infrasound.

This symptom reporting research from the larger Finnish governmental report was also published in a peer-reviewed journal article[56] and discussed how although the WHO and many epidemiological studies have found no connection between wind turbine proximity or SPLs to health impacts, apart from annoyance and sleep disturbance, there continues to be self-reporting of symptoms by individuals that associate those symptoms with infrasound caused by wind turbines. The researchers sent residents living near wind energy systems in four areas of Finland previously assessed as having the most reports of symptoms a questionnaire asking for information on these intuitively associated symptoms. The questionnaire was sent to 4,847 members in April 2019, and the response rate was 28 percent. The researchers followed up with a short telephone interview due to what they considered a low response rate, and the overall number of responses through both efforts was 1,672 (35 percent). Respondent buildings were categorized into four distance zones (≤ 2.5 km, > 2.5–5 km, > 5–10 km, > 10–20 km) from 2.7 to 4.5 MW turbines. Information on the respondents, their buildings, opinions, and annoyance were entered into a model to identify factors associated with wind turbine infrasound related symptoms. The research model indicated that living close to a wind turbine was associated with an increased probability of reporting symptoms intuitively associated with wind turbine infrasound, and that this association was strongest for those living closest to the turbines, shown as 15 percent (n=34) of respondents living within 2.5 km of turbines reported symptoms compared to 5 percent (n=70) in the whole study area. Having two or more chronic diseases and considering wind turbines to be a health risk were also associated with an increased probability of having these symptoms. The study noted some challenges such as low response rate and

[56] Turunen et al., 2021(b)

potential for bias introduced by selecting the 'worst case scenario' by pre-surveying areas for reports of symptoms.

The report by Maijala et al. also examined whether participants could detect wind turbine infrasound when exposed to samples of recorded wind turbine sounds where there were reports of symptoms associated with wind turbine infrasound. Participants were recruited from those that received the previously discussed questionnaire, as well as from groups against wind energy and general candidates near wind energy systems. Participants were provided information from a medical nurse and completed an electronic questionnaire, including a health survey. There were 37 survey respondents, of which 26 agreed to take part in the sound experiments. Researchers selected sound samples that could provide the worst-case scenario for the participants in terms of having wind turbine sound recordings with the highest levels of infrasound and amplitude modulation. Participants sat in a test chamber and were presented with the sound samples and asked to detect samples with infrasound. Another part of this research asked participants to rate the annoyance of wind turbine and reference sounds. In half of the wind turbine sound samples, sound was filtered to not contain infrasound frequencies, while in half of the reference sounds, infrasound extracted from the wind turbine sounds was added. Finally, the researchers also measured the participants' autonomic nervous system (ANS) reactions to the different noise sources and the presence or absence of infrasound using electrocardiographic (ECG) and electrodermal equipment (EDA). Additional tests were done to measure the strength of the varying ANS stress responses and calibrate differences in stress reactivity.

The results of these sound surveys indicated that wind turbine noise shows the highest annoyance ratings, with some effect caused by amplitude modulation. The survey results showed that the presence of infrasound does not seem to have a statistically significant effect on reported annoyance. The study showed no difference in sensitivity for infrasound between the groups; on average the group that reported health symptoms was less sensitive to infrasound recorded in areas near wind turbines, as well as yards and indoors. The measurements of ECG and EDA data showed no statistically significant differences during the study between the groups that participated or conditions such as the presence of infrasound. During the wind turbine noise annoyance tests, those that reported symptoms self-reported greater stress than the group that did not self-report symptoms associated with wind turbines.

The overall conclusion of the Maijala et al. study was that, at least in laboratory settings, wind turbine infrasound cannot be reliably perceived and does not result in increased annoyance, and that those individuals that report symptoms they associate with wind turbine sound are more likely to experience them due to other factors such as symptom expectancy, or the nocebo effect.

Separate from this research into infrasound in Finland, in a laboratory study[57] researchers tested the effect of 72 hours of infrasound simulating a wind turbine sound signature on 37 adults. The

---

[57] Marshall et al., 2023

sound level researchers generated ranged from 1.6 to 20 Hz, and did not expose participants to generated infrasound levels below 1.6 Hz, however ambient infrasound in the room caused by air conditioning was present at frequencies below 1 Hz. The sound level of the infrasound was ~ 90 dB which made it measurable to researchers but inaudible to participants. The researchers designed the experiment to resemble field measured infrasound, stating that "the simulated wind turbine infrasound comprised sinusoidal harmonics in the frequency range specified with monotonically decreasing amplitude and selected phase shift, resulting in a trapezoidal waveform as observed in field measurements." Participants were also exposed to generated traffic noise and aircraft noise, including at levels designed to disrupt the last three hours of sleep. The study states that although it attempted to find noise-sensitive individuals, that the study may have inadvertently recruited participants that were not sensitive to the effects of infrasound. Many different health measures were measured in the participants including sleep outcomes, cardiovascular physiology, and neurobehavioral performance. The findings did not indicate that infrasound caused ill health or perturb physiological or psychological measures in study participants.

3.1.1.1.5 Shadow Flicker

One research paper[58] was identified that described research into the correlation between shadow flicker exposure and levels of perceived annoyance. This research modeled shadow flicker at nearly 35,000 residences across 61 wind projects in the U.S. (located in 17 states). Turbines in the study ranged from a minimum hub height of 70 m (230 feet) to 100 m (328 feet) and 1.5 MW to 2.5 MW capacity. Numbers of turbines in each wind project ranged from a minimum of one to a maximum of 222 turbines. The modeled shadow flicker data provided:

- Annual number of shadow flicker hours at each home and distributions by time of day/over the year.
- Calculations of sun angles at different times of day and periods at a given latitude.
- The periods of every shadow flicker event for each resident.

The study also incorporated a survey of residences located within 2 km (1.24 mile) of the wind projects. This was done through a survey that examined the self-reported levels of annoyance as a result of shadow flicker, with 747 residences of the 35,000 that were modeled responding. The results found that exposure to shadow flicker and perceived shadow flicker had a strong positive relationship. However, the correlation between perceived shadow flicker and annoyance was much weaker, suggesting other factors influence annoyance levels. This research found other factors correlated with increased annoyance towards shadow-flicker include the response to changes in local land aesthetics, annoyance to anthropogenic sounds, as well as the age and education level of the survey respondent. The model showed that participating landowners, older survey respondents, and survey respondents that had completed college had lower odds of moving to a high annoyance level. The model found that survey respondents that expressed high

[58] Haac et al., 2022

attachment to the aesthetics of the area or high levels of general annoyances to environmental nuisances were predicted to express higher levels of annoyance at shadow flicker.

3.1.1.2 Surveys with Limited Sample Size or Scope

3.1.1.2.1 Noise Studies

The use of recorded wind turbine noise has been used in a range of studies to examine impacts to topics such as sleep, attitudes, and measurable health variables. Other studies on wind turbine noise explored the ability of individuals to hear or recognize sound that could be unique or attributable to wind turbines. One study[59] used recordings of WTN from a facility with turbines with hub heights of 50 m (164 ft.) and less than 1 MW each in power generation size. Sound recordings at five distances from 150 m (492 ft.) to 1,500 m (4,921 ft.) were made as well as one recording at 2,500 m (1.5 mile) where turbine noise was no longer anticipated to be audible. The recordings were played for 40 participants, divided into two groups of 20 subjects. One group of 20 participants had familiarity with WTN, while the other had never been exposed to WTN. The study sought to determine whether there was a measurable difference in the ability to recognize WTN at different distances and corresponding sound levels. The study found that at near distances (150 m to 300 m) there were no significant differences in the ability to identify WTN, but that differences between the groups increased as distances were larger. The participants with previous familiarity with WTN were more likely to have false positive recognition of WTN. The study was limited to audible noise frequency ranges and did not study the ability to detect low frequencies or infrasound.

Another study[60] examined whether there was a statistically significant association between students taking a cognitive test evaluating attention when exposed to background noise, recorded WTN infrasound and low-frequency noise, and infrasound created without amplitude modulation. The study recorded WTN in the field, 250 m (820 ft.) from a wind turbine, which was filtered to only produce infrasound when played in the experiment. The study exposed 129 students to the different sounds as they completed a questionnaire, and the results showed there were no significant differences between subjects performing the test in the various sound exposure conditions.

Studies also examined the relationship between audible noise and levels of infrasound (IS) and low-frequency noise (LFN) that would be experienced by receptors. One study[61] measured IS within buildings and outdoor levels of LFN at distances of 400 m (1,312 ft.) and 900 m (2,953 feet) from turbines to evaluate whether levels were within auditory threshold levels. The turbines in this study had a power capacity between 1.5 and 2.4 MW. The researchers measured these noise levels with devices designed to measure low-frequency range with screens to minimize background noise from wind or pressure fluctuations. The study found that indoor IS

---

[59] Maffei et al., 2015
[60] Małecki et al., 2023
[61] Berger et al., 2015

levels were below auditory threshold levels while LFN levels at distances >500 m were similar to background LFN levels. The study observed LFN due to wind turbine operation at a distance of 480 m (1,575 ft.) and found this corresponded to an overall increase in audible sound measured in dBA. All measurements of IS in the home were 25 decibels below human auditory thresholds and may be attributable to background IS. This correlation in audible and LFN supports using audible noise levels with wind turbine siting guidelines to evaluate, monitor, and set protective levels of WTN for nearby receptors.

One study[62] examined the relationship between LFN exposure from wind turbines and heart rate variability (HRV) for residents living within a 500 m (1,640 ft.) radius of wind turbines in Taiwan. The researchers claim that HRV can be an indicator of an autonomic imbalance in the nervous system. Researchers used electrocardiogram (ECG) recorders on residents at two public sites and seven homes in July and December, 2018. Closer proximity to the turbines resulted in higher LFN, and building construction impacted LFN exposure within the home. Ultimately, LFN from turbines had a higher effect on HRV than traffic noise but less than PM2.5 and ambient temperature increases. However, the researchers were only able to record the LFN from within seven residents' households, out of their original 30 test subjects. The researchers recommend those living near turbines use airtight windows and that the Taiwanese government create and enforce setback regulations.

In another study[63] on responses to noise, 148 residents of Germany were recruited to report noise disturbances caused by wind turbines over the course of two months. Of this population, 46 were able to report disturbances in an app, 17 users sent in noise reports in said app, and 4 of those users had audio equipment installed in their homes so researchers could compare sound measurements to the reports of the disturbances. Additionally, data was gathered from acoustic, ground motion, and meteorological reports in the area to compare to the residential noise reports. The app data indicated that higher complaints occurred in the early evening and night times. The study also indicated that both a change in rotation rate of the wind turbine blades as well as higher rotation rates was a cause of annoyance for the residents. The study authors indicated that more research was needed into the correlation of complaints and noise levels of wind turbines with a larger sample size of participants.

3.1.1.2.2 Sleep Studies

A Swedish study[64] published in early 2020 was the first investigation into the effect of wind turbine noise on physiologic sleep in a controlled environment. A total of 50 participants were recruited to participate in a three-night sleep study in a laboratory. Participants were required to have a BMI less than 30 kg/m2, of age between 30 and 70, not use sleep aid medication, not experience sleep apnea, report good auditory acuity, and keep a habitual sleep time broadly

[62] Chiu et al., 2021
[63] Gaßner et al., 2022
[64] Smith et al., 2020

comparable with the study protocol times (23:00 – 7:00). Participants were considered exposed if they lived within 1 km of a wind turbine and/or reported annoyance or sleep disturbance resulting in 24 exposed participants and 26 non-exposed. Each participant spent three consecutive nights in the sound exposure laboratory rooms with the first night serving as a habituation night.

Without the knowledge of the participants as to which night was occurring, one night wind turbine noise was played into the rooms and one night was left quiet to act as a baseline sleep reading. During the noise-exposure night, continuous wind turbine noise averaging LA_{eq} of 45 dB was played with four brief noise-free periods in which just the sound of wind was played. Sleep electrophysiology was measured using polysomnogram (PSG) per recommendation of the American Academy of Sleep Medicine, and the data was then analyzed for various sleep macrostructure variables. The morning after, a participant self-assessment was completed, and saliva samples were collected three times to measure cortisol concentrations using an enzyme-linked immunosorbent assay (ELISA) technique. Physiologic effects were slight, with REM sleep being the only macrostructure that was significantly impacted by the wind turbine noise. There were also no differences in the exposed and non-exposed groups, and no effect of wind turbine noise on the cortisol awakening response. However, self-reported sleep was adversely affected by the wind turbine noise with responses indicating worse sleep quality and less restorative sleep, in comparison to the wind turbine noise free night, suggesting that wind turbine noise of 45 dB can elicit sleep disturbance.

Another study from Liebach et al. studied the interference of wind turbine noise on the initiation of sleep.[65] The study measured the sleep onset period with noise levels at 33 dBA to simulate wind turbine noise and at a control level of 23 dBA to simulate background noise. Twenty-three participants were measured using two overnight polysomnography studies and asked to self-record their sleep latency in a sleep diary following their night of sleep. The research explained that sleep latency was chosen because it is a main marker of the ability to attain sleep, the physiological need for sleep, and the environmental/psychological factors that may impact sleep. Study results did not find that objective or subjective sleep latency was impacted by wind turbine noise in young, healthy, good sleepers. The study finds that the percentage of individuals who took longer than 20-30 minutes to fall asleep were no different in the WTN and control study groups. The conclusion of the study notes that many of the suburban study participants may frequently experience noise levels above 23 dBA which may impact their tolerance for noise.

Research from Jalali et al. investigated how turbines impacted self-reported sleep.[66] The study was conducted in Ontario, Canada and accounted for noise levels within the study area and sleep research to understand the impacts of noise levels on sleep. All participants included in the study lived within 2,000 meters (6,561 ft.) of wind turbines. Initial noise measurements were taken after construction was complete, but prior to the start-up and operation of turbines to avoid

---

[65] Liebach et al., 2021
[66] Jalali et al., 2016 (b)

construction noise impacts on sleep. Subsequent noise measurements took place at a similar time of year (March) after the wind energy system started operating. The research used the Epworth Sleepiness scale to measure daytime sleepiness, the Pittsburg Sleep Questionnaire Index (PSQI) to measure sleep quality and disturbances, and the Insomnia Severity Index (ISI) to measure a variety of sleep difficulties. The research also asked participants to respond to questions about their noise sensitivity and attitudes toward turbines on 5-point scales. In addition to the sleep measurements, objective noise levels were measured in a small number of participants' bedrooms. The results from these metrics and surveys found that participants reported poorer sleep quality if they had a negative attitude towards wind turbines, had property devaluation concerns, or were able to visually see turbines from their properties. The research specifically found that changes in the PSQI and ISI values were strongly associated with negative attitudes towards wind turbines. Changes in PSQI scores among participants were also associated with the visibility of the turbines.

3.1.1.3 Additional Research Topics

3.1.1.3.1 Social/Attitudinal Research

Several researchers looked at how different ways that individuals could be influenced or 'primed' to anticipate or experience attitudes towards wind turbines. A Canadian study[67] examined the tone of 421 newspaper articles on wind siting in areas near five wind energy systems in Ontario from 2007 to 2011. Researchers determined and coded the number of occurrences of positive or negative words within the articles to deduce tone. Over 99 percent of the articles had a negative tone, and articles were more likely to mention health generally than specific health impacts. Non-print media such as television and radio, as well as internet postings such as blogs were excluded from the study. The article hypothesizes that regular exposure to negative media articles may cause negative attitudes in the readers.

Similarly, research in Australia[68] illustrated that expectations of effects of wind turbine noise and infrasound can influence symptoms and moods reported by study participants in both positive and negative directions. At the University of Auckland, 60 undergraduates were sectioned into either positive or negative expectation groups. Each group was then shown a video that either discussed the potential negative effects of wind turbine noise and infrasound in the negative expectation group and the positive group was shown a video on the possible therapeutic effects of infrasound. After the priming, both groups were subject to audible wind turbine noise and infrasound, and participants were then asked to assess their symptoms and mood on a 7-point Likert scale. The groups were both exposed to infrasound (9Hz, 50.4dB) and audible wind farm sound (43dB), which had been recorded 1 km (0.62 mi) from a wind energy system. Results suggested that the expectations participants had prior to the exposure influenced their mood reports in respective directions (i.e., those primed to have positive attitudes reported positively,

[67] Deignan & Hoffman-Goetz, 2015

[68] Crichton et al., 2013

and vice versa). The researchers hypothesize that the information presented influenced the students, and that information presented in a neutral manner may reduce negative health reports.

A study[69] published in 2016 followed up the Crichton et al. (2013) study (discussed in the previous paragraph) as several criticisms arose that the level of infrasound was too low (40 – 50 dB). Therefore, this study was very similar to the aforementioned study, with some modification to address the criticisms that were made. A total of 72 participants in four groups were exposed to a detailed recording of infrasound with maximum peak sound pressure level of 82 – 89.5 dB that was taken at the Shirley Wind Farm in Wisconsin. Each group completed a questionnaire related to different symptoms and were then instructed they would be watching a video with background information on infrasound, followed by 23 minutes of recorded infrasound. The participants did not know that there were two background videos designed to modify expectations positively or negatively, and the participants did not know that one of the infrasound recordings was a sham. Following the video and exposure, participants again filled out an identical questionnaire to the initial questionnaire prior to the exposure. In groups that viewed the background video designed to positively impact expectations, the number of reported symptoms were reduced. In the groups that viewed the background video designed to negatively impact expectations, the number of reported symptoms were not significantly higher nor lower. The study concluded that the presence of infrasound did not statistically increase the number or intensity of symptoms, and those that came in with preconceived negative notions about infrasound reported significantly more symptoms than those who did not. These results affirmed the results of the Crichton et al. (2013) study.

One study from Jalali et al. researched the impacts of negative attitudes toward turbines on quality-of-life factors for individuals living near wind energy systems.[70] The research used self-reported quality of life in residents living within 2 kilometers (1.24 miles) of wind turbines by collecting data before and after turbine operations. The researchers developed a questionnaire that surveyed participants in Ontario, Canada on housing, community, environmental stressors, overall quality of life, health perceptions, and demographics. The results of this study were expressed in two scores, the Mental Component Scale (MCS) and the Physical Component Scale (PCS). The first set of data was collected across 43 households and was conducted post turbine construction but before the turbines were fully operational. The second set of data was collected across 31 participating households after the turbines became operational in 2015. The results from participants of both surveys (a total of 31 questionnaires included) found that 54.8 percent of individuals believed turbines could cause negative health effects, 71 percent were concerned about their property values, and 16.1 percent of respondents reported changes in their physical or mental health following the operation of turbines. The research ultimately found that the Mental Component Score (MCS) of participants significantly worsened in participants who have negative attitudes about turbines, have voiced concerns about property devaluation, or were

---

[69] Tonin et al., 2016
[70] Jalali et al. 2016 (a)

visually/noise annoyed. Mental health and satisfaction for participants with a positive or neutral attitudes to turbines stayed constant or changed only slightly after turbine operations began. Individuals who were annoyed, had negative attitudes, or were concerned about property devaluation experienced lower quality of life than people with positive attitudes toward the turbines. The authors conclude that factors such as annoyance, negative attitudes, or concerns over devaluation may have important roles in the health complaints of people living in the vicinity of turbines.

Other research indicated the factors that influence local government attitudes toward wind projects and the outcome of these attitudes on siting in local communities. One article[71] focused on the factors influencing a local government's likelihood of developing stringent wind ordinances. The research assessed 1,603 counties in 23 states, not including Wisconsin and other states where state governments have final authority over wind siting. The study finds that when county governments have more interactions with wind developers, they are more likely to take formalized action to regulate wind projects in their area. They are not necessarily more likely to enact stringent regulations. The article also finds that policymakers tend to develop regulations when neighboring counties implement restrictions. While decisions to implement ordinances do spread throughout counties, no influence on stringency between counties developing ordinances at similar times was identified.

Additional research looked to survey communities' opinions to local wind energy projects regarding siting and policy. One Canadian study[72] in Ontario surveyed five primarily island, agriculture-based communities regarding their feelings towards the local wind farms and their opinions on policy of the siting process. One third of the housing stock was made up of summer cottages. A total of 40 interviews were conducted with a mix of those opposed, those in support, and local representatives, officials, and participating landowners. Three specific policy elements were found to be the most impactful for community trust: approval authority, community benefit arrangements, and spatial restrictions of turbine placement. Applicants indicated that the streamlined process of project siting to one central authority negatively impacts community trust because it removes local planners and authorities from participating in the process. Second, trust with a community can only be built when there are tangible benefits to the impacted community, and many feel as though the opposite will occur due to the possibility of decreases in property values. Finally, several interviewees felt that there are too few siting restrictions, and that projects have not considered natural or historic resources enough in previous siting processes. The authors conclude the study by suggesting that siting decision making should be completed flexibly with an option for municipal government to opt-in to take on an approval if desired.

A smaller study[73] at two wind project sites in Ohio and Minnesota that had been constructed prior to 2012 was conducted to look at planning process and community acceptance. The

[71] Lerner, 2021
[72] Fast and Mabee, 2015
[73] Elmallah and Rand, 2022

research was based on a 50-question multi-modal survey of a random sample of residents living within five miles of utility-scale wind turbines. The Ohio wind project (Blue Creek) had 64 responses to the survey, and the Minnesota project (Bent Tree) had 18 responses. The research used these survey responses and interviews with individuals that were involved with the planning and construction of each wind project to investigate how the respondents perceived the planning process for each project. The research found that earlier community notification and engagement by developers, and increased availability of information for the public via websites, staff offices, and public meetings beyond what is mandated by a regulatory process can improve community participation and procedural justice.

One case-control study conducted in Canada discussed the perceptions of health risks, economic benefits/fairness, and intra-community conflict in the siting of turbine facilities.[74] This research conducted a survey comparing a community living with nearby turbines and a community not living near to a turbine site. The study selected the community near the earliest wind energy developments in Ontario, Canada. The control community, West Perth, was selected because it had no turbines near the community and similar characteristics to the community chosen with turbines. Researchers randomly administered 350 surveys for both the control and sample communities. The questionaries included 35 questions with topics including support for the turbines, self-assessed knowledge and preferences for wind energy, aesthetic impacts, health impacts, animal impacts, economic impacts, siting process fairness, community enhancement and conflict, and sociodemographic information. Most items were measured using a 5-point Likert scale measurement.

Results of the research found that case-community residents are more likely to vote to support a referendum supporting wind energy in the province than the control community. Self-assessed knowledge of wind electricity was found to be not significantly correlated for either sample. The study found that residents in the case community who have been living near turbines were more likely to find turbines visually appealing than the control community. The control community was found to be the more concerned about health impacts and negative economic impacts. The level of concern for fairness of siting was found to be higher in the control community.

The research discusses several hypotheses from the results of the surveys. The first hypothesis is that low community support in the control community could be explained by the increasingly politicized nature of turbines and the location of the community relative to proposed turbine developments. The authors second hypothesis finds that there is not support for a "Not-in-My-Backyard" (NIMBY) idea, but instead that researchers and policymakers should focus on the processes and relationships that sustain support in communities. In the final hypothesis, the article discusses that perceived health risk predicts the level of community support a project may have, even if visual and aesthetic impacts were controlled. The article also discusses that community in-fighting is necessary to consider as an impact. The article concludes that support

[74] Baxter et al., 2013

was generally low in the rural control community and generally higher in the case community. The authors argue that these findings provide a strong case for highlighting how perceptions of turbines should be included in social research on turbines and how perceptions can have real consequences on communities.

3.1.1.3.2 Air Quality and Public Health Benefits

A number of research articles conducted modeling to try and quantify the public health benefits attributed to wind power through reduction of air pollutants produced by other power generation facilities such as coal, oil, or gas. These articles find that different factors, including regional location and policy, cause the benefits of renewable energy to differ in location and time. Modeled differences in the relative benefits of renewables in different parts of the country are associated with the type of power being offset, with greater benefits being associated in areas where coal is a primary fuel source being displaced by renewables.[75]

In one such study[76], researchers evaluated the effects of a 3-MW wind turbine at more than 33,000 locations (and a 1-kW solar panel at 900 locations) in the United States and examined the health and environmental benefits from SO2, NOx, and PM2.5 reductions and the climate benefits from CO2 reduction due to shifts in energy generation in different regions of the US. The researchers found that in the Midwest, benefits from shifting to wind and solar are higher than most other regions due to the current coal-heavy energy mix. The estimated social benefits of wind and solar are up to $100/MWh in the Midwest. The researchers also considered these benefits in comparison to the Production Tax Credit ($22/MWh) and found that the social benefits from wind farms are roughly 60 percent higher than the cost of that subsidy. The researchers recommended that government subsidies should be differentiated by different regions to account for the differing sizes of social and environmental benefits if there is a goal of maximizing health and environmental benefits.

Quantifications of health benefits from renewable deployment were provided by Millstein et al. 2017, which determined the magnitude and delivery location of all solar and wind generation across US between 2007 and 2015 and used a statistical model to determine what was avoided due to solar and wind generation. This model showed that:

- Emissions avoided between 2007 and 2015 produced $28.4 to $107.9 billion in air quality and public health benefits and $4.9 to $98.5 billion in climate benefits.
- During the study period, 2,900 to 12,200 premature mortalities were avoided.

A similar type of study[77] researched how health and climate benefits of renewable energies (RE) and energy efficiency (EE) are different depending on the type of energy, location, differing electricity generation or savings by location, electric grid characteristics, and population patterns. The research developed the Environmental Policy Simulation Tool that modeled public health

[75] Silar-Evans, et al., 2013; Millstein et al., 2017; Buonocore et al., 2019
[76] Siler-Evans et al., 2013
[77] Buonocore et al., 2015

impacts and monetized the health impacts of different energy scenarios for the eastern United States. The research simulated 24 scenarios that included four different types of installations including 500 MW wind, 500 MW solar, 500 MW peak demand side management (DSM), and 150 MW baseload DSM in six different areas throughout the study area.

The authors found that there was substantial variability across all 24 scenarios, including in the generation displaced, proportion of fuel types displaced, and the impacts per unit of emission of the displaced units. For example, locations with larger coal displacement experienced higher health benefits. The authors also indicated that the areas where energy efficiency or renewable energy generation are located are not necessarily the places with the most benefits. Generation and benefits will vary by location to transmission area. The authors find that these comparisons of monetized health and climate benefits should be considered in formal analyses, and that this research adds to the literature about co-benefits for communities who implement renewable energy or energy efficiency.

A separate study by Buonocore et al. 2019 modeled different scenarios of renewable energy deployment and examined health benefits for ten U.S. regions. The researchers used a social cost of carbon to determine a monetary benefit from air pollutant reduction. The modeling and analysis found that deployment of renewable energy (made up of wind, rooftop solar, and utility scale solar) has benefits to climate and health throughout the U.S., with some of the highest health benefits coming from displacing coal in the Great Lakes, upper Midwest, and lower Midwest regions of the U.S. This research estimated $1.2 trillion to $2.2 trillion dollars in health and climate benefits for 3000MW of wind energy deployment in the upper Midwest. The difference in value is due to the selected values for social cost of carbon and effect of particulate matter (PM2.5) exposure on mortality.

3.1.2 Wind Turbine-Health Research Conclusions

A significant amount of empirical research on health impacts of wind turbines has been published since the last Wind Siting report was provided to the Legislature in 2014. When reviewing literature to prepare this 2024 report, much of the research published within the accepted timeframe explored impacts of wind turbine noise on various health outcomes such as sleep and self-reported symptoms. A majority of cited publications did not find supporting evidence to conclude that audible noise at levels measured or modelled could influence self-reported health symptoms or recorded health impacts. One experimental sleep study based on a laboratory study[78] reported a slight increase REM sleep latency (time to reach REM sleep), a slight reduction in REM sleep nightly proportion, and a decrease in self-reported sleep quality due to wind turbine noise with amplitude modulation, but no other macrostructures of sleep were affected. Several publications provided evidence to show that increases in wind turbine noise and shadow flicker were correlated with increases in reported annoyance. While there was evidence to suggest an association between distance to wind turbine or noise level and

[78] Smith et al., 2020

annoyance, those that reported annoyance were in the minority. A specific subcategory of noise that gained several publications since the last report is infrasound and low-frequency noise. Several laboratory studies evaluating the impact of infrasound and low-frequency noise have been conducted, and the majority of findings do not indicate that infrasound causes ill health or severely impacts other physiological or psychological measures. One low-frequency noise study[79] suggests a slight impact on heart rate variability (HRV). It is also worth noting that some laboratory studies cited within the report used noise and infrasound recordings from wind turbines in Wisconsin.[80] Based upon literature that was accepted by the council for inclusion in the report, it is reasonable to conclude that most individuals living near wind energy systems do not experience detectable health effects directly caused by the wind turbines.

3.1.3 *Review and Opinion Articles*

The Council identified 11 papers through its literature search that are literature review and opinion articles.[81] Literature review articles are useful in that they offer expert summaries of relevant literature, but they are also limited if available research is of modest quantity and quality. Many reviews have identified trends with annoyance and wind turbine noise, as well as trends with sleep disturbance and wind turbine noise. However, these review articles have not identified scientific linkage between the health impacts and a direct result of exposure to wind turbines.[82] Many of the literature reviews contain similar conclusions to previous reviews of this topic, such as the scientific literature can show that wind turbine sound can lead to noise annoyance, but not other directly attributable health effects.[83]

Review and opinion articles on the wind-health issue generally fall into one of two categories, either supporting the claim that wind-generating facilities cause adverse health effects[84] or disputing the claim that actual physiological adverse health effects exist as a result of exposure to wind turbines.[85] Literature reviews conclude that some residents living near wind energy systems experience annoyance, often correlated to sound levels associated with the turbines. These levels of annoyance can also be affected by visual/aesthetic concerns, attitudes towards the area or wind energy, and the level of participating in the siting process.[86]

One review and meta-analysis[87] explored the association between WTN on sleep and quality of life by using data from 18 cross-sectional studies. With the compilation of data, a total of 2,433

[79] Chiu et al., 2021
[80] Tonin et al., 2016; Marshall et al., 2023
[81] Onakpoya et al., 2015; Freiburg et al., 2019; Adeyeye et al., 2020; Maijala et al., 2020; Simos et al., 2019; Solman et al., 2021; van Kamp, I. and van den Berg, F. 2021; Rand and Hoen, 2017; Karasmanaki, 2022; Krogh et al., 2018; Dumbrille et al., 2021
[82] Onakpoya et al., 2015; Freiburg et al., 2019; Simos et al., 2019
[83] van Kamp, I. and van den Berg, F., 2021
[84] Krogh et al., 2018
[85] Maijala et al., 2020
[86] van Kamp, I. and van den Berg, F. 2021; Rand and Hoen, 2017; Karasmanaki, 2022
[87] Onakpoya et al., 2015

participants were included in the analysis. Results suggested that living in areas with WT will result in annoyance and can also result in sleep disturbance and lower quality of life. There were also indications that visual perception of WTs is correlated with increased annoyance, and that reported effects are more prominent in areas with a quiet, lower noise level environment opposed to noisy environments. Results also exhibited the odds of experiencing sleep disturbance significantly increased with greater WT exposure.

One study[88] examined the quality of literature as well as the conclusions. This review identified and examined 84 articles (literature search concluded in 2017) and considered the type of study as well as potential for bias. To arrive at an evaluation of methodological quality of articles, the review evaluated the appropriateness of study design, including objectives, research questions, populations, and study protocols, as well as ethical issues, primarily those relating to potential conflicts of interest. This review found that most articles discussed noise, with nine articles including a discussion of infrasound, and two specifically discussing low-frequency noise. The results of this review found that lower versus higher quality studies produced differing results for direct effects and associations. For example, noise was not associated with quality of life, sleep disturbance, and depression/anxiety in higher quality studies, where they were found to be associated in lower quality studies.

One study from Adeyeye et al. argues that, because wind energy impacts are site specific, they should require siting procedures that are appropriate for the environmental and economic conditions of the proposed project.[89] This article finds that a robust environmental assessment during the siting process is important for mitigating the negative impacts of wind energy. Safety was discussed as a potential impact of wind energy deployment. Fires on turbines can sometimes not be extinguished because of their height and may create secondary fires on the land below them. New wind turbine technology, however, can detect these fires and shut down the turbines. Ice can also pose threats to safety if it falls off during turbine operations. New turbines prevent this safety concern by detecting vibrations during ice formation and automatically shutting down.

The research notes that noise levels at a turbine site can be influenced by factors such as temperature, humidity, reflections, and ground surface materials. Research referenced in this report by Colby et al. and Mann and Teilmann find that ground-borne vibrations are too insignificant to affect humans and there is no evidence that wind turbine noise is detrimental to human wellbeing. Other research by Leung and Yang finds that noise does produce dissatisfaction, and findings by Dai et al. demonstrate that noise can contribute to health issues. Adeyeye et al. notes that turbine technology and improvements to engineering, such as the use of insulating materials, can reduce noise levels. Early stages of wind energy development can cause a higher-level of noise disturbance on humans than operational turbines.

---

[88] Freiberg et al., 2019
[89] Adeyeye et al., 2020

This research ultimately argues that, because of these health impacts and a wide variety of environmental effects discussed in the article, site specific micro-siting (referring to the very exact location a turbine is placed, considering a range of variables) should be implemented. Using a multi-criteria siting process can help with successful siting and reduce these impacts. Environmental assessments of all wind energy projects that could lead to environmental impacts are also important in this micro-siting process. Policymakers and stakeholders should also be introduced to public involvement in the process to improve overall societal acceptance of the project.

Part of the Finnish government study on infrasound[90] included a literature review on the topic impacts of WTN and infrasound. Generally, the human ear has poor sensitivity for sound frequencies below 20 Hz and the sound level for those low frequencies must be high (i.e. 80 dB at 20 Hz to above 100 dB at <5 Hz) in order for people to perceive infrasound. The literature review showed few sources that directly measured these levels and does not rule out the ability for some individuals to perceive infrasound at levels lower than identified. The literature review also identified research that proposed that the amplitude modulation characteristic of WTN may contribute to more ease in detection and annoyance than sounds such as traffic noise at similar levels. Finally, the review discussed studies that found brain activity could be induced by exposure to infrasound, but pointed out that the levels generated by wind turbines are lower than that in the study and that activity in the brain is not an indication of adverse health effects. The study discussed research into priming or a 'nocebo' response based on literature such as Crichton et al., 2014 and Tonin et al., 2016, which support a view that negative expectations could be one reason for exposure to WTN and health complaints.

Simos et al. conducted a literature review of PubMed and Science Direct to review health concerns of wind turbines.[91] The review included research on noise, infrasound, low-frequency noise, wind turbine syndrome, strobe effect, shadows, safety, landscape effects, social aspects, and real estate prices. Results from the literature review found that noise from turbines is perceived as more serious when other background noise is low, such as in rural settings. The review also included that anxiety, distress, and annoyance could be experienced by people living near to wind turbines. The authors mention that while the experienced symptoms can be real, it has not been scientifically established that it is a direct result of the exposure to the turbines. As a result of the self-declared impacts, annoyance, or other experienced symptoms, the authors make several recommendations for developing wind farms. These recommendations include recognizing how local community members feel about wind turbine construction, implementing an open development process with opportunities for participation, developing local management of the wind farm, and building turbines in areas with as few viewpoints as possible. Other recommendations include that no housing should be within a radius of ten times the height of the turbine mast, turbines should be constructed with white or green colors to reduce landscape

[90] Maijala, et al., 2020
[91] Simos et al., 2019

effects, smaller numbers of total turbines at any given site should be developed, housing prices should be monitored, and health impact assessments should be conducted at all sites. The Wind Siting Council notes that this review, including the articles cited, were based on outdated wind turbine technology that would not be newly sited. This may impact the conclusions or recommendations made by this article, including conclusions drawn about safety, noise, and landscape impacts.

One article used a different approach to reviewing existing studies and literature through the Bradford Hill criteria to investigate the adverse health effects of living near wind turbine facilities and explore the causality between wind turbines and adverse health impacts. [92] This article argued that demonstrating causation would have important implications for establishing an argument that links turbines as the cause of adverse health impacts. To attempt to establish causality, the authors used Bradford Hill criteria, a tool that can be used to establish causality between environmental risks and disease. The Bradford Hill criteria are: the strength of association, consistency, specificity, temporal sequence, biological gradient, plausibility, coherence, experimental evidence, and analogous evidence.

The authors gathered evidence of adverse events by compiling peer-reviewed references, other published literature, case reports, government sponsored hearings/inquires, judicial records, and government records. The article then reviewed findings for all nine criteria to provide evidence that exposure to turbines is associated with an increased risk of health effects. The article determined several areas where further research could be expanded on this topic in the future. The article finds that long-term studies using non-averaged audible and inaudible noise levels should be conducted to strengthen the understanding of health effects. The authors conclude that these studies would ideally be large-scale, controlled, and blinded studies of all age groups. The article also argues that using dBA as a measurement (instead of wind turbine audible/inaudible tonal and amplitude modulation) leads to a lack of consideration for sleep disturbance. The authors argue that there is a need to consider unique environments in future studies to avoid adverse health impacts.

A systematic review completed by Solman et al. (2021) evaluated the different forms of public engagement that invited stakeholder participation, with the goal of contributing a broader understanding of how different public groups interact with emerging technology projects like wind energy. The review included 230 peer-reviewed, academic articles from 2009 to 2019 that predominately focused on wind energy in a social scientific focus with an~~d~~ explicit focus on public engagement. Of the 230 papers, there were three distinct modes of 'co-production', meaning the public participation goes beyond just a stakeholder invitation, and public groups can choose to engage with wind energy, and continuously change decisions related to wind energy.

The first mode represents most of the literature presented, with 69 percent of papers examined being about public engagement exclusively at a local scale. The papers within this cluster

---

[92] Dumbrille et al., 2021

highlight two main points about going beyond just stakeholder participation and exploring co-production as a more substantial option for public engagement. First, delegating decision-making power on local energy production to local publics is reported to democratize the design, implementation, and use of energy infrastructure. Secondly, the authors denotate that engaging local publics is a means of enabling political action related to the concerns of wind energy projects at a regional or national scale. The second mode of co-production identified in the review is a collective mode in which spatially dispersed publics who have concerns can actively participate in decisions relating to development of wind energy. Collective publics could include those who participate in wind-energy development financially, seeing return upon investment post-development.

A second common collective identified is groups that extend the engagement beyond development and are actively involved in other stages of wind energy generation (i.e., operation). The final mode of co-production identified in the paper is through virtual modes, in which a set of practices of engagement with wind energy project mediated by information technology, incorporating those at any distance from the project. This mode has proliferated through the emergence and optimization of visualization and geospatial tools. Within this mode, the publics may concern themselves with various stages of development and operation communicated online. An example of this included in the paper would be a crowdfunding initiative that allowed residents of the whole state to participate in financing a wind project. Overall, the paper identifies how various publics at spatially dispersed levels can be actively involved in wind development.

3.2 Wind Turbine-Health Report Conclusion

Peer-reviewed scientific articles pertaining to noise, air quality, infrasound, social attitudes, sleep, and shadow flicker were reviewed by the Council. Findings from these articles are discussed in the subsections of this report and concluded below.

Many of the articles accepted for review focused on annoyance and attitudinal factors that influence perceptions of wind turbines. Articles examined how siting practices and community engagement can influence acceptance of wind projects. Research found that negative attitudes towards wind projects influenced annoyance and perceived health impacts. The review of these articles suggested that annoyance, negative attitudes, and property value concerns can influence the likelihood of health complaints from people living near turbines.

Evidence from articles presented in the Air Quality and Public Health section of the report (Section 3.1.1.3.2) suggest that climate benefits could produce monetary and public health benefits from offsetting other energy sources. The articles found that benefits from wind energy can vary geographically, with evidence suggesting that health benefits can be higher in the Upper Midwest than other parts of the country. A study reviewed for this report suggests that the health and environmental benefits associated with deploying wind energy and displacing other types of generation could be up to $100/MWh in the Midwest. This research finds that a social cost of carbon calculation can indicate the monetary benefit that occurs as a result of decreasing air pollution.

Studies that researched the effect of wind turbines on sleep were also included in the report. Sleep research articles included sleep studies in controlled environments, with both study and control groups. Other studies measured how quickly individuals were able to fall asleep (sleep latency). Results from these studies did not indicate strong impacts of wind turbines on sleep, with one laboratory study indicating impacts on sleep associated with WTN and amplitude modulation. Self-reported sleep surveys were also included in the review, with results from this research indicating that participants reported lower sleep quality if they had negative attitudes toward wind turbines.

The WSC looked for research on potential impacts of shadow flicker on health. One research article found that shadow flicker can lead to increased annoyance in participants who expressed attachment to local aesthetics. Other factors such as age, involvement in planning process, participation in the project, and education levels may also influence levels of annoyance from shadow flicker. Annoyance was the primary impact of shadow flicker on health identified in the report.

Most of the articles reviewed by the WSC for this report were about noise, including low frequency noise and infrasound. Studies included in this report identified individuals' recognition of noise and infrasound around the turbines. Some studies researched the impact of preconceived negative attitudes toward infrasound and turbines, with individuals with higher negative attitudes reporting more health symptoms. No specific direct impacts on health as a result of nearby turbine noise were identified with the exception of one study which found an association between LFN exposure and changes in heart rate variability that were greater than traffic noise but less than those from air pollution or ambient temperature increases.

The primary health effects of wind turbines identified in the literature review included the impacts of negative attitudes and annoyance, as well as the positive health effects of wind energy systems offsetting other energy sources. Research reviewed in this report does not identify strong causal links between other health impacts and wind turbines.

4.0 WIND SITING POLICY UPDATE

Under Wis. Stat. § 196.378(4g)(e), the Council is charged with reviewing regulatory developments in wind siting policy and providing a report to the Legislature and recommendations to the Commission. Working towards this end, the Council reviewed the wind siting policies of all fifty states and the District of Columbia.[93] The UW Capstone Students and Commission staff also conducted a formal academic search of the peer-reviewed literature regarding wind siting policy. This search process was similar to that done for literature on health effects and consisted of the use of the UW-Madison Libraries Article Search, which subscribes to more than 1,500 search tools that align with research in different subject areas. The students used keywords to search for articles, then applied the criteria of date range (published in 2014 or more recent), on the topic of wind turbines, and ensured the article was in a peer-reviewed

[93] See Appendix F for the results of this review.

publication. Keywords used for this literature search included: regulation or siting, wind power or wind energy, and policy.

The Wind Siting Council accepted eight papers that discuss policy topics, including aspects relating to siting jurisdiction and decision-making processes, in addition to associated discussion on how siting regimes can affect overall deployment of wind turbines. Other policy topic papers include discussion of setback distances, the consideration of project externalities, including health impacts and lifecycle greenhouse gases, and an evaluation of sound modeling processes. There was not one report or paper that evaluated the impacts of most of the siting criteria observed in state policy similar to the one referenced[94] in the 2014 Wind Siting Council report.

Rules on the siting of wind energy systems in Wisconsin are codified in Wis. Admin. Code ch. PSC 128 and have been in effect since March 16, 2012. These rules apply to local regulation of wind energy systems with a total combined generating capacity of less than 100 MW, and are the most conservative restrictions that a local jurisdiction may impose on a wind energy development in Wisconsin. Wind energy developments of 100 MW combined generating capacity or greater are subject to Commission review. The Commission is not required to strictly adhere to Wis. Admin. Code ch. PSC 128, however it must consider the requirements in its review of a proposed wind energy system. Wisconsin wind siting rules are some of the most comprehensive in the nation, covering nearly every aspect of wind siting, and include:

- 50 dBA day and 45 dBA night noise limits as measured at the outside wall of the nonparticipating residence or occupied community building nearest to the closest wind turbine, or at an alternate wall as specified by the owner of the nonparticipating residence or occupied community building.
- Turbine setback from nonparticipating landowner property lines, roads and utility rights-of-way of 1.1 times turbine height.
- Turbine setback from non-participating residences of 3.1 times turbine height, up to 1,250 feet.
- A maximum of 30 hours of shadow flicker per year at non-participating residences and mitigation if over 20 hours.
- Mitigation of radio and television interference.
- Testing of stray voltage by the wind energy system owner, if requested.
- Proof of financial responsibility for decommissioning.
- Project pre-application notification requirements for all wind energy system developers.

[94] The 2014 WSC report reviewed much of the policy update discussion in Stanton, 2012. Wind Energy & Wind Park Siting and Zoning Best Practices and Guidance for States, a report produced for the National Association of Regulatory Utility Commissioners (NARUC).

4.1 Findings Related to Wind Siting Rules under PSC 128

Outlined below is a discussion of major state and federal policies regarding wind siting. The areas of policy connected to what is regulated under Wis. Admin. Code ch. PSC 128 are described in the context of what was observed by looking at other state policy on these topics. Where relevant policy papers were identified, they are summarized for context under the topic headings.

4.1.1 Jurisdiction

The review of wind siting policies in all of the United States found that jurisdiction over wind energy developments is held at the state level in nine cases[95], the local level in eighteen cases[96], and jointly controlled in twenty-four cases[97]. Thirty-two states have some sort of wind siting rules or recommendations, whether at the state or local level. Six of these states provide local jurisdictions with voluntary guidelines which may take the form of model wind siting ordinances. Model ordinances are not legally binding; however, portions of them may reflect policy determined at the state level that is mandatory.

Research done by Lerner (in 2021) stated that 22 states preempt local control of wind siting, place restrictions on local regulation, or reserve the right to overrule local siting decisions, while the remaining 28 states give local governments the final say in regulating wind development. This second group makes up 60 percent of the land area for best wind resources. Many counties wait to adopt wind energy system regulations until they are approached by developers, or a project seems likely to be pursued.

4.1.2 Externalities and long-term effects

Research included in this report focuses on the variety of externalities, both positive and negative, that are incurred as a result of wind projects and influence attitudes towards wind development.[98] This research found that assessing impacts on wildlife, noise, health, landscape aesthetics, integration of wind energy into the grid, local economic impacts, energy security, rare earth material extraction, and other effects allows for a more favorable deployment of wind energy. The article found that understanding these externalities passed onto the public would allow policymakers to more justly site wind projects and moderate effects of the projects.

Research by Wiser et al. evaluated the relative benefits of wind energy deployment compared to a no-new-wind baseline.[99] The research used a scenario analysis to examine the impacts, costs, and benefits of wind energy deployment. The scenario of a no-new-wind deployment post-2013 was compared with the scenario of 10 percent end-use wind electricity demand in 2020, 20 percent in 2030, and 35 percent in 2050 in the United States. This comparison was intended to

---

[95] CT, IL, MD, MI, OH, TN, VT, D.C., WV
[96] AL, CA, DE, GA, HI, IN, ID, KS, LA, MA, MS, MO, MT, PA, RI, SD, TX, UT
[97] AK, AZ, AR, CO, FL, IA, KY, ME, MN, NE, NV, NH, NJ, NM, NY, NC, ND, OK, OR, SC, VA, WA, WI, WY
[98] Zerrahn, 2017
[99] Wiser et al., 2016

study the incremental impact of all wind deployed after 2013 beyond the baseline of no new wind development.

A variety of externalities were examined including greenhouse gas emissions, air pollution, water use reduction, energy diversity, risk reduction, workforce and economic development, and land use and local impacts. The research found that achieving the study scenario reduces emissions relative to no-new-wind baseline. Increased wind development may help reduce the cost of future policies intended to limit water use and make more water available. The research also found that increased wind generation may mitigate high fossil fuel costs and reduce demand for fossil fuel. There is potential for gross employment additions, but little reason to believe that impacts on employment are sizable in a positive or negative direction. Finally, the article found that wind deployment can have wide ranging impacts on local communities and on ecosystems. As a result, sensitivity to avian, bat, and other wildlife populations, landscape, infrastructure, and individuals should be considered in siting.

The article ultimately found that a future where wind plays a major role in the energy system is plausible and could result in benefits, especially if cost barriers are overcome. The range of benefits found by this research was substantial due to some uncertainties. This research can inform policy interventions that mitigate costs associated with local environmental and societal implications of wind development. These policy interventions could include tax incentives, carbon regulations, state level renewable energy standards, and other financial incentives to overcome cost barriers.

4.1.3 Noise[100,101]

States that mandate siting rules or recommend wind siting policies often provide limits on the noise levels from wind turbines that individuals living near wind energy projects may experience. The way that the limits are described vary and may be a given SPL in dBA at a residence or at a property line. Distinctions are often provided for participating or non-participating residences and community buildings. These limits at non-participating dwellings appear to range from a low level of 35 dBA (TN) to 55 dBA (WA, SD, PA, KY). States may have different limits based on day or night (i.e. 45 dBA at night, 55 dBA during the day – CT). States may also provide rules based on a set level of dBA over the ambient noise levels, for example, no more than 5 dBA over background noise at a residence (NH).

One research article[102] discussed potential challenges with how noise is measured to show compliance with the regulations set by regulatory authorities. The article provided background information on the range of noise level requirements as well as a discussion on some different noise measurement methodologies, including standards used in the UK and Australia, which are based on measuring outdoor noise levels. The article stated that in 2018 the World Health

---

[100] See the "Wind-health Review" section of this report for a discussion of the potential adverse health effects elicited by noise from wind turbines.
[101] PSC 128 imposes a 50/45 dBA day/night limit at nonparticipating residences and occupied community buildings.
[102] Cooper and Chan, 2020.

Organization recommended a noise limit for wind turbines of 45 L_{den} for outdoor average noise exposure for the European Region. The article also notes that in the US, there is no national legislation that provides a limit or recommendation for wind turbine noise, and that states may have fixed limits (i.e. 45 dBA at night) or may have an amount over ambient (i.e. +5dBA) provided as a noise limit as discussed above and shown in Appendix F.

The article goes into detailed discussion of challenges with the regression analysis used to determine noise levels for the UK and Australian standards. The methodology of how acoustical engineers would perform pre-construction sound modeling or post-construction sound measurements could be considered in a siting review case, be needed to show project compliance, or be needed to respond to noise complaints in a project area. The authors of the article discuss common challenges with sound monitoring of wind turbines in project areas, including determining ambient background noise and what noise contribution the wind turbine causes when operating. Measuring noise levels may occur on days with more or less wind, affecting both levels of ambient noise as well as noise produced by wind turbines. The article recommends wind noise measurements pre- and post-construction be taken at the same location and height, and with the same equipment. There are different acoustic environments at different times of year where seasonal variation in the wind and weather patterns, as well as bugs, frogs, and leaves can alter the acoustic environment. Therefore, pre- and post-construction noise monitoring should take place at the same time of year. The article questions how full acoustic compliance is met for all wind speeds and power production based on measurements during low wind speed or power only (e.g., just above cut-in speed). Another issue that presents difficulty in compliance testing is the actual power output of the wind farm versus the rated power output (or specified wind speed), for which the acoustic design level applies. The article does not provide analysis of noise measurement standards[103] that may be used by US states, but provides general conclusions as to the challenge and importance that methods of noise modeling can have for evaluating project impacts.

4.1.4 Turbine Setbacks[104]

For those states that mandate wind siting rules or recommend siting criteria, the setback distance of wind turbines from property boundaries, occupied dwellings, or public/utility rights-of-way vary, and may be based off set distances, but are more often based on the height of the turbine. Property line setbacks range from a low of one-times the height of the turbine (DE) to 3.5 times the height of the turbine (TN). Distances from turbines to nonparticipating residences vary from 500 feet (plus distance necessary to meet sound limit requirements – MN) to five times the height of the turbine (PA, WY).

---

[103] Such standards may include ISO 9613-2, ANSI ASA S12.9, or state specific criteria, such as developed by the PSCW for projects that require authorization from that state agency. The PSC Noise protocol can be found on the PSC website at: https://psc.wi.gov/SiteAssets/WindNoiseProtocol.pdf [PDF].

[104] PSC 128 imposes a setback of 1,250 feet or 3.1 times turbine height from nonparticipating residences and occupied community buildings, and 1.1 times turbine height from property lines and public and utility rights-of-way.

Research by Lerner (2021) showed that approximately 77 percent of counties in states with delegated wind siting authority have not defined setback distances for utility wind systems. As of the date of the review of siting rules in that article, among the counties with formal siting standards, 60 percent have setbacks from 400 feet to 600 feet from the property line (1-1.5 times height of turbine). Seventeen percent of counties have setback distances less than this, and 22 percent of counties more restrictive than 600 feet.

Research by Peri and Tal[105] examined the setback distance from human settlements that balances annoyance and the ability to generate energy. The research sought to determine ideal setback distances that account for sound, shadow flicker, potential energy site potential, and ecological impacts. The researchers used site-specific ArcGIS 10.7.1 and WindPro 3.2 data from wind project sites across Europe to predict natural environmental impacts, energy output fluctuations, noise levels, and shadow flicker with different setback distances. This research was done for potential wind energy sites in Israel, which has a nighttime noise limit of 40 dBA and setback distance requirements of 500 m (1,640 ft.) from residential areas.

Results from the GIS software data analysis found that energy output and noise levels decreased linearly with greater setback distances. Shadow flicker amounts had varied results due to topography and terrain specific study areas. The research found that greater setback distances can also positively influence public acceptance, lead to higher project costs, negatively influence the number of permits for wind turbines, and negatively influence wind generation site availability. The study found that at setback distances of 700-800 m (2,297-2625 ft.) community annoyance levels depend on site-specific conditions and may be marginal. The research found that setback distances over 1,500 meters (4,921 ft.) significantly decrease the energy potential of a wind energy project by decreasing the overall amount of area that could host wind turbines. The use of increased setback distances can also increase the length of required transmission lines, increasing the ecological footprint of a project.

The article concludes that, because impacts such as noise and shadow flicker can vary across different sites, one standard setback distance is not beneficial in all contexts. Instead, more precise calculations based on specific site conditions should be developed. The article finds that microplanning tools such as GIS and the use of transparent data are essential for achieving site specific calculations of setback distances.

4.1.5 Shadow Flicker[106]

Multiple states have regulations for shadow flicker. Many of these states, including Wisconsin, measure shadow flicker by hours per year a resident experiences shadow flicker at an occupied building. Some states require or recommend that shadow flicker be reasonably avoided, a risk

---

[105] Peri and Tal, 2021

[106] PSC 128 imposes a 30-hour annual limit at nonparticipating residences and requires a wind turbine owner provide reasonable shadow flicker mitigation for any nonparticipating residence or occupied community building experiencing 20 hours or more per year of shadow flicker.

assessment be conducted, or shadow flicker be minimized through siting (e.g. MA, ME, TN, OH). The most commonly used measurement for shadow flicker according to the observed in the review provided as Appendix F of this report is no more than 30 hours per year (e.g. IN, RI, CT, KY, IL, NY, WI). The most restrictive specific criteria for shadow flicker identified was no more than 8 hours per year (NH).

An analysis done by the Lawrence Berkely National Laboratory[107] examined regulatory authorities that restrict shadow flicker. Their research findings state:

> The most commonly enforced limit across the United States in the project areas evaluated in our study is 30 h/year, similar in value to German worst-case guidelines and other standards found in the EU. However, in the United States, the metric is rarely defined as real or worst case, and, in our experience, is most often interpreted during the application process as real case. Of the full sample population, 7% exceed 30 h worst case or 8 h real case. Of the 404 survey respondents with any modeled SF, 50% exceeded the 30/8 worst-case/real-case limits, though a majority are project participants, and 2.3% exceeded 30 h/year real-case. Respondents exceeding those limits were no more likely to be very annoyed by SF than other respondents.

4.1.6 Decommissioning[108]

Several states have regulations or recommendations for decommissioning turbine facilities when they are no longer in service. Many states require a decommissioning plan be provided before project construction (e.g. CT, KY, ME, RI, PA, OH, NE, NY, MN, IL). Some states also require projects show financial security, provide a surety bond for decommissioning, or provide financial assurance that decommissioning funds will be available (e.g. MA, NE, NC, WI, TN, IN, SD, OK, NC, MT, CT).

4.1.7 Signal Interference[109]

Very few states have policies related to the regulation of wind turbines to avoid or mitigate signal interference, which can include impacts to television, radio, communications, and radar systems. At the federal level there are working groups with the Department of Energy that focus on mitigating impacts of wind turbines on radar systems.[110] Wind project developers need to coordinate early in the siting process with federal agencies such as the FAA, National Oceanic and Atmospheric Administration, and Department of Defense to review potential turbine

[107] Haac et al., 2022
[108] PSC 128 requires decommissioning at the end of a turbine's useful life, creates rebuttable presumptions to establish when the end of the useful life has occurred, and requires a wind energy system owner to maintain proof of financial ability to fund decommissioning.
[109] PSC 128 requires mitigation of any radio, television or other communications signal interference resulting from wind energy systems by its owner.
[110] Wind Turbine Radar Interference Mitigation Working Group – Interagency Memorandum of Understanding. [PDF]

locations and address any risk of impacts to radar or other important communications infrastructure.

4.2 Other Pertinent Findings

4.2.1 Permitting Process

No specific policy paper was found that discussed potential changes or updates to permitting processes, however, there was discussion in some of the articles that were reviewed as part of the research into health effects of wind turbines that discussed responses to how projects are permitted. A general trend in the research on public attitudes and participation in the permitting process of wind energy systems indicates that acceptance of projects can improve when information is shared at an early stage, public meetings are held outside a required minimum amount, and that the concerns of local communities are considered. Several examples of this topic include research[111] done on attitudes towards wind turbines in Australia, which found that those that were opposed to wind energy system development often stated that the development process excluded the host community's thoughts and opinions. This corresponds to other research done on this topic, where three specific policy elements were found to be the most impactful for community trust: approval authority, community benefit arrangements, and spatial restrictions of turbine placement.[112] In the survey responses provided, there was an indication that a streamlined process of project siting to one central authority can negatively impact community trust because it removes local planners and authorities from participating in the process. Additional research on this topic found that sharing information and offering opportunities for participation beyond what is mandated by a regulatory process can improve community participation and project acceptance. [113, 114]

4.2.2 Life Cycle Analysis

Life cycle analysis (LCA) is a method frequently used to quantify the total impact, often represented by carbon emissions, from energy technology on the environment. These assessments often take a 'cradle-to-grave' approach in which the analysis accounts from the initial production of parts all the way to the decommissioning and recycling of materials. One such assessment[115] quantified the whole-life-cycle carbon emissions for a wind power project based in the Shi-san-jian-fang area of Xinjiang, China. The assessment included five stages: component production, material transportation, project construction, operation, and disposal and recycling. During the production phase, most emissions are generated from the production of the blades, the nacelle, and the tower. Transportation emissions are mainly composed of emissions from fuel or energy consumption during the transport of materials and components. Project

---

[111] Botterill and Cockfield, 2016
[112] Fast and Mabee, 2015
[113] Elmallah and Rand, 2022
[114] Simos et al., 2019
[115] Li et al., 2020

construction can be divided into two parts: the consumption of construction materials and the operation of machinery equipment. During operation, the analysis not only accounts for the emissions generated through energy generation, but also the production and transportation of the updated equipment. The final stage the analysis accounts for is the disposal and recycling of materials after decommissioning, which depending on the ability to reuse materials, the emissions in this stage can be negative.

Within the case study in China, a 49.5 MW facility with 33 wind turbines with single unit capacity of 1.54 MW each with accompanying transformer and 9-km line were examined in the LCA. A total of 10,490.83 tons of carbon emissions were calculated, with an estimated 4.429 g/kWh of carbon emission per unit of generation. This estimation is based on the theoretical annual generating capacity of 11.843 million kWh with the estimated life span of 20 years. The production phase was the largest contributor accounting for 70.61 percent of the total emissions followed by the construction phase accounting for 13.85 percent of the total emissions.

4.2.3 *Siting Reviews*

Some researchers evaluated the impacts of wind energy project siting on future wind deployment across different emission and technological scenarios.[116] The research combined wind resource potential analysis with high spatial resolution U.S. electricity system modeling to perform future power-sector scenario analyses between wind siting considerations and the evolution of the U.S power system. The three siting regimes include Reference Access (broadly consistent with current regulatory siting norms), Open Access (least restrictive to development) and Limited Access (most restrictive to development). These siting regimes were than modeled against many future scenarios with an examination of total deployment, costs, and emissions. These scenarios were modeled out to 2050.

The modeling showed that under different scenarios and compared to the Reference Access siting regime, the Limited siting regime led to reduction of onshore wind deployment from 5 to 11 percent contrasted to a 3 to 4 percent increase in deployment in onshore wind deployment in an Open Access siting regime. The Limited siting regime also led to increased total bulk-power systems costs and a lower decrease in CO2 emissions compared to the Reference siting regime. The study indicated that more stringent wind siting leads to a lower deployment of onshore wind resources. These more restrictive wind siting regimes result in higher electricity costs, higher CO2 abatement costs, and unless otherwise constrained, higher emissions.

One study combines two theoretical frameworks to assess Swiss policy on wind energy.[117] The researchers found that a more supportive policy environment, including the use of market incentives, environmental regulations, and inter-sectional coordination mechanisms that were present in Switzerland did not lead to increased wind turbines in the country. The researchers looked into the International Resource Regime Framework (IRR) that analyzes common pool

---

[116] Mai et al., 2021
[117] Blake et al., 2020

resource issues and the Advocacy Coalition Framework (ACF) that addresses policy formulation. The researchers argue that the use of these frameworks in combination with one another will help explain the success or failure of wind power policy.

The study seeks to understand what aspects of the IRR framework can explain the success or failures of power policy implementation. The researchers also look to answer whether the combination of the two frameworks can create a more convincing explanation of wind power policy implementation. The study formulates hypotheses to test the importance of wind power policies in a specific regime and conclude that the combined perspectives of the IRR and ACF has confirmed the relevance of both frameworks. The study finds that actors' belief systems explain their strategies for implementing wind policy. The IRR and ACF work well together because the IRR can assess the actors' motivation while the ACF can help explain their belief systems and sociological foundations. The study finds that these analytical frameworks can be effectively used in combination with one another and allows for the creation of causal chains in policy research. Because the two frameworks use the same basic suppositions, they can be used in combination with one another. The article concludes that an increase in conflict around wind energy stems from divergent belief systems and competing coalitions that oppose one another.

Another study[118] looked at the best placement for onshore wind turbines in the country of Germany. Researchers took data from 160,000 turbines to look at the best placement for cost-efficiency, landscape scenic value, and distance from the grid. The results of the study showed that in the locations that were most cost effective to build turbines tended to also have a lower scenic value. Existing wind turbines were found to be sited at locations with a scenic value of 4.25/9 which is lower than the average German scenic value of 5.0/9.

The study explains that current placement of wind turbines in Germany appears to already be taking into account cost-efficiency, landscape impact, and distance from the grid. The study further showed that expanding wind turbines regionally equally across the country has not yet been a priority. And that if Germany were to take regional equality as a priority into siting wind turbines, the new turbines would be significantly more expensive and would be built on areas that have a higher scenic value than current turbines.

4.3 Wind Siting Policy Conclusions

Research on policies relating to wind turbine siting has not increased to the extent that research into the potential health impacts of wind turbines has expanded since the Wind Siting Rules were developed or the 2014 Wind Siting Council Report was produced. Some new areas reviewed by the WSC include discussion on externalities and the LCA of turbines, including in comparison to other generation sources. Some researchers combine evaluation of these topics with an assessment of familiar policy topics such as setback distances and siting processes to evaluate different scenarios for potential wind energy deployment. Overall, the WSC has not identified significant areas of research that would prompt a substantial revision to wind siting policies in

[118] Weinand et al. 2022

Wisconsin. Current wind siting and permitting processes are intended to balance human health and community concerns with a stable and consistently applied regulatory framework.

An evaluation of the state wind siting policies in place do not show substantial changes across different states, and there are not widely accepted requirements for topics such as noise limits, setback distances, or other areas of impact that suggest a significant revision to PSC 128 or wind siting policy in Wisconsin is needed.

The Wind Siting Council reviewed several articles that discussed the topic of infrasound. The Wind Siting Council recommends that the PSC revise the PSC Wind Noise Measurement Protocol to include pre- and post-construction measurements of the wind turbine infrasound component to include frequencies down to 0.1 Hz, or as near as achievable, with the goal of capturing the blade pass frequency and its harmonics. The Wind Siting Council recommends the PSC revise the PSC Wind Noise Measurement Protocol to require the wind turbine developer post-construction sound level measurement analysis to evaluate and confirm the infrasound component, in dBG, remains well below the human hearing threshold identified in Figure 1 of this report (see page 17).

5.0 CONCLUSION

The Wind Siting Council recognizes that wind energy systems can cause concern and annoyance among some Wisconsin residents, and some research reviewed by the council showed that such annoyance can be correlated with self-reported symptoms. Some research reviewed indicated that the more that people were engaged and informed at the early stages of new proposed wind projects, the less likely they were to be annoyed with projects, lose sleep, and feel ill. To help mitigate these concerns, the WSC encourages wind developers and local community leaders to engage the public as early as possible when new wind projects are being considered.

The work done by the WSC in reviewing the scientific literature related to wind turbines found many more articles and areas of research when compared to the 2014 report. Research is anticipated to continue in this area in the future. The primary health effects of wind turbines identified in the literature review included the impacts of negative attitudes and annoyance, as well as the positive health effects of wind energy systems reducing air pollution caused by other energy sources. Research reviewed in this report does not identify causal links between other health impacts and wind turbines. Generally, the conclusions of this report are similar to those of the 2014 report, in that the great majority of articles found and reviewed, there are no demonstrated negative health effects caused by wind turbines. Wisconsin's siting regulations for wind energy systems are generally consistent with other state rules and policy developments, and no substantial changes are recommended.

Appendix A

Wind Siting Council Membership

Wisconsin Stat. § 15.797(1)(b) requires the Commission to appoint a Wind Siting Council. Specifically, the Legislature set forth the following representation on the Council:

- Two members representing wind energy system developers (Developer Members).
- One member representing towns (Towns Member) and one member representing counties (County Member).
- Two members representing the energy industry (Energy Members).
- Two members representing environmental groups (Environmental Members).
- Two members representing realtors (Realtor Members).
- Two members who are landowners living adjacent to or in the vicinity of a wind energy system and who have not received compensation by or behalf of owners, operators, or developers of wind energy systems (Landowner Members).
- Two public members (Public Members).
- One member who is a University of Wisconsin System faculty member with expertise regarding the health impacts of wind energy systems (UW Faculty Member).

Consistent with the Legislature's directive, the Commission appointed people of diverse backgrounds and experiences, satisfying the explicit legislative statutory criteria. At the time of this report, the following individuals are members of the Council:

- Wes Slaymaker - Developer Member
- Brodie Dockendorf - Developer Member
- Glen Schwalbach, Town of Rockland - Towns Member
- Scott Godfrey, Iowa County - County Member
- John Kettenhoven, We Energies - Energy Member
- Zack Hill, Alliant Energy - Energy Member
- Jennifer Giegerich, Wisconsin Conservation Voters - Environmental Member
- Katie Nekola, Clean Wisconsin - Environmental Member
- Tim Roehl - Realtor Member
- Tom Syring - Realtor Member
- Richard Jinkins – Non-Compensated Landowner Member
- Dick Anderson – Non-Compensated Landowner Member
- Bruce Krawisz - Public Member
- Matt Stefkovich - Public Member
- James Tinjum – UW Member

<u>Appendix B – Glossary of Terms</u>

A-weighted: Standard adjustment made to audible sound measurement to reflect how the human ear perceives the sound. Typically used for the frequency range from 20Hz to 20kHz which reflects the range the human ear is sensitive to.

Air pollutants: as defined as "air contaminant" in Wis. Stat. § 285.01(1); dust, fumes, mist, liquid, smoke, other particulate matter, vapor, gas, odorous substances or any combination thereof but shall not include uncombined water vapor.

Air pollution: the presence in the atmosphere of one or more air contaminants in such quantities and of such duration as is or tends to be injurious to human health or welfare, animal or plant life, or property, or would unreasonably interfere with the enjoyment of life or property. Per Wis. Stat. § 285.01(3)

C-weighted: standard adjustment made to sound measurements to reflect how the human ear perceives the sound. Primarily used for high level measurements above 100 decibels or peak sound pressure levels.

Cross-sectional studies: a scientific, observational research method that assesses a group or population at a particular time point.

Decommissioning: removing wind turbines, buildings, cables, electrical components, roads, and any other facilities associated with a wind energy system that are located at the site of the wind energy system and restoring the site of the wind energy system. Per Wis. Stat. § 196.378(4g)(a)2.

Electromagnetic fields (EMF): a field that is made up of associated electric and magnetic components, that results from the motion of an electric charge, and that possesses a definite amount of electromagnetic energy.

Emissions: a release of air contaminants into the atmosphere. Per Wis Stat. § 285.01(15).

Empirical research: a type of research that is evidence/data-based provided through direct observation and/or measurement.

Energy potential: the achievable energy generation with consideration for economic factors and system performance abilities, as well as topographic, environmental, and land use constraints.

Epidemiologic study: a type of evidence-based research that examines the distribution and determinants of the health of a group or population to understand the patterns, causes and effects.

Externalities: positive or negative outcome of a given economic activity that affects a third party that is not directly related to that activity, per the International Institute for Sustainable Development.

Geographic Information System (GIS): computer-based tools that can be used to analyze and visualize geo-spatial data.

Hair cortisol: a matrix for measurement of production of the stress hormone cortisol that provides a window of longer-term exposure, typically months.

Ice-throw: projection of accumulated ice from rotating blades of a wind turbine.

Infrasound: commonly refers to sound waves below 16 or 20 Hz, in a range where the human ear has poor sensitivity to detecting sound.

L_{eq}: the A-weighted, equivalent continuous sound level, in decibels having the same total sound energy as the fluctuating level measured.

L_{den}: A descriptor of sound level based on a time weighted L_{eq} incorporating adjustments for the evening and night-time periods.

Longitudinal research: research that is constituted of repeated observations or measurements over an extended period of time.

Participating residences/landowner: private landowner or party who entered a lease, agreement, waiver, or other contract, which may or may include compensation, with a developer of a land-development project.

Particulate matter: mixture of solid particles and liquid droplets of varying size found in the air that have the potential to contribute to serious health problems when inhaled.

Polysomnogram (PSG): a type of sleep study that monitors and records various body functions which is used to study or diagnose sleep-related disorders.

Renewable energy: electricity derived from a natural resource that is naturally replenished at a higher rate than it is consumed.

Setback: the distance between a property line or other defined point and the area or point where a wind turbine can be sited.

Shadow flicker: effect of the sun (low on the horizon) shining through the rotating blades of a wind turbine, casting a moving shadow, per the U.S. Department of Energy.

Sleep actimetry: a non-invasive method of objectively collecting data on sleep/wake patterns based on body movements, typically collected through use of wrist devices.

Sleep electrophysiology: a branch of physiologic study that studies the relationship between electric phenomena and other bodily process that occur during different sleep states.

Sound level modeling: computer-based program based on formulas for the creation and propagation of sound used to predict sound/noise levels under different conditions and/or distances.

Sound pressure levels (SPL): logarithm of the ratio of a given sound pressure to the reference sound pressure in decibels is 20 times the logarithm to the base ten of the ratio.

Stray voltage: a low-level voltage (less than 10 volts as defined by the U.S. Department of Agriculture) that can be measured between two possible contact point.

Utility-scale wind turbine: turbines that exceed 100 kilowatts in size, per the U.S. Department of Energy.

Wind energy systems: equipment and associated facilities that convert and then store or transfer energy from the wind into usable forms of energy, per Wis. Stat. § 66.0403(1)(m).

Wind turbine: a machine that turns kinetic energy from wind into mechanical power that spins a generator to create electricity. Wind turbines can have a horizontal or vertical axis, and can range in size from residential scale producing <10 kW per turbine up to utility scale producing up to 7.5 MW of energy per turbine depending on size.

Appendix C

Peer Review

Peer review is an integral part of the scientific publication process. It both provides review of the hypotheses, techniques, and conclusions of scientific literature as well as support that a publication has met the standards of the scientific and technical community.[119] Peer review typically involves review of a draft manuscript by at least two independent individuals and a journal editor.

Reviewing generally adheres to the following rules:[120]

- Peer reviewers must:
  - Have expertise in the given field.
  - Be independent of the agency/research group under review.
  - Be free of real or perceived conflict of interest.
- Peer reviewers must comment on science and not policy.
- Peer reviewers must offer independent reviews of the material.

Reviewers provide comments on the writing, hypotheses, techniques, results, and validity of the conclusions reached in the manuscript. These comments are typically then reviewed by an editor to determine if the manuscript has relevance and merit for a given scientific or technical journal. If the manuscript requires clarification or reinterpretation, it is returned to the author(s) to make changes which are then evaluated by the editor to determine if the manuscript is suitable for publication.

Although this is the "gold standard" reviewing process used by scientific and technical journals, other types of review also exist that do not provide the same level of scrutiny. For instance, summary abstracts or papers that are presented at scientific or technical conferences may be reviewed by a board of editors. There are several primary differences between this type of review and the former described.

Editors of material for conferences typically:

- Review material for the interest that it will elicit as presented material.
- Are not multiple independent reviewers.
- Do not place the material under the same level of scientific scrutiny as in the journal article review process.
- Do not require a response by the author(s).
- Do not necessarily hold expertise in the field of study.

---

[119] United States Office of Information and Regulatory Affairs 2004.
[120] American Association for the Advancement of Science 2005.

Although conference abstracts or papers may be published as part of a conference, these articles do not, generally, carry the same degree of scientific influence as those published in traditional scientific and technical journals for these reasons.

It should also be noted that the validity afforded to peer-reviewed literature is only as good as the process that was used for the review. If non-experts are consulted or if experts review materials outside of their field of study, then material has *not* been adequately academically peer-reviewed. Although high-impact[121] journals place a strong emphasis on the review process and are highly selective in materials they publish, low impact journals may not subject their manuscripts to the same level of scrutiny. This may occur for three primary reasons: 1) low-impact journals generally receive fewer manuscripts than high-impact journals, and thus inherently are not able to be as selective in choosing manuscripts to publish, 2) low-impact journals generally receive manuscripts from inexperienced researchers (e.g., a summer study by an undergraduate research assistant) which may be more technically flawed than manuscripts prepared by senior scientists, and 3) expert reviewers are often less inclined to review manuscripts for low-impact journals as the review process is voluntary, reviewers have limited time, and reviewing for a low-impact journal does not add the same level of prestige to the reviewers' career as reviewing manuscripts for a high-impact journal. This is not to say that valid scientific research is not published in low-impact journals, however caution may be warranted when interpreting low-impact publications.

[121] "Impact factor" is a calculation based the number of times a journal is cited over the total number of all citations in a given time period and is a proxy for importance. High-impact journals carry more weight, prestige, and influence than low-impact journals and include journals such as *Science, Nature,* and *The New England Journal of Medicine*.

Scientific Documents

There are several types of scientific and technical publications, all of which carry different levels of scientific purpose, scope, scrutiny, and influence. These are general descriptions and do not represent any and all cases. Footnotes indicate examples of each that are available in the relevant wind-health literature.

Type	Scope	Peer-reviewed?	Influence	Description
Articles	Research	Yes	High	Presents the results of an original study that has been vetted to ensure that it complies with accepted scientific standards, including study design, sampling techniques, and statistical methods.
Articles	Meta-analysis	Yes	High	Presents the summarized, analyzed results of multiple research articles. Both the articles used for the analysis and the meta-analysis itself have been vetted to ensure they comply with accepted scientific standards, including to study design, sampling techniques, and statistical methods.
Articles	Review	Yes	High	Presents a summary of multiple research articles and meta-analyses. Both the articles used for the review and the review itself have been vetted to ensure they comply with accepted scientific standards.
Articles	Opinion	Yes	Moderate	Presents the opinions of the author(s) on a scientific topic. The opinion has been vetted as reasonable, informative, and advancing from a scientific or technical viewpoint.

Type	Scope	Peer-reviewed?	Influence	Description
Major Governmental or Non-governmental Organization	Research	No	High	Presents the results of an original study that has been conducted by appointed experts. Although these types of studies are not necessarily vetted, the researchers are generally considered to be leaders in their field and therefore conformists with scientific standards. Publications directed by major governmental agencies (e.g., state, federal, or international agency) or non-governmental organizations (e.g., World Health Organization) are generally considered to hold similar validity as top research articles.
Major Governmental or Non-governmental Organization	Review	No	High	Presents a review of research articles and meta-analyses conducted by appointed experts. Although these types of reviews are not necessarily vetted, the researchers are generally considered to be leaders in their fields and therefore conformists with scientific standards. Publications directed by major governmental agencies (e.g., state, federal, or international agency) or non-governmental organizations (e.g., World Health Organization) are generally considered to hold similar validity as top review articles.
Major Governmental or Non-governmental Organization	Guidelines	No	High	Presents recommendations on a given subject based on the knowledge and experience of appointed experts. Although guidelines are not necessarily vetted, the writers are generally considered to be leaders in their fields and therefore conformists with scientific standards. Guidelines recommended by major governmental agencies (e.g., state, federal, or international agency) or non-governmental organizations (e.g., World Health Organization) are generally considered as balanced and based on relevant scientific evidence.

Type	Scope	Peer-reviewed?	Influence	Description
Reports	Report	No	Limited	Presents the results of observations, often by a scientific or technical consulting firm. The report procedural design generally complies with accepted sampling techniques, however it generally does not represent a broad sampling, the results of which could be statistically applied over other geographic areas or situations.
Self-published material, Websites, Blogs, etc.	Any	No	Limited	Presents the views of experts or non-experts. These views are of varying degree of validity, review, and may or may not be reliable or attributable.

Appendix D

Works Cited

#	Author	Title	Journal	Year	Vol.	Edition or Article Number	Pages	Type	Health Effect Associated / Correlated?
1	Adeyeye, K., Ijumba, N., & Colton, J.	Exploring the environmental and economic impacts of wind energy: A cost-benefit perspective.	International Journal of Sustainable Development & World Ecology	2020	27	8	718-731	Article, Review	No direct negative impacts, wind offset of fossil fuel causes positive health impacts.
2	Barry, R., Sulsky, S., & Kreiger, N.	Using residential proximity to wind turbines as an alternative exposure measure to investigate the association between wind turbines and human health.	The Journal of the Acoustical Society of America	2018	143	6	3278-3282	Article, Research	No negative impacts correlated to WTN.
3	Baxter et al.	A case-control study of support/opposition to wind turbines: Perceptions of health risk, economic benefits, and community conflict	Energy Policy	2013	61		931-943	Article, Research	Authors caution against causal interpretation of results. Attitudes affect support of projects.
4	Berger et al.	Health-based audible noise guidelines account for infrasound and low-frequency noise produced by wind turbines	Frontiers in Public Health	2015	3			Article, Research	Infrasound is below human auditory threshold.
5	Blake et al.	Combining the Institutional Resource Regime (IRR) framework with the Advocacy Coalition Framework (ACF) for a better understanding of environmental governance processes: The case of Swiss wind power policy.	Environmental Science & Policy	2020	112		141-154	Article, Research	Policy can affect wind siting success or failure.

6	Blanes-Vidal, V. & Schwartz, J.	Wind Turbines and Idiopathic Symptoms: The confounding effect of concurrent environmental exposures	Neurotoxicology and Teratology	2016	55		50-57	Article, Research	Without considering confounding variables, no statistically significant effect.
7	Botterill, L.C. and Cockfield, G.	The relative importance of landscape amenity and health impacts in the wind farm debate in Australia	Journal of Environmental Policy and Planning	2016	18	4	447-462	Article, Research	Health concerns are not a proxy for landscape or aesthetics.
8	Buonocore, et al. (a)	Climate and health benefits of increasing renewable energy deployment in the United States	Environmental Research Letters	2019	14	11 114010		Article, Research	Wind energy causes health benefits by displacing generation that causes PM2.5, SO2, NOX.
9	Buonocore et al. (b)	Health and climate benefits of different energy-efficiency and renewable energy choices	Nature Climate Change	2020	6		100-105	Article, Research	Wind energy causes health benefits by displacing generation that causes SO2 and other air pollutants.
10	Chiu, C.H., Lung, S.C.C., Chen, N., et al.	Effects of low-frequency noise from wind turbines on heart rate variability in healthy individuals	Scientific Reports	2021	11	17817		Article, Research	At 500 meters, LFN from turbines has more effect on HRV than traffic noise but less than PM2.5 and ambient temperature increase.
11	Cooper and Chan	Determination of Acoustic Compliance of Wind Farms	Acoustics	2020	2	2	416-450	Article, Research	Article discussed several challenges with sound measurement protocols in use to measure compliance.
12	Crichton et al.	The power of positive and negative expectations to influence reported symptoms and mood during exposure to wind farm sound	Health Psychology	2014	33	12	1588-1592	Article, Research	Attitudinal priming affects symptoms.
13	Deignan, B. and Hoffman-Goetz, L.	Emotional tone of Ontario newspaper articles on the health effects of industrial wind turbines before and after policy change	Journal of Health Communications: International Perspectives	2015	20		531-538	Article, Research	Negative tone in media causes attitude priming and affects perceptions.

14	Dumbrille et al.	Wind turbines and adverse health effects: Applying Bradford Hill's criteria for causation	Environmental Disease	2021	6	3	65-87	Article, Research	Using these criteria for reviewing literature indicates exposure to wind turbines is associated with increased risk of adverse health effects.
15	Elmallah and Rand	"After the leases are signed, it's a done deal": Exploring procedural injustices for utility-scale wind energy planning in the United States	Energy Research & Social Science	2022	89	102549		Article, Research	Planning processes can affect fairness and procedural justice.
16	Fast and Mabee	Place-making and trust-building: The influence of policy on host community responses to wind farms	Energy Policy	2015	81		27-37	Article, Research	Wind developers should improve place-making and trust-building actions.
17	Feder, et al.	An assessment of quality of life using the WHOQOL-BREF among participants living in the vicinity of wind turbines.	Environmental Research	2015	142		227-238	Article, Research	Participants living closer to wind turbines did not rate their health lower than those with less exposure.
18	Freiberg, et al.	Health effects of wind turbines on humans in residential settings: results of a scoping review	Environmental Research	2019	169		446-463	Article, Review	Higher quality studies do not show a negative impact of WTN on human health.
19	Gaßner et al.	Joint analysis of resident complaints, meteorological, acoustic, and ground motion data to establish a robust annoyance evaluation of wind turbine emissions	Renewable Energy	2022	188		1072-1093	Article, Research	Survey and measurements of sound and wind turbine operation to determine when/what characteristics caused more annoyance complaints regarding WTN.
20	Haac, et al.	In the shadow of wind energy: Predicting community exposure and annoyance to wind turbine shadow flicker in the United States	Energy Research and Social Science	2022	87	102471		Article, Research	Shadow Flicker annoyance is not strongly correlated to SF exposure, but rather to subjective response to other variables.

21	Health Canada	Wind Turbine Noise and Health Study: Summary of Results	Governmental Study – Report	2014				Governmental Report	WTN is not correlated with negative health impacts apart from annoyance.
22	Hübner, et al.	Monitoring annoyance and stress effects of wind turbines on nearby residents: A comparison of U.S. and European samples.	Environment International	2019	132	105090		Article, Research	Objective factors (distance, SPL) are not correlated with annoyance, subjective factors (perception of fairness) can be correlated with annoyance.
23	Jalali, et al. (a)	Changes in quality of life and perceptions of general health before and after operation of wind turbines	Environmental Pollution	2016	216		608-615	Article, Research	Residents with negative attitudes and annoyance have lower mental health and QoL scores.
24	Jalali, et al. (b)	The Impact of Psychological Factors on Self-Reported Sleep Disturbance among People Living in the Vicinity of Wind Turbines	Environmental Research	2016	148		401-410	Article, Research	People that benefit economically are less annoyed or disturbed. Those reporting annoyance have higher risk of sleep disturbance.
25	Karasmanaki, E.	Is it safe to live near wind turbines? Reviewing the impacts of wind turbine noise.	Energy for Sustainable Development	2022	69		87-102	Article, Meta-analysis	Research indicates different results, risk of sleep posed by WTN, annoyance is affected by visual impacts and attitudes.
26	Krogh, et al.	Health Canada's Wind Turbine Noise and Health Study – A Review Exploring Research Challenges, Methods, Limitations, and Uncertainties of Some of the Findings.	OALib	2018	5	12	1-25	Article, Review	Challenges Health Canada study conclusions and asks for more research.
27	Lerner, M.	Local Power: Understanding the adoption and design of county wind regulation.	Review of Policy Research	2021	39	2	120-142	Article, Research	Not health related – discusses when officials put in place siting rules.

28	Li et al.	Research on carbon emission reduction benefit of wind power project based on life cycle assessment theory	Renewable Energy	2020	155		456-468	Article, Research	Carbon emissions from wind is quantified and shown to be less than thermal generation sources.
29	Liebach et al.	Effect of wind turbine noise on polysomnographically measured and self-reported sleep latency in wind turbine noise naïve participants.	Sleep	2021	45	1		Article, Research	The study does not support that sleep is affected by WTN in young, healthy, good sleepers not habitually exposed to WTN
30	Maffei, et al.	Auditory recognition of familiar and unfamiliar subjects with wind turbine noise. International Journal of Environmental Research and Public Health	International Journal of Environmental Research and Public Health	2015	12	4	4306-4320	Article, Research	Auditory recognition of WTN is same for those with or without familiarity with WTN.
31	Mai, et al.	Interactions of wind energy project siting, wind resource potential, and the evolution of the U.S. power system	Energy	2021	223	119998		Article, Research	Siting restrictions play a substantial role in determining wind turbine location availability and price of wind power.
32	Maijala et al.	Infrasound Does Not Explain Symptoms Related to Wind Turbines	Prime Minister's Office: Finland. Publications of the Government's analysis, assessment, and research activities	2020	34			Govt Report, Research	Infrasound levels in areas near wind turbines are similar to those in urban areas. Those that complained about infrasound-caused symptoms were not able to identify it when exposed, and there were no observed physiological responses to infrasound exposure.
33	Małecki, et al.	Does Stochastic and Modulated Wind Turbine Infrasound Affect Human Mental Performance Compared to Steady Signals without	International Journal of Environmental Research and Public Health	2023	20	3		Article, Research	No statistically significant differences in response rates between subjects exposed to infrasound of WT origin and

		Modulation? Results of a Pilot Study.							steady IS without AM modulation.
34	Marshall, et al.	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	2023	131	3		Article, Research	Study did not support the idea that infrasound causes health impacts. High level, but inaudible, infrasound did not appear to perturb any physiological or psychological measure tested in these study participants.
35	Michaud, D.S., Marro, L., & MacNamee, J.	The association between self-reported and objective measures of health and aggregate annoyance scores toward wind turbine installations.	Canadian Journal of Public Health	2018	109	2	252-260	Article, Research	The researchers found that the annoyance of individuals to was related to self-reported health effects.
36	Michaud, et al.	Exposure to Wind Turbine Noise: Perceptual Responses and Reported Health Effects.	The Journal of the Acoustical Society of America	2016	139	3	1443-1454	Article, Research	Annoyance increases as WTN increases, particularly over 35 dB, but study does not find a relationship between exposures to WTN up to 46 dB and health-related measures in the study.
37	Michaud, et al.	Self-Reported and Measured Stress Related Responses Associated with Exposure to Wind Turbine Noise.	The Journal of the Acoustical Society of America	2016	139	3	1467-1479	Article, Research	No evidence that self-reported or objectively measured stress reactions are significantly influenced by exposure to increasing levels of WTN up to 46 dB.
38	Michaud, et al.	Clarifications on the Design and Interpretation of Conclusions from Health Canada's Study on Wind Turbine Noise and Health.	Acoustics Australia	2018	46	1	99-110	Article	WTN is associated with annoyance, but there is not enough evidence to support that more annoyance for the

									individual cause negative health effects.
39	Michaud, et al.	Response to 'Using Residential Proximity to Wind Turbines as an Alternative Exposure Measure to Investigate the Association between Wind Turbines and Human Health' by Barry, Sulsky, Kreiger (2018).	The Journal of the Acoustical Society of America	2018	144	1	330-331	Article	There is not enough evidence to support that more annoyance for the individual cause negative health effects.
40	Millstein, et al.	The climate and air-quality benefits of wind and solar power in the United States	Nature Energy	2017	2	17134		Article, Research	Emission reductions due to wind power generation have positive economic benefits.
41	Onakpoya et al.	The effect of wind turbine noise on sleep and quality of life: A systematic review and meta-analysis of observational studies.	Environment International	2015	82		1-9	Article, Meta-analysis	Living in areas with wind energy systems appears to result in annoyance and may be associated with sleep disturbances and decreased quality of life but causality cannot be established.
42	Pawlaczyk-Łuszczyńska, et al.	Response to Noise Emitted by Wind Farms in People Living in Nearby Areas	International Journal of Environmental Research and Public Health	2018	15	1575		Article, Research	A minority of individuals are annoyed, and study found that all metrics of health included in study, specifically stress symptoms, were associated with individual annoyance to WTN.
43	Peri and Tal	Is setback distance the best criteria for siting wind turbines under crowded conditions? An empirical analysis	Energy Policy	2021	155	112346		Article, Research	Used GIS to try and identify objective optimal setback distances, found at 700-800 m, annoyance was due to site specific conditions and may be marginal.

44	Pohl and Hübner	Understanding stress effects of wind turbine noise – The integrated approach.	Energy Policy	2018	112		119-128	Article, Research	Study found annoyance at WTN decreased over time, was less than annoyance at road noise, and annoyance is attributed to amplitude modulation not infrasound.
45	Poulsen, et al.	Pregnancy exposure to wind turbine noise and adverse birth outcomes: a nationwide cohort study.	Environmental Research	2018	167		770-775	Article, Research	Study found that proximity to WTN did not correlate to preterm birth, gestational age, or low term birth weight.
46	Qu and Tsuchiya	Perceptions of Wind Turbine Noise and Self-Reported Health in Suburban Residential Areas.	Frontiers in Psychology	2021	12			Article, Research	Survey results found WTN exposure and negative attitude towards wind turbines were positively associated with self-reported noticeability and annoyance due to the noise.
47	Radun, et al.	Health effects of wind turbine noise and road traffic noise on people living near wind turbines.	Renewable and Sustainable Energy Reviews	2022	157	112040		Article, Research	Study found the only health effect from WTN is annoyance and there is no conclusive effect of WTN on self-reported health.
48	Rand, J. and Hoen, B.	Thirty years of North American wind energy acceptance research: What have we learned?	Energy Research & Social Science	2017	29		135-48	Article, Meta-analysis	Sound and visual impact were correlated to both annoyance and opposition of wind turbines while socioeconomic factors lead to acceptance of wind turbines.
49	Siler-Evans et al.	Regional variations in the health, environmental, and climate benefits of wind and solar generation.	Proceedings of the National Academy of Sciences	2013	110	29	11768 - 11773	Article, Research	Health benefits from renewables by reduction of pollutants is quantified and the estimated social benefits of wind and solar are up to $100/MWh in the Midwest.

50	Simos, et al.	Wind turbines and health: a review with suggested recommendations.	Environnement, Risques & Sante	2019	18		149-159	Article, Review	Literature review found that annoyance is the only symptom backed up by solid evidence and is strongly associated with attitude towards wind energy.
51	Smith, et al.	A laboratory study on the effects of wind turbine noise on sleep: results of the polysomnographic WiTNES study.	Sleep	2020	43	9		Article, Research	Lab study found amplitude modulated continuous WTN may impact self-assessed and some aspects of physiologic sleep.
52	Solman et al.	Co-production in the wind energy sector: A systematic literature review of public engagement beyond invited stakeholder participation	Energy Research & Social Science	2021	72	101876		Article, Review	Lit review looked at ways the public is involved in the design and management of wind projects.
53	Tonin, R., Brett, J., & Colagiuri, B.	The Effect of Infrasound and Negative Expectations to Adverse Pathological Symptoms from Wind Farms.	Journal of Low Frequency Noise, Vibration and Active Control	2016	35	1	77-90	Article, Research	Participants were exposed to infrasound and the study results supported the nocebo hypothesis as the only observed and statistically significant influence on results was correlated to the beliefs of volunteers held prior to the study.
54	Turunen, et al. (a)	Self-reported health in the vicinity of five wind power production areas in Finland.	Environmental Research	2021	151			Article, Research	Study results do not support the hypothesis that broadband sound or infrasound from wind turbines could cause the proposed health problems.
55	Turunen, et al. (b)	Symptoms intuitively associated with wind turbine infrasound.	Environment International	2021	192	110360		Article, Research	Survey to get self-reported symptoms found attitudes on proximity to wind turbines, concern about health risk and annoyance were associated

									with reporting symptoms but causal relationships cannot be assessed on a questionnaire study.
56	van Kamp, I. and van den Berg, F.	Health Effects Related to Wind Turbine Sound: An Update	International Journal of Environmental Research and Public Health	2021	18	17		Article, Meta-analysis	Lit review found there is a strong association between WTN and annoyance but association between WTN and sleep disturbance is inconsistent.
57	Weinand et al.	Exploring the trilemma of cost-efficiency, landscape impact, and regional equality in onshore wind expansion planning.	Advances in Applied Energy	2022	7	100102		Article, Research	Researchers took data from 160,000 turbines to look at the best placement for cost-efficiency, landscape impact, and distance from the grid.
58	Wiser, et al.	Long-term implications of sustained wind power growth in the United States: potential benefits and secondary impacts	Applied Energy	2016	179		146-158	Article, Research	High wind deployment scenario showed air-pollution-related health benefits are estimated at $52–$272 billion.
59	Zerrahn, A.	Wind power and externalities	Ecological Economics	2017	141		245-260	Article, Review	Examination of literature showed reported annoyance, no causal health effects.

Appendix E

Wisconsin
Wind Siting Council

Minority Report

Prepared by Glen Schwalbach, P.E., Richard Jinkins, and Tim Roehl, additionally signed onto by Matt Stefkovich

Wind Energy Systems Siting

Health Review, Policy Review, and Recommendations for Legislature

May, 2024

1.0 Executive Summary

The most important objective of this minority report is to "tell the whole story" about the unique nature of wind turbine operations and their adverse health impacts upon a significant percent of the population.

The unique phenomenon of Industrial Wind Turbines (IWTs) is that, at the frequency each turbine blade passes a point an air-pressure impulse is produced at a frequency related to the rotational speed of the wind turbine blade. These impulses are not sound waves in a scientific sense. For purposes in this report, these air-pressure pulses that occur at the frequency of the turbine blade passing the tower will be called '"infrasonic" air pressure pulses', since they are occurring at frequency of less than 1 Hz.

Frequencies below 1 Hz are in the nauseogenic range, so called, because these frequencies often induce motion sickness-like symptoms. Research indicates that greater adverse health effects will be experienced as the "infrasonic" air pressure pulses occur at lower frequencies. As larger IWTs are used, the "infrasonic" air pressure pulse frequency becomes lower. This is due to the fact that larger, more powerful IWTs require longer blades turning slower past the tower producing the lower frequency air pressure pulse.

The relationship between IWTs and adverse health impacts on humans, wildlife, and livestock has become well established despite efforts by wind energy companies and their advocates to obscure the truth or pass it off as Nocebo. Residents near turbines are experiencing a wide range of symptoms: loss of sleep, headache, migraine, vertigo, balance issues, brain fog, sinus pain and ear pressure are common. These same symptoms are documented in such countries as Australia, Canada, Finland, and Germany as well as in the United States.

The connection between the symptoms and the air pressure pulse signature characteristic (below 1 Hz) of IWTs has been established by acoustics experts, engineers, cardiologists, and epidemiologists. Measurements in Wisconsin show the air pressure pulses evident in homes located even 4 miles from the nearest turbine. Homes have been vacated to preserve health. Still, the setback from residents' homes remains at 1,250 feet, less than ¼ mile for unlimited size (height and power) IWTs in Wisconsin.

The Red Barn Wind project, that commenced service last year in southwestern Wisconsin, is emitting air pressure pulses at 0.5 Hz, resulting in adverse health effects so severe that multiple families have already been forced to leave their homes. Additional Industrial Wind Turbine project pre-applications from both Pattern Energy and Invenergy are proposing even larger and more powerful turbines which will increase adverse health effects as well.

The process for reviewing applications for wind energy systems (WES) below 100 megawatts (MW) is flawed because, in almost all cases, county and town boards do not have the expertise to evaluate WES applications. They are often not aware that they could hire consultants and have the wind developer reimburse them for the consultant fees. Even if they are aware of reimbursement, it is extremely difficult to find consultants who understand all of the issues of siting WES, especially the unique acoustics of WES that cause adverse health effects in a significant percentage of the population.

As more and larger WES are already in process, an emergency legislative and executive response is needed to put a moratorium in place to provide time to overhaul the whole review process. It appears that the first action during the moratorium would be to form a legislative study committee with the appropriate experts.

This report highlights areas in PSC 128 in which health standards and practices, as reflected in the Wind Siting Council Report, do not reflect current technology, knowledge, and research that represent the best-practices designed to protect non-participating and participating residents' health, property rights, and investments. These practices strike a balance between protecting residents, including children, and creating a regulatory process that the Wind Industry can use to get approvals. This process should be balanced with consideration for the communities and residents as well as the Wind Industry.

Research limitations adopted by the Wind Siting Council for the Wind Siting Council Report assure the exclusion of valid research that would reflect the physiological burden on the human body's systems caused by modern Industrial Wind Turbines as they are currently being sited.

2.0 Introduction

Since 2009, the Wind Siting Council, (WSC) has had the responsibility of providing advice to the Public Service Commission of Wisconsin (PSC) during the rule-making process for WES installations. Through 2009 Act 40, wind turbine projects less than 100 MW could be regulated by local governments but were restricted by PSC 128 of the Wisconsin Administrative Code as to the level of health and safety protections. Act 40 also requires the WSC to submit a report to the Wisconsin Legislature every 5 years to assure that updated information regarding health research and regulatory developments are considered in the development of current siting regulations. This update requirement was prudent to account for new, evolving research, the changing technology, and growing size of Industrial Wind Turbines.

Even as local governments and affected residents around the world raise the alarm of health concerns and wildlife impact from both onshore and offshore WES, Act 40 and the manner of selecting WSC members results in a bias and, effectively, mutes the affected residents.

The push for wind and solar power generation facility construction is linked to the mandate of 10 percent power from renewable sources requirements under Wis. Stat 196.378(2)(1)2. However, per PSC REF#:470111, the 2022 Renewable Portfolio Standard Report reveals that 16.17 percent of retail sales of electrical power was from renewable resources in 2022. Because the goal of 10 percent is met, there is no overarching or urgent need to construct more wind power generation facilities without a true review of health impact of newer, larger turbines and concomitant reconsideration of siting regulations.

Wisconsin's wind siting law and rules (PSC 128) permits local governments to process applications for turbine projects under 100 MW if the local government chooses to do so. If neither the county or the towns adopt an ordinance, there are only minimal rules for the developer as to notification of landowners and government agencies and decommissioning. There are then no safety and health protections. Often, towns and, even, counties assume that PSC 128 will be in effect if they don't have their own ordinance. Since that is not true, there needs to be better statutory protections.

In cases where local governments do pass their own ordinances, they are limited to a level of safety and health protections which cannot be more restrictive than PSC 128 which is designed to encourage WES installations rather than to protect communities, wildlife and residents' health. This situation effectively removes all input from the local communities to the siting processes at all since the state has set the rules.

As more and larger WES are already in process, an emergency legislative and executive response is needed to put a moratorium in place to provide time to overhaul the whole review process. It appears that the next action would be to form a legislative study committee with the appropriate experts.

This report highlights areas in the PSC 128 in which health standards and practices do not reflect current technology, knowledge, and research that represent the best-practices designed to protect non-participating and participating homeowners' health, property rights, and investments. Proper health standards and practices are not adequately represented in the Wind Siting Council Report. These practices strike a balance between protecting residents, including children, and creating a regulatory process that the Wind Industry can use to get approvals. This process should be balanced with consideration for the communities and residents as well as the Wind Industry.

Research limitations adopted by the Wind Siting Council for the Wind Siting Council Report results in the exclusion of valid research that would reflect the physiological burden on the human body's systems caused by modern Industrial Wind Turbines as they are currently being sited.

Because Wisconsin's wind siting process is outdated, biased, and, like Illinois and New York, virtually eliminates all input from those affected in the siting decision processes, IWT development plans are increasingly met with opposition by the communities where they are proposed. The communities that do object are aware of the real concerns, that are described in this Minority Report, and fear for their families' health, their livestock, and the value of one of their largest investments—their home. Health impacts are often ignored despite research that substantiates a relationship between the installation of WES and serious health issues.

In Wisconsin, local officials are not permitted to require WES setbacks any further than the current, arbitrary, 1,250 feet or 3.1 times the total height–whichever is less—from a neighbor's occupied structure. This minimal setback from the structure rather than the property line is inadequate and an anomaly in setbacks for protection from any other hazard.

The setback to the structure essentially creates 'trespass zoning' in which some of the neighbor's land is inside the safety setback distance from the WES. That safety setback can overlap as much as 800 feet of their property and constitutes a "taking" of the owner's property rights to safely use their land for intended purposes because it is no longer possible to build with traditional setback near the property line and stay outside the 'safety setback" due to a WES situated nearby. Refer to Appendix B.

A study by a previous WSC member demonstrated the difference in rural population densities in Wisconsin where WES are installed compared to those areas in neighboring states. In effect, denser rural populations near proposed WES projects in Wisconsin assure that many more neighbors' health and well-being will be negatively impacted when compared to states such as Iowa. Additionally, the wind-resource is much less in Wisconsin than in neighboring states. So, the perceived mandate to install WES concentrates many more turbines in those smaller areas of "just adequate" wind. These areas happen to be the two of the major landforms in Wisconsin, the Niagara Escarpment and the Driftless Area of southwestern Wisconsin. Two of Wisconsin's natural beauties that already have been negatively impacted and may no longer be viable destinations for living and visiting.

Also, since the wind resource is not robust in Wisconsin, the trend is that developers install taller wind turbines to "catch more wind" which means more intense, very low frequency air pressure pulses are emitted and more adverse health impacts will be experienced by residents.

Small communities are home to many families across the state. When neighboring towns, who have a PSC 128-compliant ordinance, are targeted for WES, these neighboring communities have no input into the siting decisions that are made by the towns and, with current permitting requirements, may find that their entire community is surrounded with WES only 1,250 feet from structures on the edges of their defined land. These homeowners have no voice and no recourse.

In overall consideration, the minority concludes that Wisconsin's wind siting laws need revision for protection of health and property rights. Restructuring of the WSC makeup is essential to eliminate overwhelming bias toward building more wind projects. There also needs to be a reconsideration of the information that the WSC must review to fully advise the Legislature. Rewriting the wind siting laws to offer protection for non-participating and participating residents and to correct the bias of the WSC can assist in establishing public trust and, possibly, reduce future litigation for the wind developers, owners, and utilities.

To proceed wisely, the minority as well as many technical experts and public policy experts from around the world agree that more acoustic and epidemiological studies are needed. In 2023, Red Barn (Allete Energy) began operation in SW Wisconsin. As the largest WES in Wisconsin, this would be a valuable area for a study but funding is needed that is not bound to assured outcomes in favor of the Wind Industry. Such funding was in one of Governor Walker's budgets but was removed by the Joint Finance Committee. Similarly, funding was proposed to the Joint Finance Committee in the last budget but, again, it was not approved. So, residents near WES projects are not getting any solutions and relief for their health and financial impacts.

Finally, in light of the restrictions on input and influence of those most affected by the installation of a WES, Wisconsin needs a process and fund to compensate citizens who have had to abandon their homes in order to get relief, those who cannot move but suffer negative health impacts, and those who are forced to endure financial loss due to a neighboring WES causing a decrease in their property value. Currently, there is no recourse for those who are injured other than to complain to the WES owner/operator or local governments which have NO responsibility to make those affected truly impact-free. If the state has taken action that negatively affects certain individuals' health and property, it falls to the state to ameliorate the negative health and financial effect forced upon the residents.

3.0 Purpose:

The purpose of this Minority Report is to present the reader with additional information that the majority did not include in the Wind Siting Council report. This additional information includes the results of acoustic testing in the Shirley Wind in Brown County, Wisconsin, the adverse health impact reports of Wisconsin residents in or near IWTs, the nature and testing of very low frequency (or "infrasonic") fluctuating pressure pulsations (oscillations) unique to large IWTs, and research reports on the pathological and physiological responses by humans to pressure pulsations in the range of nauseogenicity identified in the International Standards Organization (ISO) Standard 9996 which links motion sickness to perceived or actual oscillations in the frequency range of 0.1 to 1 Hz.

The Minority Report provides a more balanced consideration of all the available data on the adverse health effects of Wind Energy Systems. Financial impacts will also be addressed. The minority members believe that a more thorough investigation is essential to protect all residents and to fulfill its obligation to the legislature and the statute. Recommendations to the Legislature are also provided as we understand our duty.

3.1 Applicable Statutes and Limitations for Expert and Public Input

The history of regulation of Wisconsin's wind siting rules, PSC 128, represents a process in which Wisconsin rural residents have been silenced by limiting the protection for residents. PSC 128 was never approved by the Wisconsin Legislature's Joint Committee for Review of Administrative Rules (JCRAR). The JCRAR had sent the draft rules back to the PSC to strengthen the provisions after a long and intense hearing. Ironically, the revised rules from the PSC were even less restrictive and contrary to the positions in the testimonies of dozens of participants and to the intent of the JCRAR.

The JCRAR then suspended the second draft of the PSC 128 proposal. The legislature drafted a bill for each house to permanently suspend the rules but never took up the bills nor held hearings. So, the rules went into effect automatically when the suspension period expired without input from experts and the public. In 2009, Wisconsin Act 40 directed the Public Service Commission of Wisconsin (PSC) under Wis. Stat. §15.797 to appoint a Wind Siting Council (WSC) to provide advice and counsel to the PSC during the rule-making process of siting WES. Additionally, under Wis. Stat. § 196.378(4g)(e), the WSC "shall report' to the Legislature every five years after surveying current health research and regulatory developments and shall make recommendations for legislation, if any changes or updates are deemed necessary.

The last five-year report was issued in 2014 and is quite outdated. The responsibility for calling a meeting to revise the report was misunderstood as some members thought the PSC would call the meeting. The WSC members from the wind energy industry were aware of massive changes in the technology which results in much larger turbines with 2 or 3 times the power of those under considerations over 10 years ago. Wind developers and project owners have no incentive to update regulations. Leaving outdated regulations in place in Wisconsin, even as other states updated their regulations, put even more Wisconsin residents in marginally acceptable wind zones at risk for adverse health effects associated with huge turbines as costs of installation in Wisconsin were less than in other areas where health and economics were accommodated.

The majority of the WSC members have either financial incentives to build more wind turbines or lack technical understanding of such and, with that, minimalize the health and safety protections from IWTs. The last report to the Legislature in 2014 reflected only what the majority voted to include. There were two minority reports written but it is not known how much of those were reviewed by the Legislature.

No report was provided in 2019. There is no provision in statutes to force the WSC to do as mandated.

In 2022, the WSC met to produce an updated report to the Legislature. But the WSC is now even more imbalanced. One member position that was not filled in 2014 was required, by state statute, to be a UW System faculty member with expertise regarding the health impacts of Wind Energy Systems. The PSC indicated they couldn't find such a person. A member of the WSC, at that time, verified that was the case. This is still the case ten years later. But the PSC has filled that position in the current WSC. The person was a UW professor who has stated he is not experienced in the health impacts of wind turbines. His expertise is in solar energy.

That UW professor offered to have graduate students do the work of reviewing articles on wind turbines and health impacts and summarizing them for the WSC, and the WSC members agreed to this way of identifying some articles. The students reviewed literature and recommended papers for the WSC to review. The literature, reviewed through this work, was broadened in scope to study articles on the health benefits of eliminating fossil fuels offset by wind energy. This takes the focus to a macro, global level instead of the micro, local focus on health impacts of residents near or in WES in Wisconsin. At the same time, some articles on the negative impacts on global climate throughout the entire life-cycle of turbines as well as on the microclimate, soils, insect life, wildlife, and human life in their vicinity were not accepted by the WSC.

After a few meetings, another UW professor replaced the first person. This professor indicated his expertise regarding wind turbines is research in wind energy geotechnical and structural aspects, such as, turbine foundations and soil stress. His qualifications do not meet the requirements of state statute. The lack of a competent and qualified individual with health expertise remains critical despite being called out in both the 2010 and 2014 Minority Reports. But filling the position, in the manner that the PSC used, merely added another vote for the majority. To be clear, the professors were approved to participate on the WSC by the PSC.

3.2 Wind Siting Council Limits Review of Literature.

The WSC put a limit on reviewing health impacts of wind turbine development with the majority's interpretation of Stat. § 196.378(4g) (e) as directing the WSC to survey **only** peer-reviewed scientific research regarding the real impacts of wind energy systems and to review **only** state and national regulatory developments regarding the siting of wind energy systems.

Although Stat. § 196.378(4g)(e) does list the type of documents that the WSC must consider, minority members do not consider that list to be exclusive of other relevant data. We find that the inclusion of other credible research, empirical evidence and personal, notarized affidavits is in the best interests of the public. Inclusion of such evidence would provide the Legislature and the PSC with a more complete and better representation of the effects that WES have on human health.

It is the responsibility of the Legislature to address the experiential realities of citizens affected by wind turbines. It is the WSC's responsibility to provide the Legislature with pertinent information that honestly and objectively addresses all the health concerns that may affect the quality of life as it relates to siting WES near homes, schools, and workplaces where Wisconsin residents spend many hours.

As mentioned, the statute requiring a five-year Report to the Legislature specifies the WSC shall survey the peer-reviewed scientific research regarding health impacts of WESs and study state and national regulatory developments regarding the siting of WESs. A suggestion was made that the WSC should also review educational literature, results of acoustic testing in WESs, such as the PSC-funded report of Shirley Wind in Brown County, and reports of health complaints to provide the Legislature with a thorough evaluation of WESs impacts on Wisconsin's residents. The majority of the WSC voted against such review. An interpretation of the statute was requested from the Legislative Council.

The Legislative Council's attorney indicated that the main focus shall be on the peer-reviewed sources but that did not preclude the WSC from reviewing other information to bring well-rounded advice to the Legislature, including expertise from practical and empirical evidence. In regard to regulatory developments, the provision is even more subjective. Review of practical, economic and social effects of such developments as related to the WSC's report are appropriate, according to the Legislative Council.

The Legislative Council's interpretation was presented to the WSC. But the WSC's majority decided to still restrict their reviews to peer-reviewed research. In addition, it was recommended by PSC staff to only review peer-reviewed research that mentioned wind turbines. This means that, even though wind turbines produce air pressure pulsations, the WSC's majority decided to not review pathological or physiological studies of the impacts of air pressure pulsations on the auditory system, vascular system, or the human brain unless the studies mentioned wind turbines. With this maneuver, the most important basic research regarding human response to pressure pulses was eliminated from possible consideration just because the report did not mention wind turbines, per se.

3.3 WSC Began Reviews Without Training on the Related Science

After the WSC decided what reports to include or leave out of the Report to Legislature, it became obvious how little some members knew about the technical aspects of industrial wind turbines, especially in regard to the nature of air pressure pulses and the significance of unique pressure pulses emitted from these turbines.

A lesson learned for a future WSC is to have training at the first couple of meetings. Also, members should visit a WES as part of that training. It is critical that those making decisions or recommendations regarding the widespread implementation have at least rudimentary knowledge and experience with the technology as well as the concept of cost-benefit analysis and the difficulty of assigning a monetary value to quality of life and human health.

3.4 Wind Developer Loophole

Currently, wind developers' proposals for WES of less than 100 megawatts (MW) are subject to review and permit approval by the local governments. Those WES that are 100 MW's or larger are under PSC jurisdiction. The PSC has a paragraph in the 2024 version of their Application Filing Requirements (AFR) for 100 MW's and larger that states as follows:

Do not break a single project into two or more smaller projects in order to avoid the regulatory review process under Wis. Stat. § 196.491(3) or to avoid the regulatory review process under Wis. Stat. §196.49 (Wis. Admin. Code § PSC 112). The above paragraph is not in the AFR for WES below 100 MW.

The question exists as to whether the PSC can prevent wind developers from avoiding the PSC process by proposing smaller projects of less than 100 MW. These smaller projects can then be sold to utilities who then also avoid the PSC process.

4.0 Minority Review of Health

Though windmills have been in use in civilization for millennia, the current models differ vastly from the scenic versions popular in Netherland's postcards. Against a blue sky and framed by tulips in the foreground, the large white vanes stand out in a picturesque manner only 100 or so feet above the ground.

Today's Wind Energy Systems (WES) are entirely different. Offshore turbines tower nearly 1,000 feet above the ocean and have proven devastating to whales and other aquatic life in their vicinity to the extent that public sentiment has recognized both the environmental and economic risk that these behemoths represent. Current onshore WES have grown in power and size as well since the PSC in Wisconsin adopted minimal requirements for WES near communities, schools, and residences. Prior to 2019, the largest wind turbines in Wisconsin were 495 feet tall and generated 2.5 MW. A pre-application has been received by the PSC for WES as large as 6.2 MW from Invenergy (Badger Hollow Wind). Pattern Energy has also submitted obstacle approval requests to the FAA for up to 698-foot industrial wind turbines. Information is available at https://oeaaa.faa.gov/oeaaa/external/searchAction.jsp?action=showCircleSearchForm in the FAA Obstruction Evaluation database.

No health or medical studies have analyzed the human impact to more powerful IWTs that will be emitting air pressure pulses at even lower and more hazardous frequencies. Proposed WES will be among the largest wind turbines in the US and will be approved and installed over objections of rural residents. Residents in Southwest Wisconsin over 4-miles away are already being negatively impacted by the 3.5 MW Red Barn IWTs. In effect, the Legislature and the PSC have shown less regard for the health and well-being of affected residents than is currently being shown to mammals and wildlife.

Eliminating any consideration of many forms of research and regulations by the WSC, such as the Madison County, Iowa setbacks of 1.5-miles with a limitation on both turbine power to 2.3MW and height of 500 feet has assured that the information presented to the Legislature is biased and leads to insufficient consideration of the risks and damages that accompany the 1,250-foot setbacks of WES without any limits of height and power currently allowed in Wisconsin.

4.1 Annoyance

Annoyance is a term that is often used in describing the impact of WES on nearby residents. It is a carefully chosen term that performs a sleight of hand in denigrating the true impact of WES. In common use, "annoyance" is used to describe irritation, a minor negative in life that should be merely accepted and "dealt with."

As early as 1991, Suter (1991) recognized that:

Annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life. This represents a degradation of health in accordance with the WHO's definition of health, meaning total physical and mental well-being as well as the absence of disease.

WHO retains that definition as a continuing principle and is evident on their current website. https://www.who.int/about/accountability/governance/constitution.

In medical and health discussions, the term “annoyance” has a much more impactful meaning because long-term annoyance has major health impacts. It can be more closely defined as distress or aversion. Annoyance might be considered subjective or an individual’s body response to some stimuli. The annoyance associated with WES may have many sources for those who are constantly exposed to their effects.

Having external noise that is variable and over which one has NO control is one avenue of annoyance. Looking out one’s window and seeing the cause of one’s pain is another. Annoyance can exist when having to have all the windows closed and curtains drawn on a spring day or, in the event of an air conditioner failure, on a very warm day. Knowing that your property value has declined or that the only recourse is a hopeless lawsuit against a multi-national corporation that has billions of dollars and employs a vast legal staff is also an annoyance.

Yet these go beyond something one can “get over” or just accept. Subjected to the impact and the stress of having no way to deal with it are major health concerns due to the associated chronic stress. Chronic stress has been linked to heart disease, high blood pressure, high cholesterol, diabetes, impaired immune system and even neurological disorders. (Rasheed, 2016) These associations are well-publicized in health magazines and on all health information sites. (https://www.yalemedicine.org/conditions/stress-disorder; https://www.mayoclinic.org/healthy-lifestyle/stress-management/in-depth/stress/art-20046037)

Chronic stress and hopelessness are often mentioned in connection with depression and anxiety and can pose mental as well as physical issues for some individuals. At least one researcher has analyzed available data from around the U.S. comparing suicide rates in or near counties where new Industrial Wind Turbines were installed and compared it to the neighboring counties that were farther away. In an unpublished statistical analysis, Zou (2017) found a higher suicide rate among the elderly and among teens who lived in communities near the WES installations. The elevation in suicide rate was statistically significant but, to the amazement of many readers, the additional deaths were deemed “acceptable cost” for the implementation of unreliable, intermittent power generation facilities in their communities. The true cost of suicide, however, is very difficult to calculate when the longer-term result of survivor guilt and anger or depression extends to future generations.

By describing the constant exposure to WES noise, flicker, air pressure pulses, visual disruption, loss of property value and control as “annoyance,” the true negative impact on the health of residents is hidden. While the wind companies might find it an annoyance to discuss the impacts, residents continue to suffer real health consequences.

It is important to remember with any external stimulus, different individuals exhibit a wide range of sensitivity to each stimulus. What is pleasant to some is likely be noxious to another. Some are more sensitive to sound or light and are negatively impacted to an extent that is unimaginable to those immune to the stimulus. The WSC should work to protect the rights of the most sensitive as a precaution to preserve the rights and health of the greatest number of citizens.

4.2 Wind Turbine Shadow Flicker

Wind Turbine Shadow Flicker (WTSF) is a well-documented aspect of WES operation. Any time the turbine is between the sun and a residence, that residence is subjected to alternating dark with flashes of light as the rotating blades pass the path of the sunlight. The intermittent light/dark creates a strobing effect that can be disturbing to many people.

Some people experience physical symptoms when exposed to such strobe lighting. They may become dizzy or nauseated or even have balance issues when they see such movement of light and shadow. (Pierpont, 2006)

This phenomenon is sufficiently disturbing to concentration and peace that it has been addressed to the extent of limiting shadow flicker to 30 hours per year in PSC 128. That limit seems reasonable until it becomes clear that there is no enforcement on that limitation. Measurement, documentation and complaint processing falls to the affected resident. Then, verification by the turbine operator is necessary for any effort at amelioration of the impact.

Under PSC 128 criteria of 30 hours per year, it has been found developers use this criterium as the “real experience” for use in their computer models. But, in other countries, developers use 10 hours per year as the “real experience” for modeling purposes. But the WSC majority voted to not recommend a change to PSC 128.

Amelioration usually consists of a purchase of shades or blackout curtains for the residence and advice to keep the windows and shades closed if the flicker is problematic. The situation results in being essentially imprisoned in the home to avoid the WTSF. Such measures may also limit the individual resident who is prevented from timely attention to crops or livestock which affect their livelihood.

Because the size of WES has increased dramatically, the minimal setback from an occupied structure poses a risk to many uncompensated property owners and severely limits the use of personal property. With a low sun angle and an approximately 700-foot turbine, blade shadow flicker will limit usage of any portion of the property that receives shadow flicker even if the residence itself is spared. This is a case of “trespass zoning” which allocates control over one person’s property to another entity and forces uncompensated property owners to forfeit use of their property.

The legislature should require shadow flicker be limited to 10 hours per year for modeling purposes and, during those hours of flicker, shut down the turbine by use of either shadow sensor devices on the non-participating property or remote-control programming.

4.3 Audible Noise

Audible noise receives significant attention in discussion of Wind Energy Systems' effect on health. It is impossible to ignore the issue due to the pervasive nature of the sound generated by rotating turbine blades. Several organizations have published guidelines or established limits for audible environmental noise. Environmental noise is considered a health risk even when the noise level poses no risk to hearing.

Noise is often considered as 'unwanted' sound or anything that interferes with signal transmission to a receiver. Sound that is audible is within the human range of hearing and, generally, is between 20 Hz to approximately 15,000 Hz. The particular characteristics of audible WES noise combined with the location of the WES in formerly quieter areas increase the probability that audible noise generated by the turbines will be considered a problem by nearby residents. Turbine noise is more annoying than traffic sounds due to the specific characteristics as well as the imposition in areas where traffic is not a problem. Turbine noise is often constant and is amplitude modulated or impulsive in cadence. The constantly changing sound activates the human brain to attend to the change and then appraise the risk cognitively. Because the sound is both constantly present but changing, the state of human sensory alertness inhibits acclimatization to the sound.

The audible pulsing or "swoosh, swoosh" aspect of the blades flexing is characteristic of the turbines and unlike naturally occurring sounds. This aspect of artificiality and constant change causes an ever-present alerting condition which contributes to many of the symptoms that residents report. The symptoms include: loss of sleep, nervousness, anxiety. (Krogh et al, 2012)

Even during sleep, the auditory system remains active. Incoming sounds are processed and evaluated though waking is not always noted by the sleeper. The constant re-alerting causes sleep disruption requiring cognitive response with concomitant sleep disturbance. Audible noise can then increase the time to return to sleep. It is well recognized that loss of sleep is a known health risk contributing to depression, lower cognitive performance, fatigue, increased accident rate, obesity, diabetes and cardiovascular disease. (Institute of Medicine, 2006)

Annoyance from environmental noise is dependent upon a number of factors including proximity, ability to access relief, sound characteristics, sound pressure levels and normal ambient environmental noise.

Janssen, et al (2011) found that annoyance from environmental noise increases rapidly as sound levels exceed 35 dBA outdoors and 40 dBA indoors. Note: PSC 128 allows 50 dBA during the daytime and 45 dBA during the nighttime at a residence.

Annoyance complaints from WES in Wisconsin are handled in the same manner as shadow flicker. There is no measure of accountability in Wisconsin law to ensure that operators are pursuing corrective action. Complaints are made to the WES operator which then addresses or ignores the complaint as deemed appropriate to them. Because there is very low probability of action or help from the turbine operators due to the lack of legal incentive, it is likely that underreporting of noise complaints is common.

Also, it should be noted that PSC 128 restricts local governments from requiring a daytime decibel level less 50 dB(A) and a nighttime decibel level less than 45dB(A). Per a Marini, et al. (2019) report and a Nieuwinhuizen and Kohl (2015) report, not reviewed by the WSC, many, if not all, European countries require lower sound levels. Belgium and Germany are at dB(A) levels of 45, Denmark at 44, parts of the United Kingdom at 35 or 40 dB, Finland at 45 during the day and 40 at night, and France at 35. Note that a 10 dB increase is twice as loud to a human being.

This means that there will be more adverse impacts from audible sound from WES in Wisconsin than in many countries. Besides this, setbacks are often greater in other countries and in parts of the U.S. than in Wisconsin. Changes need to be made.

That said, air pressure pulses are even a more significant problem with their direct physiological impacts to cause adverse health effects. This phenomenon will be described in the next section of this report.

To ameliorate any such environmental hazard, three options exist. The approach can only affect the source of the sound, the path of travel, or the receiver. The operator is not likely to shut down turbines no matter how many residents complain. The path of travel is through the open air and turbines are too tall for acoustic barriers to be effective. That leaves the resident with the options of adding extra sound insulating material to their homes at high cost, or adding ear plugs or noise-cancelling ear muffs in hopes of avoiding headaches, nausea, and loss of sleep. In effect, the resident is required to make accommodation with their finances as well as their health to accommodate the WES operators. However, these accommodations have proved futile for neighbors who, having tried sleeping in basements, and even outside the home in RVs, trucks, cars and tents when weather permitted, found themselves having to seek relief from sleep disruption and motion sickness by relocating miles away.

4.4 Air Pressure Pulses

Note that a somewhat lengthy explanation of air pressure pulses which are unique to Industrial Wind Turbines was provided in the “Executive Summary” for the convenience of the readers. This section will describe this phenomenon in greater detail. Much of the research reviewed by WSC discussed low frequency sound usually defined as 10 – 100 Hz which cause adverse health effects. Only a few of the reports approved by the Wind Siting Council even identify the aspect of the air pressure pulses which have the greatest negative impact.

Some of the reports cited throughout this section refer to infrasound or low frequency noise but, often, the component of acoustics that is occurring also is air pressure pulses that are the real concern.

Acoustic stimuli are not restricted to the range that is audible or cognitively comprehended by the human nervous system. Sound waves at a frequency that is below or above the audible range still impacts the human with a resulting effect on the body. Every WES produces air pressure pulses (below 20 Hz) as well as low frequency noise in the range of 20-200 HZ. The pressure pulses and low frequency noise components travel much farther than higher frequencies, reflect readily off the atmosphere and terrain, travel more easily through walls, and resonate or increase in intensity throughout buildings. The pressure pulses are generated by blade pressure loading and dumping power accumulated while rotating through wind shear profiles resulting in orthogonal dipole moments and flapping at blade eigenfrequencies (natural frequencies) each time a blade of the WES passes through the slower air in front of the support tower. Low frequency noise is generated from rotating blades encountering continuously fluctuating inflow turbulence. Noise levels have been found to be higher broadly upwind and downwind, and lower directly crosswind.

Taller IWTs with their longer blades cause more adverse health effects because they produce pressure pulses at lower frequencies. Following are the recent recording graphs of three Wisconsin WES with different heights and power levels.

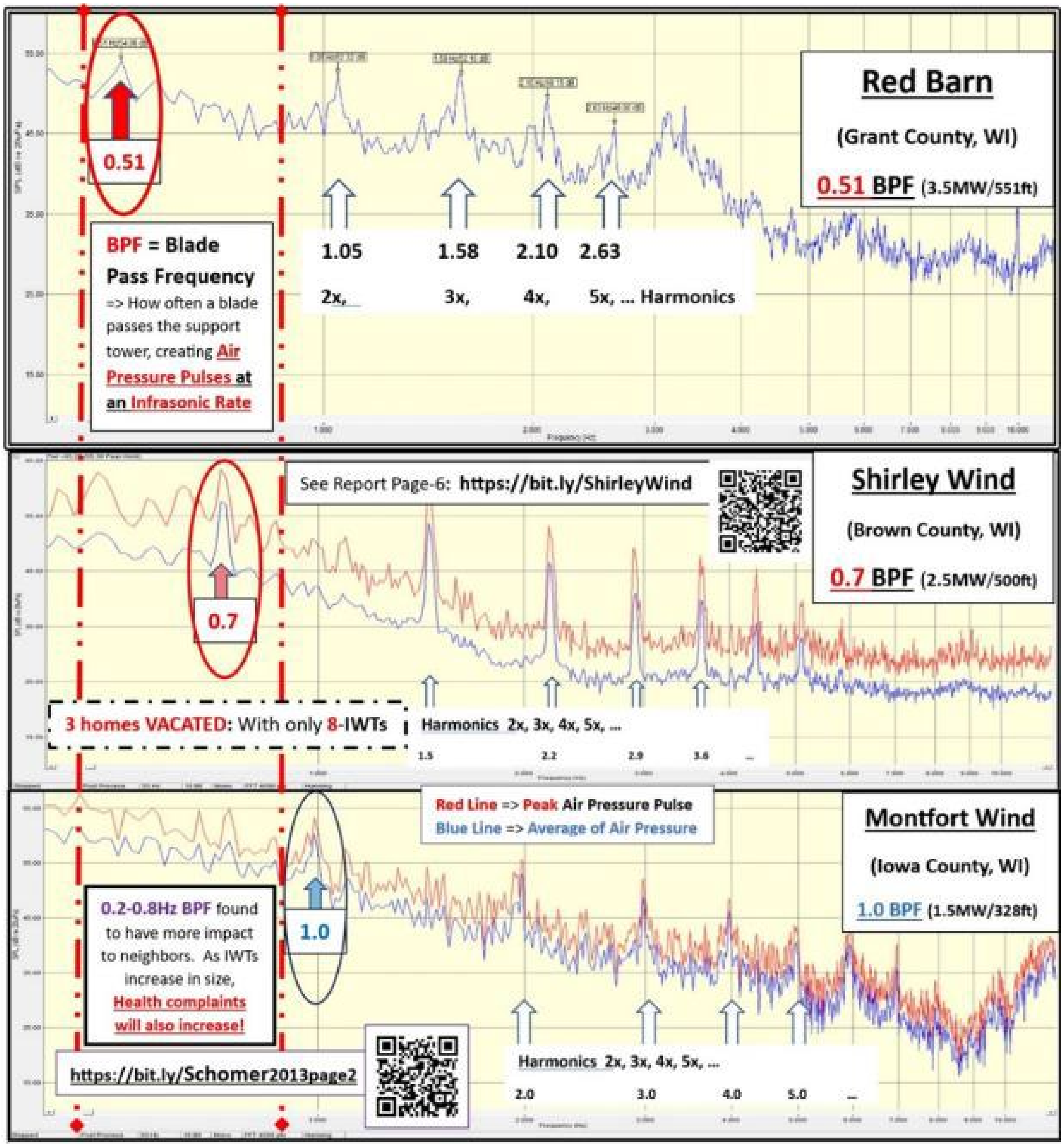


Figure 1 - All Industrial Wind Turbines (IWTs) generate barometric air pressure pulses and low-frequency noise each time a blade passes the tower. More powerful IWTs turn slower and generate more powerful pulses that travel for miles. IWT pulses quickly impact 10-15 percent of the population who are most sensitive. Pulses in the range (0.2-0.8Hz) marked in **RED** above are known to cause nausea, headache, vertigo and loss of sleep. Because Montfort IWTs turn faster, generating pulses outside that range, their impact has been less. Shirley Wind's 8-IWTs resulted in vacated homes. Already, Red Barn neighbors are pleading with the operator to shut IWTs off at night so they can sleep! 28 Red Barn IWTs are generating over a million air pressure pulses per day, negatively affecting residents in homes MILES away. **+220 larger IWTs** are planned for Southwest Wisconsin. **The impact on health and community WILL be devastating.**

As early as 1982, Dawson (Dawson,1982) recognized the relationships between low frequency noise and distress for some individuals. He reported that if a person displays "some sensitivity to low frequency noise, further exposure lowers the sensitivity threshold." In effect, once an individual has been exposed and developed a sensitivity, additional exposure is apt to exacerbate the physiological response. He identified "low frequency sensitivity syndrome symptoms as feelings of irritation, unease, stress, undue fatigue, headache, nausea, vomiting, heart palpitations, disorientation, swooning, and prostration." These symptoms are mirrored by research from around the world using subjects who have never heard of Dawson and are likely to have no information on the adverse health effects of very low frequency fluctuating pressure pulsations. One research report, not reviewed by the WSC, even though it mentions wind turbines, is by Weichenberger, et al. (2017). They subjected healthy participants to infrasound and observed brain activities through use of an MRI device. They reported brain activity in brain areas which play a crucial role in emotional and autonomic control. The latter is the nervous system that regulates involuntary physiological processes including heart rate, blood pressure, respiration and digestion. Salt and Lichtenhan (2014) provided evidence of a biological link between very low frequency pressure oscillations and adverse health effects. The body's response to this inaudible stimulus is still in need of additional research given the impetus to inflict it on vast swaths of rural America.

Though inaudible, these air pressure pulses can cause a cluster of symptoms consistent with motion sickness in a percent of those exposed. Research into the adverse health impacts of WES outside the US has been ongoing even while it has been minimalized in US studies. Many of these focus on the impact of pressure pulses below the auditory level of detection within human capability.

Research shows that there are many people, but not all, who are negatively affected by very low frequency pressure pulsations and vibration. The range of nauseogenicity is documented in ISO 9996 as between 0.1 and 1 Hz, exactly the range of blade pass rates or frequencies for large wind turbines. Symptoms are often vague but can be devastating. These symptoms were cataloged and investigated by Dr. Pierpont (2009) after it was realized that a cluster of patients were suffering similar injuries and symptoms. Dr. Pierpont's book, *Wind Turbine Syndrome*, describes the impact on residents in the vicinity of WES. These motion sickness symptoms are consistent with sick building syndrome that emerged in office buildings with the use of variable vanes that resulted in air pressure vibrations in the air conditioning ductwork.

Numerous researchers have documented the commonality of symptoms comprising Wind Turbine Syndrome including: sleep disturbance, headache, migraine, tinnitus, ear pressure, sibilance problems/dizziness, vertigo, nausea, visual blurring, irritability, problem with concentration, panic episodes, and tachycardia (Pierpont, 2006). Throughout global installations, researchers have correlated these symptoms with proximity, exposure, wind direction and wind speed. These include medical doctors, such as Pierpont (2009) and Johnson (2020), but also acoustics engineers such as Salt and Lichtenhan (2014) and Schomer (2015).

As the number and size of turbines installed near homes have increased, so have the complaints and cries for relief. These many case studies are collected in papers by Acker (2019), Frey and Hayden (2012) and even in the frequently-cited Shirley Wind report prepared in 2012 for the Wisconsin PSC (available at: https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=178263).

Another noteworthy study was done by Steve Cooper of The Acoustic Group in the Cape Bridgewater Wind Farm in Australia. Mr. Cooper studied a select few people who were identified as sensitive to wind turbine acoustics. The study's intent was to verify the individuals' complaints and whether they correlated to the wind turbines mode of operation without the presence of audible sound nor visual view of the turbines. His findings were that the responses correlated with the wind turbine power being generated which suggests that more powerful IWTs will have more severe impacts. Paul D. Schomer and George Hessler, who both were part of the Shirley Wind study, note that Cooper's study makes the point that "there is at least one non-visual, non-audible pathway for wind turbine emissions to reach, enter, and affect some people".

Research in Canada by Dumbrille et al. (2021) demonstrated a relationship between adverse health impacts of WES and proximity to the turbines. The research applied the Bradford-Hill Criteria to establish a relationship between the inaudible infrasonic component of WES-generated acoustic emissions and various health impacts. The Bradford-Hill criteria (Hill, 1965) provide a reliable, repeatable metric for scientifically assessing a wide range of environmental hazards and reliably positing a causal connection between symptom and environment. The nine criteria have been reviewed by researchers for over 50 years and found to provide a robust tool for determining causal relationships between many environmental factors and adverse health impacts. These criteria follow.

1. Strength of Association is well established by the sheer number of reports from international locations. The similarity of symptoms in unrelated persons, like most disease clusters, provides incentive to researchers to identify the commonalities in all situations—in this case, Wind Energy Systems.
2. Consistency of symptoms and complaints from unrelated studies by numerous researchers in a variety of international locations.
3. Specificity was identified by collecting reports and research describing the multiple symptoms that were present in residents living near IWTs. Comparing these symptoms, the list of common issues was derived. These specific symptoms constitute Wind Turbine Syndrome.
4. Temporality of onset and relief of symptoms concurrent with proximity and removal from sites near WES.

5. Dose-Response Gradient showing that symptoms worsened with increased exposure. For all symptoms, greater exposure and closer proximity increase the probability of occurrence while leaving the area provides relief.
6. Plausibility is confirmed by Salt and Lichtenhan's (2014) research showing the physiological impact of very low frequency vibration on human anatomy through the mechanism of infrasonic acoustic pressure in conjunction with the structures of the human vestibular and auditory system on a cellular level.
7. Coherence. Coherence is similar to biological plausibility (Fedak, et al, 2015). Research showing the impact of longer-term ultralow frequency acoustic impulses on the cells of other mammals such as horses, pigs, or cows logically reveals a very high probability of similar impact on humans. The impact on foals (Costa Pereira e Curto, 2012) and mink (Alves-Pereira, 2007) demonstrates coherence of the effect of "infrasonic" air pressure pulses on humans. Increased stress indicators have been detected in animals living near IWTs (Lupucki, 2018) which is in accord with findings in a meta-analysis by (Chiu et al, 2021) showing increased stress among human subjects living near IWTs as indicated by a decrease in heart rate variability which is a recognized objective measure of physiological stress. Additionally, research by Bellut-Staeck (2023) described the mechanism of impact on microcirculation in both humans and animals exposed to infrasound "especially with very low frequencies and impulsive character" as that generated by IWTs.
8. Experimental Evidence has been gathered in many studies both longitudinal and cross-sectional. Despite a relative dearth of research performed on site with operational WES of the size currently installed, the relationship has been systematically demonstrated and documented in meta-reviews of the literature.
9. Analogous Evidence is present in similar cases of exposure to unseen or unheard factors in the environment which also have adverse health effects. These could include radiation of many types, carbon monoxide or, for some sensitive individuals, nuts.

These criteria have been repeatedly applied to draw a conclusion between the WES-generated air pressure pulses at the blade pass rates and the cluster of symptoms that are commonly reported by those who are exposed.

Marianna Alves-Pereira (2007) has shown that pressure pulsations and constant vibration in that range has an effect on the human cardiovascular system by vibration of the body's many organs and blood vessel which are loosely connected and suspended in fluids. Her research on vibroacoustic disease spans decades and includes post-mortem analysis of body cells showing the greater thickness and loss of elasticity in heart and blood vessel wall cells.

A paper by Schomer, et al. 2015 paper, *A theory to explain some physiologic effects of the infrasonic emissions at some wind farm sites,* explains a possible physiological causal modality which would result in the commonly reported symptoms from residents near WES.

In 2020, Dr. Johnson of Madison County, Iowa, who authored a 184-page summary of the current literature along with his own clinical experience, was instrumental in Madison County (Johnson, 2020) achieving a greater protective setback of 7,920 feet (1.5 miles) from residences but also from schools, churches and communities. Dr. Johnson emphasized the impact on sleep and the many well-recognized negative health effects resulting from chronic sleep loss. Refer to Appendix D.

Jerry Punch and Richard James (2017) compiled a comprehensive review of the literature regarding infrasound and human health through 2016. This paper is a thorough review to that date and provides essential information.

Noteworthy is that, in 2022, the World Health Organization added a new code (T75.23) to its International Classification of Diseases (ICD) to identify "vertigo from infrasound". The ICD is used internationally to track health conditions, to aid research, to provide mortality statistics, and for reimbursement systems.

Virtually all research regarding WES and health call for additional research on the effects of acoustic pressures below 20 Hz on human anatomy. It is logical that this be performed on site using persons who are already known to be sensitive to sensory conflict, i.e. prone to motion sickness. Roughly one-third of the population is highly susceptible to motion sickness (Hromatka, 2015). Because a significant percentage of the population is known to be affected near IWT's, this group must be assured representation in research studies as well as protection in their homes and communities. The moratoriums that some communities have enacted provide the opportunity to complete that research before additional WES are built with resultant negative impact on the health of citizens.

Taking the proper precautionary approach and acting to protect current residents who are already affected to the point of being forced to vacate their homes or experience ongoing physical symptoms is prudent. However, these are not the only ones in danger. Young children and teens are currently subjects in a vast, long-term experiment with risks of which they have not been advised and in which their participation is non-voluntary.

4.5 WES Empirical Evidence

Experiments were conducted on behalf of the PSC in 2012 in Shirley Wind in Brown County Wisconsin. The Shirley Wind Report, though conducted by four acoustic authorities of the day representing both the wind companies and the PSC, was rejected for consideration by the WSC majority.

The results of this study demonstrated clearly the presence of pressure pulsations within the Shirley Wind installation. The research team took measurements in three homes that were vacated. One technician who stayed on site also experienced adverse impacts from the exposure.

Acoustic measurements from the Shirley Wind Report show pressure pulsations. Recent acoustics measurements from a number of Wisconsin locations near WES facilities have been made. These were made under the guidance of Robert Rand, P.E. by trained technicians and engineers.

The original Shirley Wind research report has been cited often internationally. It clearly demonstrates the presence of air pressure pulsations occurring at the blade pass rate when the nearby WES are operating. This is shown in the Figures in the original research report submitted to the Wisconsin PSC and is available here: https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=178263

Because the wind facility operator, Duke Energy, did not agree to shut the turbines off during the testing, the WI wind lobby agreed that "infrasound" (pressure pulsations) was measured in the home, but the source could not be determined to be the Shirley Wind Turbines, even though the frequency of the air pressure pulses reported matched the Shirley Wind turbine blade pass rates.

One paper by Schomer, et al. in 2015 cited the findings of the Shirley Wind study. They stated the results suggest a relation between wind turbines and motion sickness symptoms. Also, they pointed out that the repetitive acoustic pressures from the wind turbines are some three times greater than the force that the U.S. Navy rates in the nauseogenic range.

Since Shirley Wind was "unable" to shut down the turbines during the 2012 testing, the wind industry lobbyists in Wisconsin concluded that "the source of the air pressure pulses could not be determined. Of course, with a stopwatch, anyone could time the frequency that the Shirley Wind Turbine blades were passing the support tower and would find that the timing calculation of nominal 0.7Hz would match the frequency reported in the Shirley Wind report, the link for which is shown above. The graph from the Shirley Wind report is included in Appendix A, where the nominal 0.7Hz air pressure pulse is graphed and also identified in the text, along with identifying the harmonics of 2X, 3X, 4X, and 5X.

Independent researchers have continued to record the air pressure pulse data near IWTs operating at a number of sites in Wisconsin. On Feb 8, 2022, Richard R. James, ASA, provided testimony with a presentation to the Kansas Senate's Committee on Utilities highlighting the research he had completed using Infra20 micro barometer data collected at Shirley Wind. The data collected by James at the Brown County house is shown in Figure 1 below. The pressure frequencies are clearly evident while the turbines are running but absent when the turbines are not in operation.

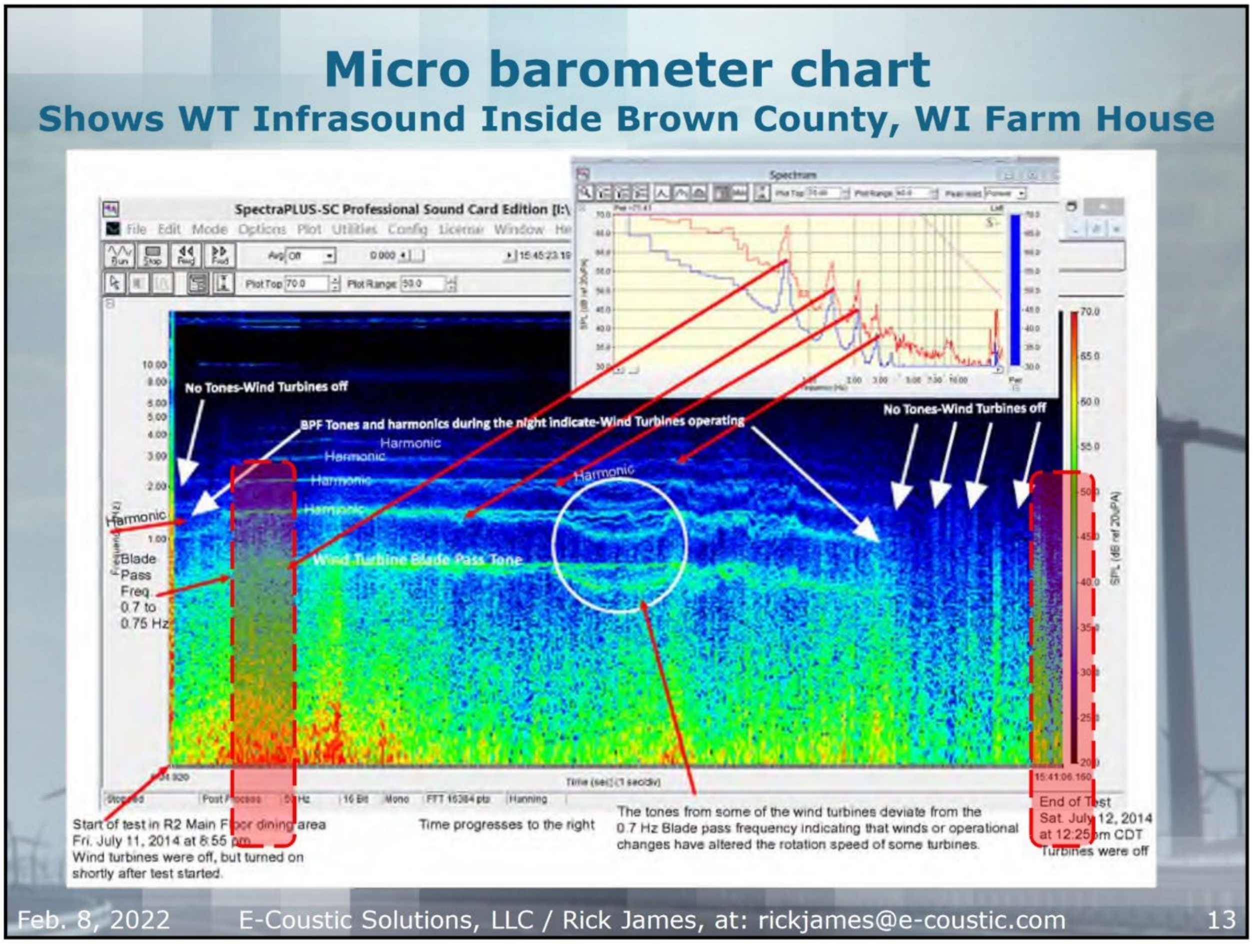


Figure 1 Shirley Wind Infrasound analysis showing pressure pulsations at the blade pass rates.

The presentation and testimony to their Senate Committee on Utilities should be recommended background for all PSC staff involved with WES. In addition, all WSC members should have received an unbiased factual technical introduction to the IWTs and the air pressure pulses they emit. Without such basic knowledge, it is impossible to make informed decisions on many of the valuable research and reports suggested to the WSC for inclusion. Too often, valid peer-reviewed reports were rejected by majority vote of the WSC. This is all available on the Kansas site:

Richard James' entire Presentation available here on the Kansas site here:

https://kslegislature.org/li_2022/b2021_22/committees/ctte_s_utils_1/documents/testimony/20220208_03.pdf

Testimony by Richard James and Dr. Jerry Punch also on the Kansas site here:

https://kslegislature.org/li_2022/b2021_22/committees/ctte_s_utils_1/documents/?date_choice=2022-02-08

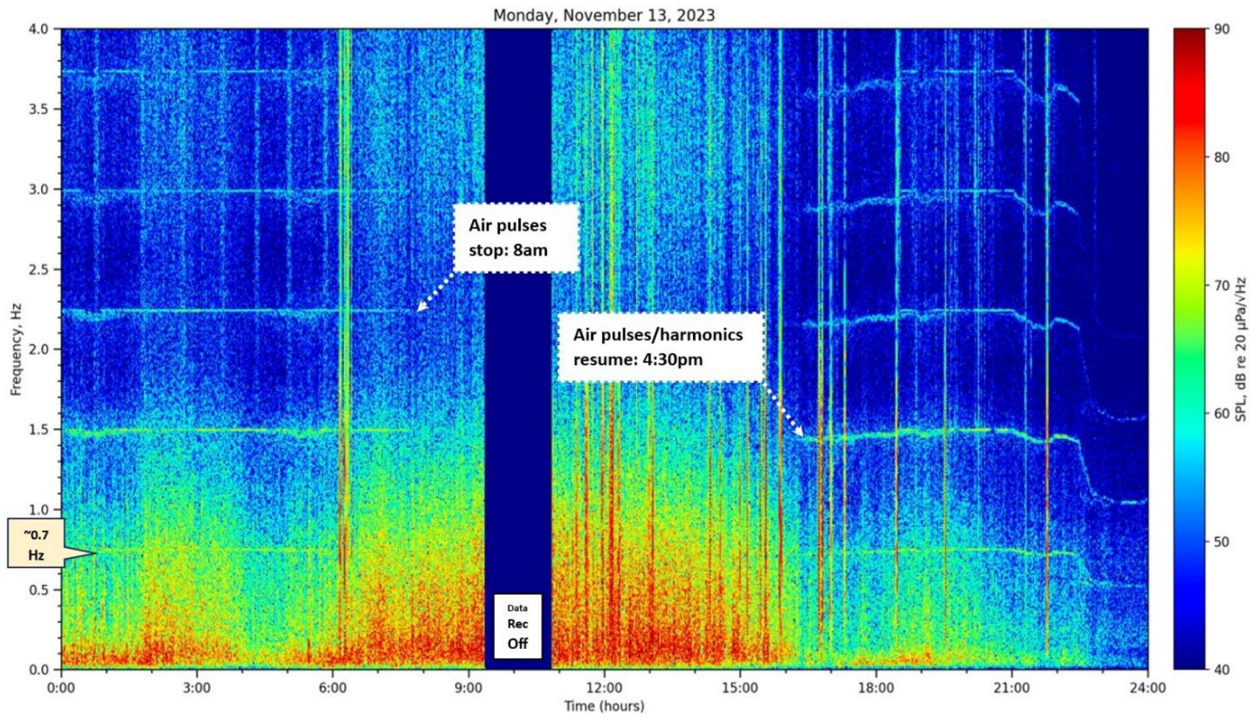


Figure 2 Shirley Wind Maintenance Shutdown Monday November 13, 2023 between ~8:00 a.m. and 4:30 p.m.

The same sensor technology (Infiltec Model INFRA-20) that was used by Rand Acoustics in 2012 for the Shirley Wind Study (Appendix A), is also the sensor technology that was used to record the air pressure measurements at a 50Hz rate on November 13, 2023 at Shirley Wind as shown in Figure 2 above. The horizontal lines showing the air pressure pulse at 0.75Hz, along with the harmonics at 2X, 3x 4X and 5x are seen stopping about 7:30-8:00 a.m. and resuming normal operation near 4:30 p.m. on the timeline. The exact stop and start times could be verified with Shirley Wind operations. The graphical data also displays the frequency of the wind turbine generated air pressure pulses slowing down after 9:30 p.m. to midnight.

Concurrent research measurements have also been made in an independent study at three locations within an approximately 4-mile distance of the Red Barn Wind Energy Facility in southwestern Wisconsin. These are shown in Figure 2 in which all measurements were taken simultaneously at distances of 1.2, 2.5, and 4.1-miles from the nearest turbine. The frequencies and harmonics for the wind turbine's pressure pulsations are clearly visible in each location's graph.

In Iowa and Grant Counties, south and west of Red Barn Wind, three Infra20 sensors + recorders were placed in homes 1.1, 2.5 and 4.1-miles from the nearest of the 28 IWTs operating in eastern Grant County. Figure 3 below, depicts 24 hours of Infra20 sensor data recorded concurrently at all three homes. The turbines were off until about 5:30 p.m. on Jan 31, 2024. The pressure pulses are clearly evident 4.1-miles from the nearest Red Barn turbine. The residents of home #1 have taken steps to spend time away their home during windy conditions due to the symptoms that they suffer.

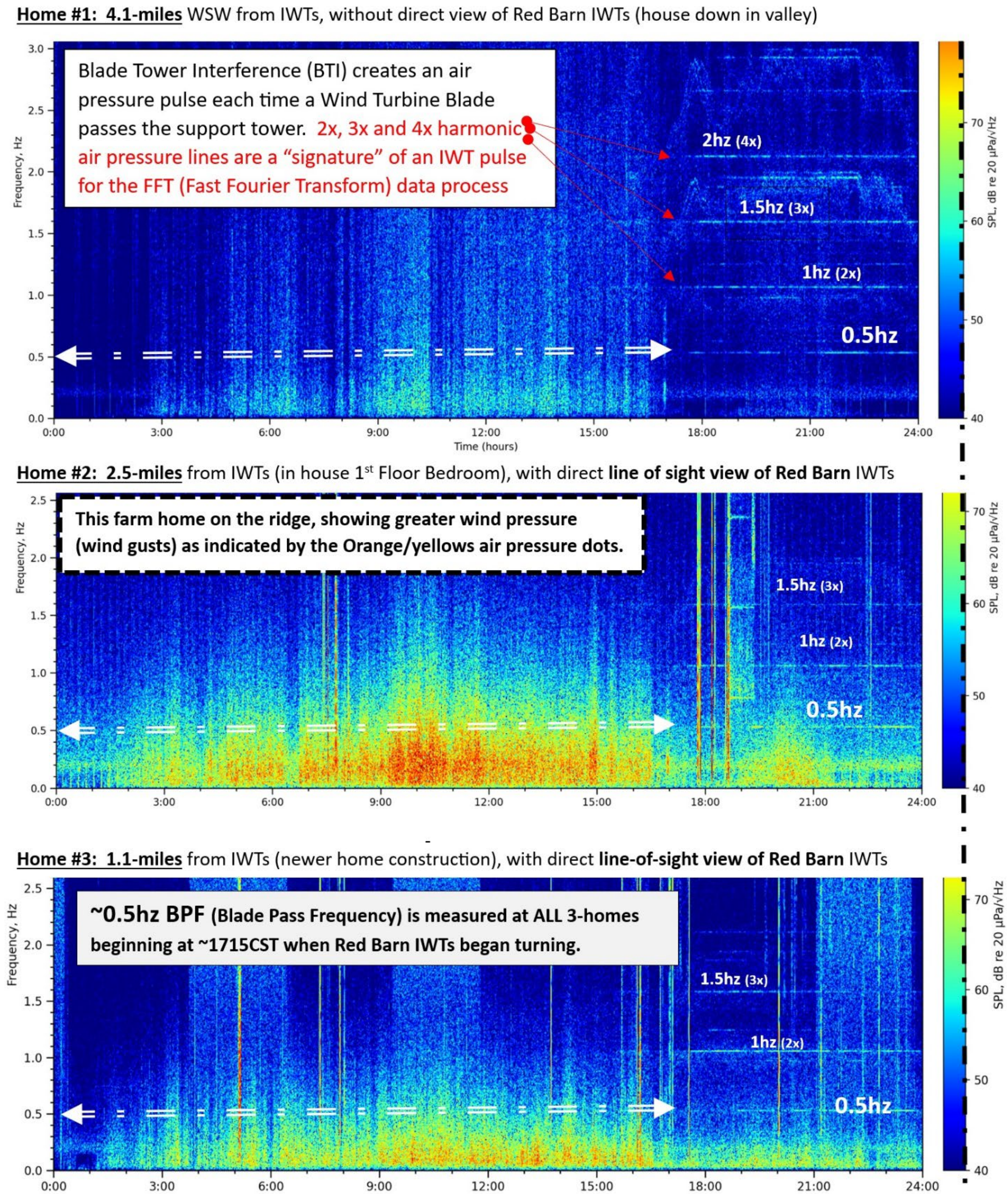


Figure 3 Spectrogram of micro-barometer recording near Red Barn Wind. Horizontal lines show repetitive pressure pulsations occurring at 0.5 Hz (once every 2 seconds), and related harmonics.

4.6 Personal WES Affidavits

Personal experience and self-reported symptomology are essential in medical diagnosis and is almost always the first point of contact with a nurse or doctor by any individual seeking treatment. However, despite this fact, the WSC majority has repeatedly deleted personal experience and affidavits from consideration in setting or updating regulations on WES siting.

Several people with direct experience living in proximity to WES volunteered to share their knowledge and experiences with the WSC. This group included individuals who have been forced to vacate their homes, spend time in their basements or who are unable to move yet suffer many ill effects. These people have direct and personal experience in living near WES. Their experiences are not a simulation in a lab and could have helped the WSC members to fully understand the impact of their decisions. But the WSC did not invite them to present or be interviewed.

Their symptoms include insomnia, chest pain/pressure, headache, nausea, vertigo, brain fog, inability to concentrate, inability to recall well-known information, eye pain, sinus pressure, ear pressure, and the loss of ability to speak.

The WSC did not agree to incorporate this compelling testimony into the WSC report.

Because it was not published, the study of school children who lived or attended school near WES was disallowed despite compelling change in behaviors, attendance, and academic performance in a longitudinal study of the same school populations before and after installation of WES near the school. This small study showed an increase in disruptive behavior, sleepiness, illness and absences as well as lowered scores on academic performance measures. It is imperative that true, objective research be undertaken before future generations of students are subjected to intelligence and education limiting environmental elements that can affect the rest of their lives.

Some Wisconsin students will be impacted by IWT-generated pressure pulses when they are at home, others will be affected only for their school day. In Southwest Wisconsin communities like Livingston, Darlington, Rewey, Montfort, and Belmont, the students may well be affected 24 hours a day, every day, unless their families move away from the environmental hazards. Refer to Section 9.1.

To read personal letters from susceptible people about how wind turbines have destroyed their quality of life, refer to this link "In Your Own Words – In the Shadow of Wind Farms: https://stories.usatodaynetwork.com/windfarms/in-your-own-words/.

A number of the stories come from Wisconsin including harm caused from the Blue Sky Green Field wind complex near Fond du Lac, Glacier Hills Wind, and Shirley Wind, now with new owners again, in Brown County.

5.0 Minority Regulatory Review

The majority review of current regulations governing WES siting was, at best, superficial with regard to human health impact. By restricting the review of existing or proposed regulations to only those at the state level within the U.S., virtually all regulations which have the goal of protecting the health of citizens have been excluded from consideration. According to the National Conference of State Legislatures, in their September 2020 report, forty-one states have WES. In at least twenty-two, maybe more, of these states, local governments have primary responsibility for siting regulations. Four states designate the state with primary responsibility. Most of the rest have some hybrid process in which the local governments regulate up to a certain size and larger ones are handled by the state. There are also cases in which the WES projects need both state and local approval.

States such as Illinois, New York and, of course, Wisconsin have asserted state level jurisdiction over all WES siting decisions. In Wisconsin, by limiting the protections that local government can require. Effectively, this puts all control over the decisions in the hands of those who are unaffected by the WES themselves and who, often, stand to profit from the installations. In states where those whose lives will be affected are allowed input, objections are evident and restrictions are greater.

As recently as March of 2024, popular media have begun to acknowledge the massive groundswell of opposition to the inefficient and expensive WES as concerns about the health of residents become mainstream. According to USA Today, (24 February, 2024) 15 percent of counties across the US have established moratoriums or bans against WES.

On April 9, 2023, *Full Measure* with Sharyl Attkisson, a nationally syndicated, televised broadcast on various traditional commercial networks, featured the turmoil in southwestern Wisconsin as renewable developers take over the driftless terrain. They focused on solar. But in that episode, a former PSC Commissioner was interviewed and stated that Wisconsin needs a pause [moratorium] to analyze where we are and what is the right path which will include renewables. The decisions made today will impact Wisconsin for decades. Typically, *Full Measure* revisits the areas it has visited and provides updates to see whether conditions have improved or gotten worse.

An article in *Forbes* magazine (Bryce, 2021) described local opposition to both solar and wind installations is growing as local communities recognize the health risks and conflict over land use that affect the local economy. At the time of that article, 317 Industrial Wind Facilities had been successfully rejected by local opponents. According to The Renewable Rejection Database, that number is now 420 successful rejections of Industrial Wind Power Generation Facilities within the United States. This growing number represents the recognition by the grassroots communities and affected residents that these WES installations are not safe or effective.

6.0 Setbacks

PSC 128 sets a limit on setbacks that are inadequate in two ways. First, the setbacks are measured from a residence or community building rather than the traditional or conventional measurement from a property line. Somehow, it appears, the wind industry has gotten the non-conventional metric in some early state rules and, then, some other states just copied the metric. Many jurisdictions have maintained the convention of basing setbacks from property lines. Appendix B explains the effect and the rational for measuring setbacks from property lines.

Second, the amounts of setbacks in PSC 128 are too small even if measured from the property line. Currently, with today's taller IWTs over 600 feet in height, the limit on setback is 1,250 feet, about the same as for a 400-foot turbine. Scotland requires setbacks of two kilometers or 1.24 miles. Setback regulations were originally based upon audible sound. Today, acousticians and researchers better understand the unique nature of wind turbine noise which includes production of pressure pulsations at the blade pass rates, a standard characteristic of bladed rotation machinery. These impulses in the nauseogenic range are the cause of adverse health effects in susceptible people. As stated elsewhere acoustic pressures at low frequencies below 100 Hz travel much farther than audible sound, travel easier through walls, and reflect off the ground and thermoclines. This phenomenon requires much greater setbacks.

Many smaller communities and rural counties across the US are implementing much larger setbacks from residences, schools and community property limits. Some communities prohibit WES installation closer than 3 miles from a school.

In Iowa, Madison County worked with Dr. Ben Johnson's research and recommendations, set limits on wind turbines, including distance through 1.5-mile setbacks, and also on size (500 ft) and generating power (2.3 MW) to protect ALL citizens of the county from even larger IWTs. A presentation by Dr. Ben Johnson justifying his recommendations is available on the Kansas Utility committee website here:

Assessing Adverse Health Effects– (Confirmed and Potential) from Industrial Wind Turbine Noise Emissions (kslegislature.org)

In 2014, in Wisconsin, the Brown County Board of Health declared that the presence of Shirley Wind WES in close proximity to occupied structures, such as residences, constituted a human health hazard. (Proceedings of the Board of Health, October 14, 2014.)

7.0 Review of Real Estate and Property Value Impact

Wind turbine companies are happy to assure reluctant landowners and neighbors that there is no evidence of a negative impact on land values. In fact, some companies will go so far as to claim that the installation of WES has a positive impact on value. No mention is made of past complaints of adverse health effects and that some families have to move to find relief.

No change in property values is not proven to be the case even when the negative implications and impact of WES are concealed from the general public. When the public is fully informed about the impact on livestock, wildlife, agriculture and the microclimate in the immediate area, fewer potential buyers see value in the land, leaving those owners who must move at the mercy of international land agents.

In a paper that Andersen and Hener presented at the annual Environmental Economic Conference-2022 in Denmark, the conclusion was “that wind turbines inflict significant damage on the value on local properties up to 2.5 km away”. That is over 1.5 miles from the IWTs.

Livestock have been shown to have health problems associated with WES installations. A dissertation, *Acquired flexural deformation of the distal interphalangeal joint in foals,* by Teresa Margarida Costa Pereira e Curto at the Technical University of Lisbon (2012) showed the structural deformation of joints in foals was related to proximity to WES. An investigation showed only one identifiable commonality among the 11 foals studied. When removed from pastures near the WES, the foals showed improvement. Such an impact would logically limit use and, thus, diminish the value of agricultural property in a state known for dairy producers.

In a similar manner, deer and other mammals are likely affected but have greater mobility and freedom to relocate if they sense discomfort or threat. Though few agricultural facilities in the state raise deer or venison, hunting provides economic gains to many areas and many properties are sold as ‘hunting’ grounds to those who enjoy hunting but reside in urban areas. When deer and other mammals find the area uninhabitable, then hunting properties are diminished in value.

Many residents cite the lack of bats, birds and even insects after the WES are installed. The devastation to the larger birds of prey such as eagles and hawks is recognized and, now, bats are threatened as well. The absence of cricket noises is an unexpected but common observation by residents near WES and this, too, has an impact on the productivity of the land, the scenic value, and the potential enjoyment of the property.

A robust controlled study done in India and published in 2022 (Kumara, et al.) found that the disappearance of birds and mammals in wind farms was evident. Another study done in Finland by the Luke Group in 2023 “compiled 84 studies from 22 countries to identify 160 cases with information about the distance how far wind turbines affect different groups of birds and mammals. Effects identified in the studies included decreases in population sizes and offspring production, changes in birds’ mating behavior and increases in offspring mortality”. For some species, the movement away from the turbines was over 3 miles.

These likely impacts on wildlife and livestock certainly impact the value of real property in the vicinity of IWTs.

Setbacks (the distance that IWTs are away from a reference point) can also have impacts on property values.

Currently, PSC 128.30 requires that the developer of a wind turbine project of less than 100 MW submit an application to the local government(s) who have jurisdiction with specific information about the project. But no information is required regarding property values of the land and improvements in or near the wind turbine project.

The developer should be required to provide appraisals of the surrounding properties before the application is submitted but after consultation with the local governments to get their approval of the choice of appraiser. The appraisal should appraise the land and improvements as to the value before the project was made public and provide an estimate of the values as if the project is constructed and operating.

Studies on property values near wind projects have shown conflicting results. None of them, reviewed by the WSC, studied the impact of the larger size and power of wind turbines being erected in Wisconsin today. One recent study by the U.S. Department of Energy, which promotes renewables, ignored the impact of acoustic pressure pulsations which can affect susceptible people more if they reside farther away from the turbines than those who live closer. This study is entitled "Commercial wind turbines and residential home values: New evidence from the universe of land-based wind projects in the United States", Eric J. Brunner, Ben Hoen, Joe Rand, and David Schwegman.

This study only included sales of properties. It did not examine how many homes were on the market but did not sell. It did not determine whether some owners wanted to sell but could not afford to move. Such a case exists near Shirley Wind in Brown County, Wisconsin. One resident has stayed and slept in her basement for more than ten years because of the adverse health impacts. In another case near the same project, a home was vacated because three members of the family, including a baby, were impacted. Because a potential buyer could not get a mortgage due to the wind turbines' impacts, the owners had to let the home go into foreclosure.

When any type of imposing structures, such as wind turbines, are added to adjoining properties, the value of the adjoining properties, generally, go down. A property owner deserves an evaluation to see what effect wind turbines are going to have on their value. And, they deserve compensation from the developer when a loss occurs.

The legislature needs to require that appraisals for wind energy project proposals be part of Wisconsin's statutes. The legislature also needs to develop a means to compensate property owners who have been financially and physically harmed by existing wind energy projects. The state is liable for not protecting public health after hearing hours and hours of testimony describing the adverse health effects and for not holding a hearing on the second draft of PSC 128.

8.0 Other Considerations

8.1 Monitoring of Compliance by the WES Owner

PSC 128 allows a county, village, or town to create a monitoring committee to receive complaints from residents in regard to the WES in their area. But PSC 128 does not specify the authority the local government has to enforce its findings. PSC 128 does refer to s. 66.0401(5) which provides that any aggrieved person, including the WES owner, can appeal a local government's decision to the PSC. But still no direct accommodation for fines or other enforcement action when warranted.

Some Australian states have a very specific process which includes monitoring by the state governments to ensure compliance to the standards. This way the local governments are not responsible for enforcing the complex, technical standards. Costs of the monitoring process were recommended to be paid by the WES owner in the 2015 report that was reviewed. The Australian government's Independent Scientific Committee on Wind Turbines in their annual report issued in 2022 described their work to advise wind farm operators on providing maximum transparency to the public by publishing information on wind speed, operational statistics, operating hours and sound monitoring which includes low frequency noise (20 to 200Hz) and "infrasound" (acoustic and barometric pressure oscillations at rates below 20 Hz.

Wisconsin needs a state-wide system with authority to collect and disseminate information that allows proactive, constant monitoring of WES operations and resulting negative impacts. This is best done by the state with subject matter experts. Requiring more public information from WES owners would provide a database to support future analysis of factors affecting susceptible people and perhaps lead to resolutions. WES owners should be held accountable for violation of standards and negative impacts.

8.2 Impact to Wisconsin's Major Landforms

As mentioned, the areas attracting the wind developers happen to be in two of Wisconsin's major landforms. Both of these areas consist of carbonate bedrock, such as limestone. A feature of these rock formations is the abundance of karsts which are fissures in the rock. Karst areas are very susceptible to groundwater contamination. A few years ago, over 100 private wells became contaminated in Brown County when manure seeped down the karsts to the groundwater.

The many connector cable trenches associated with IWTs results in a likely increase in contamination because now the runoff has more paths to flow horizontally until the trench crosses a karst. Then the flow has a direct path to groundwater.

In 2021, the Ohio Power Siting Board rejected a permit for a WES because it was planned for a karst area in Ohio.

The state has the responsibility and the authority to protect these landform and geological areas from desecration. The legislature should make it clear to the Department of Natural Resources that wind energy does not trump protection of our natural resources.

8.3 Changing the Process of WES Application Review and Deposition

The most important and absolutely necessary recommendation (presented below) is to overhaul the process of reviewing WES under 100 MW by local governments. The WSC minority generally supports local control and the input of local residents. After over thirteen years of experience of WES applications handled by counties and towns under PSC 128, it has been found public health and welfare of the many susceptible residents have not been protected.

It has been shown that those applications for WES of 100 MW and larger, which fall under the jurisdiction of the PSC, also resulted in lack of protections. The necessary technical and administrative changes discussed herein are intended to apply to all sizes of WES that are one MW or larger. For now, this section is focusing on the local application review process.

County and town boards almost always do not have the scientific, technical, or medical expertise to investigate and make decisions on these complex industrial machine complexes. They often don’t realize that PSC 128 does allow them to get reimbursed by the WES owner for expert consultants, such as acousticians, engineers, and medical professionals. That said, it is very difficult to find consultants who have the necessary knowledge and experience.

Worse yet, even with legal advice, counties and towns often assume that, since they cannot be more restrictive than PSC 128, passage of a wind siting ordinance serves no purpose. They often are not advised that, without an ordinance, there will be no restrictions on a WES in their political subdivision, except for some notification requirements, restrictions for locating in residential and commercial zones, and decommissioning requirements if the WES is one MW or larger. So, past experiences and the real adverse health effects impacting susceptible residents require that all WES of one MW or larger be of the purview of a governmental body that is staffed with the necessary experts to fully evaluate the peculiarities of each WES application with guidance from a completely new standard.

This initiative requires action by the legislature and the governor to be bold to protect its susceptible citizens as many European countries and Australia states do.

9.0 Conclusion and Recommendations

9.1 Conclusion

An unbiased view of the research regarding impacts of WES on nearby residents reveals that there are—as always—negative aspects associated with any decision or plan. The built-in bias of the WSC prevents the Legislature from seeing the complete picture of the impact of legislation promoting WES installation. The only way the legislators could get the full facts is to assign staff to do the research. This Minority Report summarizes some of "the rest of the story". Without the whole story and new changes to the statute, the international wind companies and their stockholders will continue to find it easy in Wisconsin to reap massive benefits of billions of dollars at the expense of the health, home, community, and life investments of Wisconsin residents. Such a situation is inevitable when those who make the decisions reap rewards while others pay any and all costs associated with the decision.

It is clear that, when the affected residents are allowed to have input, their concerns are valid but ignored. The health and livelihood of Wisconsin is clearly at risk. Air pressure pulses emitted by huge WES generating up to 6 MW, have a chronic, lifelong impact on all nearby residents and an acute health impact on a smaller but significant percentage of the population who are highly susceptible to sensory conflict resulting in motion sickness and many other adverse health effects.

The constant exposure to children has not even been studied and, yet, is declared by wind companies to present "no risk" to brain or body development or to learning. Though their company personnel are adamant of the lack of risk, they do not live in the area and their children will not attend a school such as Iowa-Grant which currently has 6 IWTs within a 3-mile radius and proposed to have 17 more. Belmont school is positioned to have 25 within 3-miles of their school. Platteville and Dodgeville schools have 4 or less, but still will be impacted. The concentration of turbines near schools is evident in the map show in Figure 4 below where dashed white circles indicate a 3-mile radius around each school.

With such a concentration of turbines near schools, it is clear that the future of the state is at risk along with the health of the residents unless greater protections are allowed for those who are affected. In addition, take a look at the close proximity to many of our villages like Livingston and Belmont.

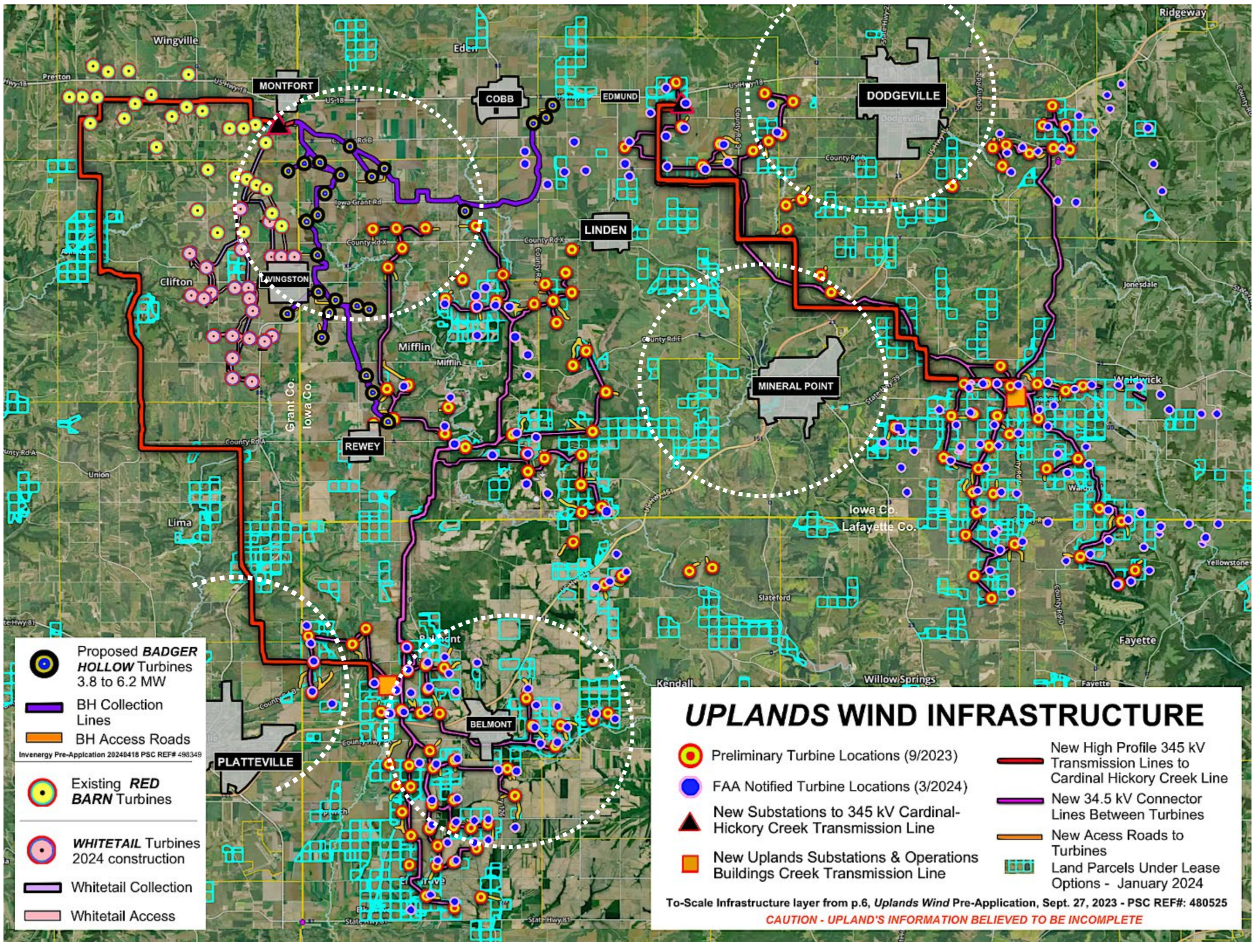


Figure 4: Four IWT Projects (Red Barn-2024, Whitetail Wind, Uplands Wind, Badger Hollow) in Southwest Wisconsin. White dashed circles highlight schools in the area.

9.2 Recommendations for Legislative Solutions to Reduce Harm Done from Wind Energy Systems in Wisconsin.

Following are the most urgent actions for the legislature to consider for the fast-track. Damage to certain susceptible residents and to property values has been done and continue to get worse as Wisconsin has been discovered to be an "easy" state for WES developers to mine the corporate welfare of federal tax subsidies. Time is needed to fix the assault on public safety and welfare. Thus, the first Recommendation is the most important –

1. **URGENT: Impose a moratorium on WES projects in Wisconsin until on-site, unbiased research can be completed to form the basis for any new legislation to regulate WES. The inadequate wind turbine siting regulations and increasing harm being done to more residents requires this action.**

2. The legislature should consider creating a legislature council study committee on wind turbine siting. Acoustic experts, medical professionals, scientists, and Professional Engineers should be represented on the committee. Note that medical professionals and Professional Engineers have a statutory responsibility to protect public safety and welfare under the penalty of law. The aforementioned moratorium would provide the time for the committee's work.

3. Require that all WES of one MW or larger applications are the jurisdiction of a state government entity staffed with experts, similar to the proposal for the legislative council study committee. Replace PSC 128 with an administrative code under the Department of Safety and Professional Services handled similarly as other industrial projects, a new division in PSC, or a stand-alone agency.

4. Pass legislation to develop a means to compensate property owners who have been financially and physically harmed by **existing** wind energy projects. The state is responsible for the ongoing damage to public health. The Legislature heard hours and hours of testimony describing the adverse health effects from the WES in operation at the time. Still, they did not hold a hearing on the second draft of PSC 128 and left the inadequate rules go into effect automatically after the suspension period.

There are numerous other necessary actions needed by the Legislature. They are all important to fix Wisconsin's "open borders" to large WES developers. The additional actions are listed in Appendix C of this minority report. The complexity of some of the recommendations suggest the need for a Legislative Study Committee.

REFERENCES

Acker, W. (2019) *Some of the Case Studies that Have Convinced Me that Industrial Wind Turbines Make People Sick.* Acker & Associates.

Andersen & Hener, (2022) *The Danish Environmental Economic Conference-2022, Denmark.*

Alves-Pereira, M. & Castelo Branco, N.A.A. (2007). *Vibroacoustic disease: biological effects of infrasound and low frequency noise explained by mechano-transduction cellular signaling.* Progress Biophysics & Molecular Biology, 93, 256-279.

Bellut-Staeck, U. (2023) *Impairment of the Endothelium and disorder of Microcirculation in Humans and Animals Exposed to Infrasound due to Irregular Mechano-Transduction.* Journal of Biosciences and Medicines. Vol. 11. pp. 30-56.

Brunner, et al. (2023) *Commercial wind turbines and residential home values: New evidence of land-based wind projects in the United States.* Elsevier. https://emp.lbl.gov/publications/commercial-wind-turbines-and

(Bryce, R. (2021*) Here's the List of 317 Wind Rejections the Sierra Club Doesn't Want You to See*. Forbes. September 26. https://www.forbes.com/sites/robertbryce/2021/09/26/heres-the-list-of-317-wind-energy-rejections-the-sierra-club-doesnt-want-you-to-see/?sh=4d13782e5bad

Bryce, R. (March 1, 2024) https://robertbryce.com/renewable-rejection-database/

Chiu, C. et al. (2021) Effects of low-frequency noise from wind turbines on heart rate variability in healthy individuals. Scientific Reports. Pub. 8Sep2021 available at: https://www.nature.com/articles/s41598-021-97107-8

Chronic Stress. Yale Medicine. (March 2, 2023) https://www.yalemedicine.org/conditions/stress-disorder.

*Chronic stress puts your health at risk. (*March, 2024) https://www.mayoclinic.org/healthy-lifestyle/stress-management/in-depth/stress/art-20046037

Costa Pereira e Curto. T. M. *Acquired flexural deformation of the distal interphalangeal joint in foals*. Dissertation, Technical University of Lisbon, 2012.

Dawson, H. (1982) *Practical aspects of the low frequency noise problem*, Journal of Low Frequency Sound Vibration. 6(4). pp. 28-44.

Dumbrille, A. et al. (2021) *Wind turbines and adverse health effects: Applying Bradford Hill's criteria for causation. Environmental Disease.* 6(3) p 65-86. Available from: https://journals.lww.com/endi/fulltext/2021/06030/wind_turbines_and_adverse_health_effects__applying.1.aspx

Fedak, K. et al. (2015) Applying the Bradford Hill criteria in the 21st century: how data integration has changed causal inference in molecular epidemiology. Emerging Themes in Epidemiology. Vol. 12. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4589117/

Kumer, etal. (2022) Response of birds and mammals to long-established wind farms. Springer Nature. https://www.nature.com/articles/s41598-022-05159-1

Hill, AB. *The environment and disease: Association or causation?* J R Soc Med. 1965;589. pp. 295–300

Institute of Medicine (US) Committee on Sleep Medicine and Research; Colten HR, Altevogt BM, editors. *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem.* Washington (DC): National Academies Press (US); 2006. 3, *Extent and Health Consequences of Chronic Sleep Loss and Sleep Disorders.* Available from: https://www.ncbi.nlm.nih.gov/books/NBK19961/

James, R. (2022) Presentation to Kansas Senate Committee on Utilities Available at: https://kslegislature.org/li_2022/b2021_22/committees/ctte_s_utils_1/documents/testimony/20220208_03.pdf

James, R. and Punch. J. (2022) Report to Kansas Senate Committee on Utilities. Available at: https://kslegislature.org/li_2022/b2021_22/committees/ctte_s_utils_1/documents/?date_choice=2022-02-08

Jauchem, J. and Cook, M., *High-Intensity Acoustics for Military Nonlethal Applications: A Lack of Useful Systems.* Military Medicine. 172(2) pp 182-189.

Johnson, W. B., A Madison County, Iowa, *Cardiologist's Investigation and Response to Industrial Wind Turbines in the Rural Residential Countryside Regarding Concerns of Adverse Health Effects and, Exploration of the Relevant Accompanying Larger Issues*. (2020) Prepared for Madison County, Iowa Health Department.

Krogh, M., et al (2018) Health Canada's Wind Turbine Noise and Health Study—A Review Exploring Research Challenges, Methods, Limitations and Uncertainties of Some of the Findings. *Open Access Library Journal* 5: e5046

Lopucki, R. et al. (2018) *Living in habitats affected by wind turbines may result in an increase in corticosterone level in grown dwelling animals*. Ecological Indicators. Vol. 84. Jan. 2018.

Luke Group. (2023) *Review: Several groups of birds and mammals avoid wind turbines.* Finland. https://www.luke.fi/en/news/review-several-groups-of-birds-and-mammals-avoid-wind-turbines

Mayo Clinic Staff. Chronic Stress Puts Your Health at Risk.

https://www.mayoclinic.org/healthy-lifestyle/stress-management/in-depth/stress/art-20046037 Retrieved: March 2024

Punch, J. and James, R., *Wind Turbine Noise and Human Health: A Four-Decade History of Evidence that Wind Turbines Pose Risks,* Michigan State University, 2017.Pierpont. N. (2006) *Wind Turbine Syndrome: A Report on a Natural Experiment. 2009.*K-Selected Books. Santa Fe.

Rasheed, N. *Prolonged Stress Leads to Serious Health Problems: Preventative Approaches* International Journal of Health Science 2016, Jan. 10(1) V-VI.

Roscoe, C., et al. *Association between Noise and Cardiovascular Disease in a Nationwide U.S. Prospective Cohort Study of Women Followed from 1988 to 2018*. 131(12) Environmental Health Perspectives. Dec. 2023. Available from: https://doi.org/10.1289/EHP12906

Salt, A. and Lichtenhan, J., *How Does Wind Turbine Noise Affect People,* Acoustics Today, Winter 2014.

Schomer, P., et al., *A Theory to Explain Some Physiological Effects of the Infrasonic Emissions at Some Wind Farms*, Acoustical Society of America, February 2015.

Suter, A., *Noise and Its Effects,* Administrative Conference of the United States, November 1991.

Stubbs, Christopher, et al., *Tactical Infrasound*, Mitre Corporation, May 2005.

Weise, E. et al*. Counties are blocking wind and solar across the US — maps show energy capacity in your area.* USA Today. 24 February. Retrieved from: 2024.https://www.usatoday.com/story/graphics/2024/02/27/renewable-energy-sources-ban-map/72630315007/

Weichenberger, M., et al. *Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold – Evidence from fMRI,* PLOS ONE, April 2017.

World Health Organization Constitution. https://www.who.int/about/accountability/governance/constitution Retrieved: March, 2024

Yale Medicine Website. *Chronic Stress.* https://www.yalemedicine.org/conditions/stress-disorder; retrieved: March 2024

Zou, E. (2017) *Wind Turbine Syndrome: The Impact of Wind Farms on Suicide.* University of Illinois at Urbana-Champaign. Department of Economics.

APPENDIX A

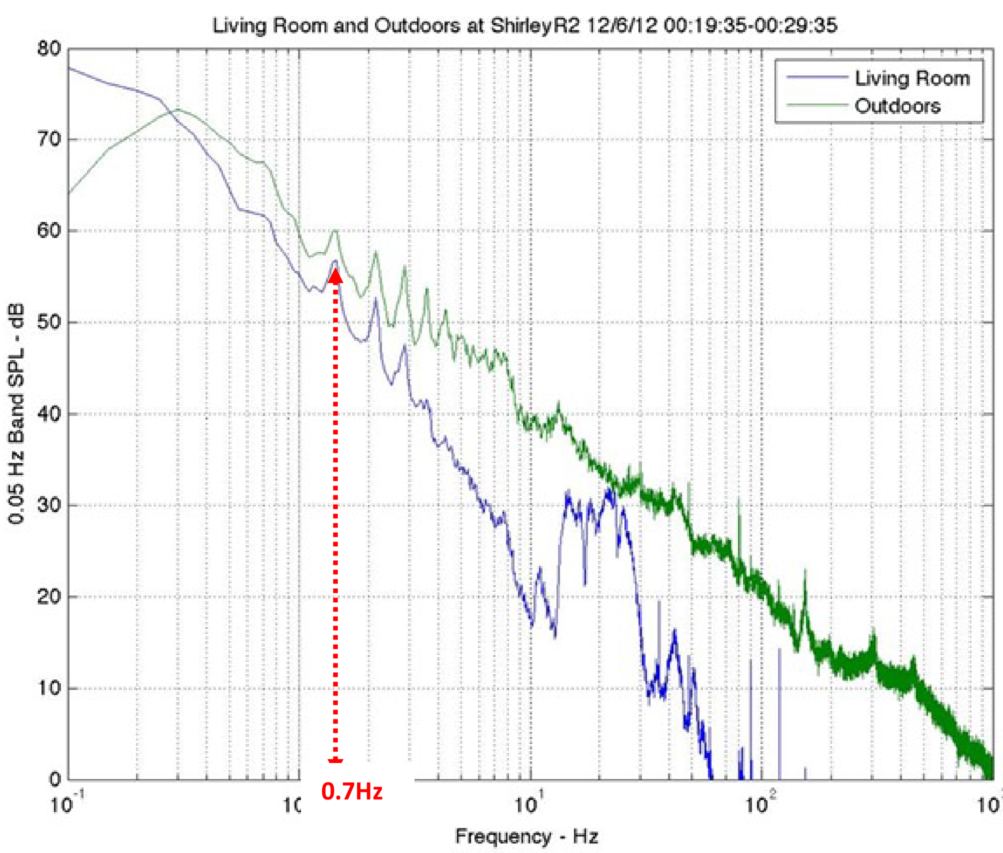
Shirley Wind Study available on WI PSC ERF here:
https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=178263

Shirley Wind Study Excerpt:

4.0_Conclusions

This cooperative effort has made a good start in quantifying low frequency and infrasound from wind turbines.

Unequivocal measurements at the closest residence R2 are detailed herein showing that wind turbine noise is present outside and inside the residence. Any mechanical device has a unique frequency spectrum, and a wind turbine is simply a very very large fan and the blade passing frequency is easily calculated by RPM/60 x the number of blades, and for this case; 14 RPM/60 x 3 = 0.7 Hz. The next six harmonics are 1.4, 2.1, 2.8, 3.5, 4.2 & 4.9 Hz and are clearly evident on the attached graph below. Note also there is higher infrasound and LFN inside the residence in the range of 15 to 30 Hz that is attributable to the natural flexibility of typical home construction walls. This higher frequency reduces in the basement where the propagation path is through the walls plus floor construction but the tones do not reduce appreciably.



Appendix B

Handout for April 17, 2024 Wind Siting Council agenda item 4a

Prepared by Scott Godfrey

Purpose of turbine setbacks

When asked, PSC staff was not able to find documentation that explains the basis of the current setbacks, whether it be for public health protection or based on existing state policies at that time.

Absent any documentation, it is reasonable to deduce the existing setbacks were established to comply with Ch. 196.378 (4g) 4 (b), which says in regards to the siting rules: "The subject matter of these rules shall include setback requirements that provide reasonable protection from any health effects, including health effects from noise and shadow flicker, associated with wind energy systems."

It is therefore reasonable to presume a turbine that is closer to an occupied community building or residence than the current setbacks create a higher likelihood of negative health effects. This would hold true regardless of which existed first, the turbine or the buildings.

Current turbine setbacks in PSC 128.13(1) Table 1

Setback Description	Setback Distance
Occupied Community Buildings	The lesser of 1,250 feet or 3.1 times the maximum blade tip height
Participating Residences	1.1 times the maximum blade tip height
Nonparticipating Residences	The lesser of 1,250 feet or 3.1 times the maximum blade tip height
Participating Property Lines	None
Nonparticipating Property Lines	1.1 times the maximum blade tip height
Public Road Right–of–Way	1.1 times the maximum blade tip height
Overhead Communication and Electric Transmission or Distribution Lines — Not including utility service lines to individual houses or out- buildings	1.1 times the maximum blade tip height
Overhead Utility Service Lines — Lines to individual houses or outbuildings	None

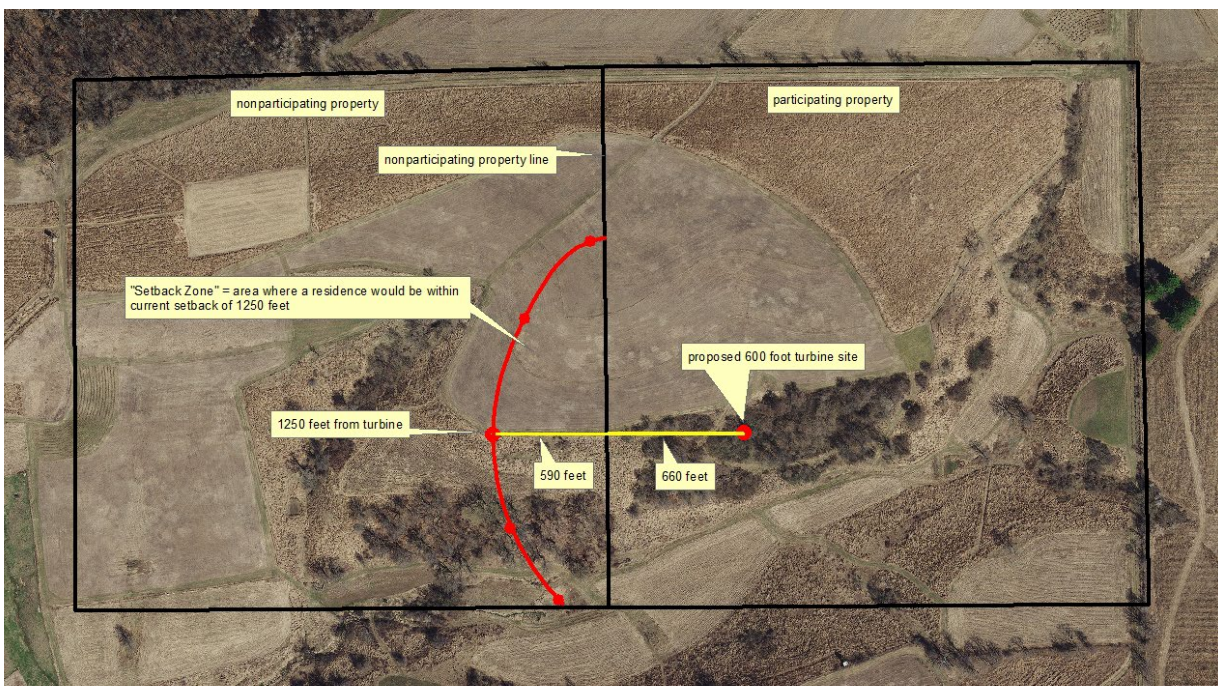
Consideration:

Operating under the presumptions above, it is logical that there should be setbacks established that promote a consistent minimum setback of a turbine to an occupied community building or residence regardless of which is constructed first. The statute is silent as to when setbacks are to be applied, meaning whether to existing development or future development. Therefore, it is within the Council's purview to make that determination.

As the Council representative of the Wisconsin Counties Association, I approach this issue from the perspective of administrating the code. A paramount principle of code enforcement is consistency. The current turbine setbacks are inconsistent in that they do not anticipate impacts to future development that may occur after a turbine has been built.

For example, with the typical height of today's turbines, the de facto current setback is 1250 feet to a nonparticipating residence due to the "lesser" terminology. The setback to a nonparticipating property line is 1.1 times the maximum height. If a proposed turbine is to be 600 feet tall, the setback to the nonparticipating residence would be 1250 feet and to a nonparticipating property line 660 feet.

Currently, this 600-foot turbine can be built up to 660 feet to a nonparticipating property line if there is no nonparticipating residence within 1250 feet. This in effect creates an area 590 feet into the nonparticipating property owner's land (1250 – 660 = 590) illustrated below:



The area bounded in red to the shared property line is labelled as "Setback Zone" following the presumptions that building a house or community building in this area after the turbine exists would be a greater risk to health than building 1250 feet away (the distance the turbine must be if the house or community building existed first).

Conclusions

Establishing a setback to a property line creates consistency in achieving the charge of the state to "provide reasonable protection from any health effects" by establishing a setback not based on which exists first … a turbine or a house/community building.

It also addresses the current lack of consideration of any other occupied structure other than a house or community building. For example, a nonparticipating property may have a free-stall barn, manufacturing building, retail establishment, etc. well within the setback distance that now only applies to a residence or community building (school, church, daycare, library). These other types of buildings may be occupied to the same or greater degree.

Bear in mind, PSC 128.13 (1)(d) does provide that the owner of a nonparticipating residence or occupied community building may waive the applicable wind turbine setback distance computed by the blade tip height.

APPENDIX C

The numbering of these additional recommended actions for the Legislature will continue from the four recommendations list in the body of this report. The order of this list is to group recommendations in similar categories which may not reflect their priority. These steps including the four discussed above lay out an agenda of issues for a Legislative Study Committee to address.

5. Pass legislation to prohibit construction of Industrial Wind Turbines in karst areas such as the Driftless Area and the Niagara Escarpment. Both areas have significant importance, state support, promoted tourism attractions including cave tours, and significant bat populations.

6. Instruct the Department of Health Services to inform medical professionals in the state that there is a new International Classification of Diseases (ICD) code to identify “vertigo from infrasound”. The medical professionals shall be instructed to ask patients who complain of vertigo whether they live or work in the vicinity of a WES and how far away are the Industrial Wind Turbines. The medical professional shall log and report such incidences to the DHS who shall report the results to the PSC in a form that can be made public.

7. Provide funding for epidemiological studies in existing WES in Wisconsin. Two WES could be considered: 1) Shirley Wind because the adverse health effects are still an issue since 2011 and the preliminary Shirley Wind Study has been done and 2) Red Barn Wind because it is the newest and more impactful by causing very significant adverse health effects from the time of its startup.

8. Pass legislation to require WES developers to do to a property and improvements appraisal of properties within x miles of a proposed wind turbine. The appraisal shall reflect what the value of the property and improvements were before the project was announced. It might be possible to substitute the local governments’ property tax equalized evaluations. If a separate appraisal is needed, the appraisal shall be done in consultation of the local governments to approve the appraiser. One year after the WES is operating, new appraisals shall be done. Property owners shall be compensated by the WES or WES owner for any loss in property and improvements value and for other financial loss such as costs for moving. Property owners could petition for a reduction in property taxes for any reduction in property values.

9. For WES projects of one MW or larger, the political subdivisions within x miles of the project’s nearest wind turbine may request time to hold a referendum or a meeting of electors to approve or disapprove the WES development. This includes projects under the new state entity’s or PSC’s jurisdiction. Such local approval has been addressed in other states.

10. Make it clear to the new state entity or the PSC that their review process and development of a new administrative code shall reflect the Legislature's intent to put public safety and welfare as the highest priority.

11. Require developers of any size WES of three or more wind turbines to contact the local government and the new state entity or the PSC ninety days before contacting landowners and hold a public information meeting sixty days before contacting landowners. Landowners shall have ninety days to make a final decision on any agreement submitted to them. If competing projects develop, the landowners will be able to get the best value for the use of their land.

12. Add more impartial experts to the WSC. Medical professionals, acoustic experts, and scientists who are experienced in WES' impacts and Professional Engineers with expertise in the mechanics, physics and acoustic nature of WES should be considered.

13. Pass legislation to require setbacks for wind turbines to be measured from property lines.

14. Pass legislation to require the PSC to revise their Measurement Protocol for Sound and Vibration Assessment of Proposed and Existing Wind Electric Generation Plants to include acoustic testing for infrasound, including pressure pulsations below one Hz. Note: This provision should include all electric generation plants.

15. Pass legislation to require consultants and WES developers and WES owners to do acoustic testing for air pressure pulses, including below one Hz. Currently, testing is done only for audible sound above 16 Hz.

16. Pass legislation to require consultants and WES developers and WES owners to model shadow flicker to the current PSC 128 restrictions for the "worse-case" as done in Europe until modified appropriately in a new administrative code.

17. Pass legislation to require WES owners to use shadow sensors or remote computer-controls to shut down turbines when they project shadows on occupied buildings and non-participating properties.

18. Pass legislation to require aircraft detection lighting systems on wind turbines wherever approved by the Federal Aviation Administration.

19. Pass legislation to create a group to proactively monitor WES for compliance with national and state codes, local ordinances and PSC's orders. The legislation must include definitive provisions for holding WES owners accountable through cease-and-desist orders, fine-levying, and compensation to affected residents.

20. A five-year report to the legislature would still be required from the WSC. Provide a means to ensure that the WSC meets the statutory five-year requirement. Besides reviewing peer-reviewed reports on health impacts and regulatory requirements of various nations, the WSC would be required to do the following:

a. Review reports of mandatory acoustic testing including measurements of the air pressure pulses created at the same frequency as wind turbine blade passes by the tower (Blade Tower Interference) BTI.

b. Report on the trend in the design, size and acoustic nature of wind turbines used or projected to be used in Wisconsin.

c. Conduct interviews of residents who have been negatively affected by WES.

d. Review any affidavits of residents regarding adverse health effects. Survey medical professionals as to complaint of adverse health effects that appear caused by WES.

e. Survey schools located within three miles of a WES and those beyond five or more miles in the area.

f. Determine the number of homes vacated or conditionally sold in the area of WES.

g. Review complaint records of local governments near WES.

h. Review local government regulations for WES in the U.S.

The first of such report of items a. and b. should be due one year after the statute becomes effective and thereafter be included in the five-year report to the legislature. Funding will need to be available to engage appropriate consultants to gather information and advise the WSC for this first report.

APPENDIX D

The letter below is an example of concerns school officials have for WES impact upon school children.

District 225
ARMSTRONG TOWNSHIP HIGH SCHOOL

30474 Smith St.
P.O. Box 37
Armstrong, IL 61812
School: (217) 569-2122
Fax: (217) 569-2171

William Mulvaney, Superintendent
Darren Loschen, Principal

Dear Chairman Weinard,

My name is Bill Mulvaney and I am the Superintendent of Schools for Armstrong Township High School and Armstrong-Ellis CUD #61. I also served on the wind panel that met to try and give direction to the county board on wind turbine ordinances. Our panel did not come up with any recommended changes, but I would like to share a few thoughts with you.

I have noticed that we have some children in our district that appear to be having some medical issues related to the wind turbines. Headaches, lack of sleep and jaw issues seem to be the most common. The students also complain about not being able to sleep or not getting a full night's sleep due to sound issues.

We have also been advised that we will be losing a couple of families because the wind turbines were placed close to homes and the families can no longer handle the flicker and noise issues.

While these issues were brought up at our panel discussions, I was not fully aware of the impact that the wind turbines would have to my school districts. It is never a good thing when children have health issues or families have to leave their homes to get away from the turbines. The revenue generated by the turbines is a blessing to our schools, but the unintended consequences are real.

I hope this letter sheds some light on real issues that affect districts that house wind farms. I also hope that when ordinances are discussed in the future, that these issues are considered.

Sincerely,

William C. Mulvaney
Superintendent
Armstrong Schools

Appendix F

Summary of National Wind Siting Policies of all Fifty States and the District of Columbia

This table was compiled by surveying relevant wind-energy policy sources and should not be considered an authoritative or exhaustive review of all national wind policies. Below is a summary of states' policies relevant to rules that are mandated under Wis. Admin. Code ch. PSC 128. Some states may provide lesser jurisdictions with a model wind siting ordinance. The siting criteria in the model ordinances are recommendations and are not legally binding, unless otherwise noted. PSC 128 also outlines rules on signal interference and stray voltage which are not addressed in this table. States with policy updates from the 2014 WSC Report are indicated with a Δ. Sources for this table, overall and by each state, are provided at the end of this appendix.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Alabama	Local, Legislature granted explicit authority to Baldwin, Cherokee, Dekalb, and Etowah Counties to regulate wind siting. No statutory authority for state wind siting.	No state specifications identified.
Alaska	State A Certificate of Convenience and Necessity by the Regulatory Commission of Alaska to operate. Local ordinances may also apply to siting.	No state specifications identified.
Arizona	Hybrid Mandatory certificate of environmental compatibility from Arizona Power Plant and Transmission Line	No state specifications identified.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
	Siting Commission, at 100 MW or more. Some zoning restrictions/requirements at the county/local level.	
Arkansas	Local, local authority over specific siting rules. No statewide siting rules, CPCN required for large energy generation from Arkansas PSC.	No state specifications identified.
California	Hybrid, Local authority for siting standards. State authority to issue a certificate for projects 50 MW or greater.	Noise maximum restrictiveness: Governor's Office of Planning and Research provides guidance to local jurisdictions on plans for noise regulation, not specific to wind turbines, that identifies Community Noise Exposure levels of 50 – 60 dB as "Normally Acceptable".
Colorado	Both, Local and State Local authorities have 120 days to issue a final decision on siting applications. If local governments deny the permit, the applicant can appeal the decision to the state Public Utilities Commission. State issued noise law.	• Increased environmental permitting needed for turbine structures over 50 feet in height. • Noise restrictions of 55 dBA day, 50 dBA night at distance of 25 feet or more from property line by state code.
Connecticut	State, state sets siting rules. Mandatory; Connecticut Siting Council issues permits utility scale > 65 MW.	• Noise: Restrictions at 55 dBA day, 45 dBA night at residential property line, 2.5 times turbine height for > 65 MW and 1.5 times for <65 MW or manufacturers recommendation, whichever is greater. • Property Setbacks: 2.5 times turbine height for >65 MW projects; 1.5 times turbine height for <65 MW projects or manufacturers recommendation, whichever is greater.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
		• Not more than 30 hours per year of shadow flicker as measured at off-site occupied structure. • Must submit a decommissioning plan and proof of financial security.
Delaware	Hybrid, Local authority with state mandated maximum siting restrictiveness. State adopted law that bars county and municipal governments that are more restrictive than a set of constraints.	• State mandates local regulations cannot be more restrictive than noise levels at ≤ 5 dBA over ambient, up to 60 dBA at the property line by state statute. • State mandates local regulations cannot be more restrictive than property setback 1.0 times turbine height.
Florida	Hybrid, State and Local. State Siting Coordination Office has primary authority over projects 75 MW or greater. All other siting decisions can be made by local governments.	No state specifications identified.
Georgia **Δ**	Local	No state specifications identified.
Hawaii	Hybrid, Local primary with state mandatory state noise level.	• Wind projects must comply with Hawaii Dept. of Health Ch. 46 Community Noise Control Rules. Maximum permissible sound levels in dBA vary with zoning districts and 'are enforceable at the facility property boundaries'. For Class A Zoning (includes residential) the limits are 55 dBA(day) and 45 dBA(night. For Class C zoning (includes agriculture) the limits are 70 dBA (day and night). • No other state specifications identified.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Idaho	Local	No state specifications identified.
Illinois **Δ**	State State required siting guidelines and restriction implemented through 2023 HB 4412.	• 2.1 times the maximum blade tip height to the nearest point of occupied community buildings, non-participating residences, Fish and Wildlife Areas, and Illinois Nature Preserve Commission Protected Lands. • 1.1 times the maximum blade tip height of the wind tower to the nearest point of participating residences, nonparticipating property, public road rights-of-way, and overhead communication, electric, and distribution facilities. • No occupied community residence or nonparticipating residence can experience more than 30 hours of shadow flicker per year. • A county may not set sound limitations that are more restrictive than Illinois Pollution Control Board limitations. These vary by zoning type and appear to be measured at property line. • A county cannot adopt regulations that disallow wind energy development in any district that allows agricultural or industrial uses. • A county **may not** set a blade tip height limitation that is more restrictive than the height allowed under a determination of no hazard to air navigation by the Federal Aviation Administration (FAA) under 14 CFR Part 77. • A county **shall not** require standards for construction, decommissioning or deconstruction of a commercial wind energy facility or commercial solar energy facility or related financial assurances that are more restrictive than those of the Illinois Department of Agriculture (IDOA).

<table>
<tr><th>State</th><th>Relevant Policy; Primary Authority; Mandatory or Voluntary</th><th>Topics of Regulation - May include:
• Turbine Size,
• Noise,
• Shadow Flicker,
• Property Setback,
• Residence Setback,
• Other Setbacks,
• Decommissioning</th></tr>
<tr><td>Indiana
Δ</td><td>~~None,~~ Local, with default standards concerning the following with respect to wind power projects in units that are certified as wind energy ready communities, or that otherwise adopt the standards.</td><td>• 1.1 times the maximum blade tip height (measured from the ground) from a tower's vertical centerline to the centerline of public rights-of way, runways, or railroad easements or rights-of-way.
• 1.1 times that height to the nearest edge of another utility transmission/distribution line.
• 3 times that height to "the nearest point on the outer wall" of a dwelling on property not part of the tower's facility; and
• 1 mile to the property line of a state park.
• No more than 30 hours of shadow flicker at any nonparticipating dwelling.
• Minimize and mitigate any signal interference.
• Decommissioning plan and bond required.
• 50 dBA-limit at the outside wall of a residence.</td></tr>
<tr><td>Iowa
Δ</td><td>Hybrid, State and local authorization from Iowa Utilities Board required for projects 25 MW or greater. Under 25 MW projects require any applicable local/county land use approvals.</td><td>No state specifications identified.</td></tr>
<tr><td>Kansas</td><td>Local.</td><td>No state specifications identified.</td></tr>
<tr><td>Kentucky
Δ</td><td>Local Authority for facilities <10 MW.

All wind generating facilities 10 MW or more must be granted a construction certificate from Board on</td><td>• Property Setback: At least 1,000 feet from the property boundary of any adjoining property owner.
• Other Setbacks: 2,000 feet from any residential neighborhood, school, hospital, or nursing home facility.</td></tr>
</table>

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
	Electric Generation and Siting. The property setbacks are stated in Ky. Rev. Stat. § 278.704	
Louisiana	Local, No installed capacity.	No state specifications identified.
Maine	Hybrid, State authority for decisions on grid-scale wind developments. Local Authority with State Recommendations for small-scale developments.	• Size recommendations: All capacities, however most recommendations regard ≥ 100 kW • Noise Recommendations: 55 dBA day/45 dBA night limit within 500 feet of a sleeping quarters, 55 dBA for protected areas, 75 dBA at property lines, 5 dBA penalty for repeating sounds. • Other Setback Recommendations: 1.5 times turbine height for public/utility rights-of-way, the department may require recommendations of a civil engineer or recommendations from manufacturers. • Shadow Flicker: Facility must be designed to avoid unreasonable adverse shadow flicker effects at any occupied building located on property not owned by the applicant, subject to a lease for a duration at least as long as the anticipated project life, or subject to an easement for shadow flicker in excess of 30 hours per year. • Decommissioning Plan Recommendations: Submit a decommissioning plan.
Maryland	Hybrid, the Public Service Commission of Maryland regulates projects over 70 MW, may require applicants obtain a CPCN from the agency. Projects may receive an exception if they are land based, do not exceed 70 MW, power is sold only on the wholesale market, or the commission provides an opportunity for public comment.	No state specifications identified.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Massachusetts	Local Authority with State Voluntary Recommendations. Massachusetts Energy Facilities Siting Board reviews only the environmental impacts of wind generating facilities over 100 MW. Massachusetts Executive Office of Environmental Affairs sets voluntary standards developed through Model-By-Law as of March 2012 to assist cities with wind siting recommendations.	• Noise Recommendation: Not more than 10 dBA over ambient, conform with Department of Environmental Protection's Division of Air Quality Noise Regulations. These criteria are measured both at the property line and at the nearest inhabited structure. • Property Setback Recommendation: 1.5 times turbine height. • Residence Setback Recommendation: 3 times turbine height. • Other Setback Recommendations: 1.5 times height for public/utility rights-of-way. • Shadow Flicker Recommendations: Site in a way that "minimizes shadowing or flicker impact". The applicant has the burden of proving that this effect does not have significant adverse impact on neighboring or adjacent uses.
Michigan **Δ**	State, new rules on siting authority passed November of 2023. State rules give state final approval of wind projects. Utilities can either seek approval through the local community or the Michigan Public Service Commission. Developers are required to notify local governments of their proposal and have public meetings.	MI PUC currently working on guidance relating to compatible renewable energy ordinances, to be in place prior to new law going into effect Nov. 29, 2024.
Minnesota	Hybrid, State with local regulation of smaller projects possible.	• Noise: If background sound levels are equal to or greater than the applicable state standard at the nearby receptors, the windfarm should not contribute more than 45 dBA to total sound levels at the nearby receptors.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
	Projects over 25 MW regulated by Minnesota Public Utilities Commission. Counties can regulate projects between 5 - 25 MW if approved by the PUC or can be considered a Large Wind Energy Conversion System (LWECS) under PUC authority.	• Property Setbacks: Wind access buffer requires 3 rotor diameters on secondary wind axis, 5 diameters on primary wind access, from neighboring property, including public lands for all LWECS or turbines higher than 200 feet. • Residence Setbacks: 500 feet from dwelling and sufficiently far to meet noise standards for all LWECS or turbines higher than 200 feet. • Other Setbacks: 250 feet from road rights-of-way for all LWECS or turbines higher than 200 feet. • Decommissioning: Submit a decommissioning plan for all LWECS or turbines higher than 200 feet.
Mississippi	Local, No installed capacity.	No state specifications identified.
Missouri	None, Local	No state specifications identified.
Montana **Δ**	Both, Local with state required decommissioning criteria.	State law requires facilities obtain surety bond for decommissioning.
Nebraska	Both, Local with State Mandatory Decommissioning Plan. Mandatory decommissioning standard, all other siting guidelines are subject to local or county jurisdiction. Energy generation projects must be approved by Power Review Board. Private developers are not	Decommissioning: The applicant or of the facility must submit a decommissioning plan and security money within 10 years of board approval.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
	required to receive approval a special generation projects (less than 10 MW) must be approved if the project meets certain requirements.	
Nevada	Both, Local with State Restrictions. Local jurisdiction over siting requirements; State restricts local governments from implementing ordinances that unreasonably restrict wind energy. State statutes direct local authority to make zoning decisions that promote wind energy systems. Regulations can be implemented to address noise, safety, setbacks, welfare, FAA regulations, and health concerns.	State prohibits unreasonably restricting wind development. Governing bodies may deny application if the system is a danger to health and safety or is not compatible with the character of the area.
New Hampshire Δ	Both, Local with State restrictions. State mandatory restrictions that cannot be exceeded by municipalities for projects 100 kW and greater. Ordinances by municipalities cannot unreasonably limit installations or performance of installations. State has rules for projects seeking approval through Site Evaluation Committee (SEC) (over 30 MW).	SEC - Noise: L-90 A-weighted sound levels shall not exceed the greater of 45 dBA or 5 dBA above background levels, between 8:00am-8:00pm, and the greater of 40 dBA or 5 dBA above background levels at all other times of day as measured using microphone placement at least 7.5 m from any surface where reflections may influence measured SPL at nearest residential building to wind turbine. SEC - Shadow Flicker: no more than 8 hours per year at or within residence, learning space, workplace, health care setting, outdoor or indoor public gathering area or other occupied building. Muni - Noise: criteria cannot be more restrictive than 55 dBA at property lines for community turbines.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
		Muni - Property setback: criteria cannot be more restrictive than 1.5 times the turbine height.
New Jersey	Both, Local with State mandatory restrictions for small wind energy systems. Local governments cannot adopt ordinances that unreasonably limit development.	Noise Maximum Restrictiveness: 55 dBA at property lines for community turbines. Property Setbacks Maximum Restrictiveness: Ordinances may not require setback greater than 1.5 times turbine height.
New Mexico	Hybrid. Local governments regulate through land use zoning. The New Mexico Public Regulation Commission must approve project 300 MW or greater. The Commission is not allowed to approve a project that violates local land use laws, unless the commission finds the law to be unreasonably restrictive.	No state specifications identified.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
New York **Δ**	Both, Local authority up to 25 MW. All projects over 25 megawatts must be reviewed through an Article 10 process and the Office of Renewable Energy Siting. Local governments manage land use and zoning permits. The Office of Renewable Energy Siting produced regulations and uniform standards and conditions for wind project. Local jurisdictions are responsible for determining zoning/siting requirements for projects under 25 MW and will be reviewed by the State Environmental Quality Review Act.	• Property line setback: 1.1 times turbine height. • Public road setback: 1.1 times turbine height. • Non-participating residence setback: 2 times turbine height. • Shadow flicker shall be limited to 30 hours per year at any non-participating residence. • Noise levels shall comply with maximum limits of 45 dBA at the outside of a non-participating residence and 55 dBA at the outside of a participating residence. • An approved decommissioning plan is required.
North Carolina **Δ**	Hybrid – Local and State Authority	Decommissioning Requirement: Shall establish financial assurance that will ensure that sufficient funds are available for decommissioning of the facility and reclamation of the property to its condition prior to commencement of activities on the site.
North Dakota	Both, Local and State. Projects must comply with local regulations for zoning and land use, state laws establish setback requirements. Local zoning may require greater setbacks than required by state law. State mandatory regulations for projects 0.5 MW or greater. Smaller facilities regulated at the local level.	• Noise: 50 dBA within 100 feet of inhabited residence or community building • Property Setback: 1.1 times turbine height from property line of nonparticipating landowner, unless variance is granted. • Non-participating Residence Setback 3 times turbine height • Other Setback Recommendation: 1.1 times turbine height from inter/ state highway; same + 75 feet from county or town road centerline. • Exclusion areas apply.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Ohio **Δ**	State Rules shall prescribe reasonable regulations regarding wind farms of sounds and noise, shadow flicker, and decommissioning in Rule 4906-4-09 effective December of 2021.	Property Setback: 1.1 times turbine height to wind farm property line and at least 1,125 feet from tip of the turbine's nearest blade at ninety degrees to the nearest adjacent property line. Residence Setback: At least 1,125 feet in horizontal distance from the tip of the turbine's nearest blade at ninety degrees to exterior of habitable, residential structure unless waived. Noise: Facility may not result in noise levels at any non-participating sensitive receptor within one mile of the project boundary that exceed the project area ambient nighttime average sound level by 5 dBA. During daytime hours facility may operate at the greater of the project area ambient nighttime Leq plus 5 dBA or the validly measured ambient Leq plus 5 dBA at the location of the sensitive receptor. Shadow Flicker: The facility shall be designed to avoid unreasonable adverse shadow flicker effect at any non-participating sensitive receptor within one thousand meters of any turbine. At a minimum, the facility shall be operated so that shadow flicker levels do not exceed thirty hours per year at any such receptor. Non-participating, as used in this context, refers to a property for which the owner has not signed a waiver or otherwise agreed to be subject to a higher shadow flicker level. Decommissioning: The applicant shall provide the final decommissioning plan to the board and the applicable county engineer(s) at least thirty days prior to the preconstruction conference.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Oklahoma **Δ**	Both, Local with mandatory state decommissioning and setback standards. All other siting guidelines are subject to local or county jurisdiction. Setback standards apply after August 21, 2015, from Okla. Stat. tit. 17 § 160.20.	Decommissioning: After 15 years of operation, proof of financial security. Other Setbacks: No less than 1.5 nautical miles from the centerline of any public use airport runway, public school, or hospital.
Oregon **Δ**	Hybrid - Local with State model ordinance. Local jurisdictions are responsible for determining zoning/siting requirements for smaller energy facilities.; however, the state provides a model ordinance. The Oregon Energy Facility Siting Council makes siting decisions for large energy facilities (50 MW or more).	• Property Setback Recommendation: 1.5 times turbine height. • No increase over 10 dBA over ambient noise levels (assumed at 26 dBA unless otherwise measured) or over limits provided as measured at either 25 feet towards the turbine from the nearest noise sensitive building or the point on the noise sensitive property line nearest the turbine, whichever is furthest from the noise source. Industrial and Commercial Noise Source Standards apply to wind turbines: Day limits are L50 – 55 dBA, night limits are L50 – 50 dBA. Noise increase of more than 10 dBA can be agreed to through legally effective easement or covenant.
Pennsylvania	Local jurisdictions are responsible for determining zoning/siting requirements; however, the state provides a model ordinance.	• Noise Recommendation: 55 dBA at occupied buildings. • Property Setback Recommendation: 1.1 times turbine height. • Residence Setback Recommendation: 5 times turbine height. • Other Setback Recommendation: 1.1 times turbine height to public road. • Shadow Flicker Recommendation: Owner should make a reasonable effort to minimize shadow flicker at residences. • Decommissioning Recommendation: Submit a decommissioning plan and proof of financial security.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Rhode Island	Local jurisdiction with state recommendations. Applicable to proposed turbines ≥ 200 feet in height or rated to produce ≥ 100 kW of power.	• Noise Recommendation: Three recommended noise options based on either maximum sound level or ambient sound increase at property lines. • Property Setback Recommendation: 1.5 times the maximum tip height of the turbine from the nearest property line. • Residence Setback Recommendation: 3 times maximum tip height from nearest residential structure or commercial building. • Other Setback Recommendation: 1.5 times the maximum tip height of the turbine from the nearest private or public way. • Shadow Flicker Recommendation: Shadow flicker should be limited to no more than 30 hours per year at occupied structures or sites permitted for occupied structure construction at the time of wind project permitting. • Decommissioning Recommendation: Decommissioning shall consist of: (a) Physical removal of all wind turbines, structures, equipment, security barriers and transmission lines from the site. (b) Disposal of all solid and hazardous waste in accordance with local, state, and federal waste disposal regulations. (c) Stabilization or re-vegetation of the site as necessary to minimize erosion. The Site Plan Review Authority may allow the owner to leave landscaping or designated below-grade foundations in order to minimize erosion and disruption to vegetation.
South Carolina	Hybrid, State PUC has authority for projects > 75 MW. Local governments regulate siting of facilities <75 MW.	No state specifications identified.
South Dakota	Local with state voluntary model ordinance by Public Utilities Commission.	• Noise Recommendation: ≤ 55 dBA at occupied building

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
	Local jurisdictions are responsible for determining zoning/siting requirements; however, the state provides a model ordinance *for turbines equal to or greater than 75 feet tall.*	• Property Setback Recommendation: 500 feet or 1.1 times turbine height, whichever is greater, unless easement has been obtained from adjoining property owner. • Residence Setback Recommendation: 1,000 feet for nonparticipant landowner; 500 feet or 1.1 times turbine height for participant landowner, whichever is greater. • Other Setback Recommendation: 500 feet or 1.1 times turbine height to public right-of-way, whichever is greater. • Decommissioning Recommendation: Submit a decommissioning plan and proof of financial security after 10 years of operation.
Tennessee Δ	State State sets minimum guidelines for siting as passed in Public Chapter No. 825 during 2018 legislative session.	• Noise: 35 dBA at non-participating landowner dwelling and 45 dBA at non-participating landowner property line. • Property Setback from non-participating landowner: 3.5 times turbine height • Property setback from participating landowner: 1.1 times turbine height • Shadow Flicker: Environmental assessment should include a risk assessment and mitigation recommendation for shadow flicker. • Decommissioning: The applicant must establish financial security at 100 percent of the total estimated cost to decommission.
Texas	None, Local.	No state specifications identified.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Utah **Δ**	Local with State military requirement. Requirement for developers to be approved through Military Aviation and Installation Assurance Siting Clearinghouse. Passed in House Bill 436 in 2021 General Session.	Department of Natural Resources must determine that the proposed construction does not encroach upon or otherwise have a significant adverse impact on the military.
Vermont	State. Developer must receive Certificate of Public Good from the Vermont Public Service Board. State law provides parameters on the height of the structures and prohibits municipal regulation of small wind turbines.	Height of turbines less than 20 feet in diameter cannot be regulated by municipalities unless bylaws provide specific standards for regulation.
Virginia **Δ**	Local zoning applies for projects. Projects must show compliance with local requirements and approvals from local counties, though many counties do not have specific wind ordinances. For projects between 5 and 150 MW, permit by rule applies (9VAC15-40-20). The VA Dept of Env Quality has rules for permit by rule. Wind energy developers must obtain approval from the State Corporation Commission (SCC) through a CPCN if project is greater than 150 MW. SCC may consider local siting and environmental issues.	No state specific rules identified. DEQ Model Ordinance referenced but not currently found on webpage.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
Washington	Yes, State and local. County jurisdiction, but projects can choose state Energy Facility Site Evaluation Council jurisdiction or are required to if the project is 350 MW or greater.	Noise: State noise law, limits residential noise to 55 dBA during day, 45 dBA at night.
Washington DC	None, PUC	No specifications indicated.
West Virginia	None, State	No state specifications identified.
Wisconsin	Hybrid, Local with State requirements for maximum restrictiveness on projects up to 100 MW.	• Noise Maximum Restrictiveness: 50 dBA Day, 45 dBA Night apply at the outside wall of a nonparticipating residence or occupied community building. The measurement shall be as near as possible to the outside wall nearest to the closest wind turbine, or at an alternate wall as specified by the owner of the nonparticipating residence or occupied community building. • Property Setback Maximum Restrictiveness: 1.1 times turbine height • Residence Setback Maximum Restrictiveness: Lessor of 1,250 feet or 3.1 times height from nonparticipating residence. • Other Setback Maximum Restrictiveness: 1.1 times turbine height from public/utility rights-of-way • Shadow Flicker Maximum Restrictiveness: No more than 30 hours per year at a nonparticipating residence or occupied community building. Mitigation required if more than 20 hours per year.

State	Relevant Policy; Primary Authority; Mandatory or Voluntary	Topics of Regulation - May include: • Turbine Size, • Noise, • Shadow Flicker, • Property Setback, • Residence Setback, • Other Setbacks, • Decommissioning
		• Decommissioning Maximum Restrictiveness: Maintain proof of financial security.
Wyoming	Yes, State and Local. Counties retain jurisdiction of siting requirements outside of minimum setbacks defined by the state for projects over 0.5 MW.	• Property Setback Requirements: 1.1 times turbine height unless waived by landowners. • Residence Setback Requirements: 1,000 feet or 5.5 times turbine heights, whichever is greater, unless waived by landowners. • Other Setback Requirements: 1.1 times turbine height to road, 5.5 times turbine height (or minimum of 1,000 feet) to "platted subdivisions", ½ - mile to city limits.

Sources

Sources include a) DSIRE: Database of State Incentives for Renewables & Efficiency, b) National Conference of State Legislatures: State Approaches to Wind Facility Siting, c) additional state-specific internet searches regarding state policies and ordinances shown below. All citations are current as of April 4, 2024, and subsequent changes to state policies may affect future accuracy of these citations.

Alabama

State Approaches to Wind Facility Siting (ncsl.org)

Alaska

https://www.akleg.gov/basis/statutes.asp#42.05

https://rca.alaska.gov/RCAWeb/AboutRCA/Commission.aspx

Regulatory Affairs & Public Advocacy Section - Alaska Department of Law

Arizona

Arizona Rev. Stat. 40-360.03. Applications prior to construction of facilities

State Approaches to Wind Facility Siting (ncsl.org)

AZ Title 11 - Counties

Arkansas

State Approaches to Wind Facility Siting (ncsl.org)

California

Gov Code Title 7 Planning and Land Use Div 1 Planning and Zoning Chapter 4 Zoning Regulations Article 2 Adoption of Regulations 65850

Gov Code Title 7 Planning and Land Use Div 1 Planning and Zoning Chapter 3 Local Planning Article 5. Authority for and Scope of General Plans 65302(f)

CA Governor's Office of Planning and Research – General Plan Guidelines – Appendix D, Noise

Colorado

Colorado C.R.S Title 25 Article 12 – 103 Maximum permissible noise levels

Colorado Code 4-CCR 723-3

Connecticut

WindRegulations2011 (ct.gov)

Chapter 277a – Public Utility Environmental Standards Act

eRegulations - Browse Regulations of Connecticut State Agencies

Delaware

Delaware Code Online – Title 29 ch. 80

State Approaches to Wind Facility Siting (ncsl.org)

Florida

Statutes & Constitution :View Statutes : Online Sunshine (state.fl.us)

State Approaches to Wind Facility Siting (ncsl.org)

Georgia

https://windexchange.energy.gov/states/ga

GA Ch. 36-66-2: Georgia General Assembly |Public Access | Main Page (lexis.com)

Hawaii

State Approaches to Wind Facility Siting (ncsl.org)

11-46.pdf (hawaii.gov)

Idaho

State Approaches to Wind Facility Siting (ncsl.org)

Chapter 65 – Idaho State Legislature

Illinois

HB 4412 Issue Brief.pdf (isacoil.org)

Illinois General Assembly – Illinois Compiled Statutes (ilga.gov)

Indiana

https://iga.in.gov/laws/2023/ic/titles/8

https://iga.in.gov/laws/2023/ic/titles/36#36-7-4-600

Iowa

State Approaches to Wind Facility Siting (ncsl.org)

https://www.legis.iowa.gov/docs/ico/chapter/476.pdf

Kansas

Chapter 12.—CITIES AND MUNICIPALITIES (ksrevisor.org)

State Approaches to Wind Facility Siting (ncsl.org)

Kentucky

KY statute Section 278.702: statute.aspx (ky.gov)

KY statute Section 278.704

Louisiana

State Approaches to Wind Facility Siting (ncsl.org)

Maine

https://legislature.maine.gov/legis/statutes/35-A/title35-Ach0sec0.html

https://www.mainelegislature.org/legis/statutes/38/title38sec481.html

https://www.maine.gov/dep/land/sitelaw/wind/index.html

Wind Energy Facility (WEF) Ordinance Guidebook (maine.gov)

Maryland

Div 1-Title 7-Subtitle 2-Section7-207 Article - Public Utilities (maryland.gov)

CPCN Exemptions - Electricity (state.md.us)

Massachusetts

https://www.mass.gov/info-details/wind-energy-model-zoning-by-law

General Law - Part I, Title XXII, Chapter 164, Section 69J1/4 (malegislature.gov)

Michigan

https://www.legislature.mi.gov/documents/2023-2024/publicact/htm/2023-PA-0233.htm

https://www.michigan.gov/mpsc/commission/workgroups/2023-energy-legislation

https://legislature.mi.gov/Laws/MCL?objectName=MCL-295-2008-8

Minnesota

A Guide to Noise Control in Minnesota-Report (mn.gov)

MN DOC order General Wind Turbine Permit Setbacks and Standards for Large Wind Energy Conversion System [PDF]

Guidance for Commercial Wind Energy Projects (state.mn.us)

Public Health Impacts of Wind Turbines (mn.gov)

https://mn.gov/eera/web/doc/13641/

Mississippi

State Approaches to Wind Facility Siting (ncsl.org)

Missouri

State Approaches to Wind Facility Siting (ncsl.org)

Montana

hj-38-wind-solar-may-2020.pdf (mt.gov)

State Approaches to Wind Facility Siting (ncsl.org)

Nebraska

Nebraska Legislature 66-902.01

State Approaches to Wind Facility Siting (ncsl.org)

Nevada

NRS: CHAPTER 278 - PLANNING AND ZONING (state.nv.us)

State Approaches to Wind Facility Siting (ncsl.org)

NRS 278.02077 – Prohibition against prohibiting or unreasonably restricting use of system for obtaining wind energy (public.law)

New Hampshire

https://www.gencourt.state.nh.us/rsa/html/LXIV/674/674-63.htm

https://www.gencourt.state.nh.us/rsa/html/XII/162-H/162-H-10-a.htm

Chapter 674 LOCAL LAND USE PLANNING AND REGULATORY POWERS (state.nh.us)

Electric | NH Department of Energy

New Jersey

New Jersey statutes 40:55D-66.12 Municipal ordinances relative to small wind energy systems

New Mexico

Current New Mexico Statutes Annotated 1978 - Section 62-9-3 The Utility Franchise

New York

https://ores.ny.gov/regulations

State Approaches to Wind Facility Siting (ncsl.org)

New York State Wind Energy Guide - NYSERDA

Local Role in Planning and Permitting [PDF]

North Carolina

Chapter 143 - Article 21C (ncleg.gov)

North Dakota

North Dakota Century Code Ch. 49-22-1 et. seq

Ohio

Ohio revised code section 4906.20

https://codes.ohio.gov/ohio-administrative-code/rule-4906-4-09

https://www.dickinson-wright.com/news-alerts/ohio-legislature-adopts-new-wind-and-solar-siting

Oklahoma

Okla. Stat. title 17 § 160.20.

Oregon

Oregon Dept of Energy – Model Ordinance for Energy Projects (icma.org)

https://www.oregon.gov/lcd/nrre/pages/energy-siting.aspx

https://oregon.public.law/rules/oar_340-035-0035

Oregon Secretary of State Administrative Rules

Pennsylvania

https://www.dep.pa.gov/Business/Energy/Wind/Pages/default.aspx

Model Ordinance (state.pa.us)

Rhode Island

WindSitingGuidelines_1-31-2017_FINAL.pdf (ri.gov)

South Carolina

State Approaches to Wind Facility Siting (ncsl.org)

South Dakota

Codified Law 43-13-24 | South Dakota Legislature (sdlegislature.gov)

Codified Law 49-41B-2 | South Dakota Legislature (sdlegislature.gov)

Tennessee

pc0825.pdf (tnsosfiles.com)

TN Title 65 Public Utilities and Carriers Chapter 17 Wind Energy Facility Siting

Texas

State Approaches to Wind Facility Siting (ncsl.org)

Utah

HB0436.pdf (utah.gov)

Vermont

State Approaches to Wind Facility Siting (ncsl.org)

Vermont Laws – Title 24: ch. 117

Virginia

Code of Virginia Code - Chapter 10.1. Utility Facilities Act

https://law.lis.virginia.gov/admincode/title9/agency15/chapter40/section20/

Washington

https://app.leg.wa.gov/wac/default.aspx?cite=173-60-040

Washington D.C.

State Approaches to Wind Facility Siting (ncsl.org)

West Virginia

State Approaches to Wind Facility Siting (ncsl.org)

Wisconsin

State Approaches to Wind Facility Siting (ncsl.org)

Wisconsin Legislature: Chapter PSC 128

Wyoming

WY Stat 18-5-504

Appendix G – Policy Recommendations

Recommendation – Public Service Commission Wind Noise Measurement Protocol Update

The current PSC Wind Noise Measurement Protocol[122] requires wind turbine noise sampling and the following measurement criteria be determined pre- and post-construction with wind conditions just above cut-in speed.

a. At a minimum, unweighted octave-band analysis (16, 31.5, 63, 125, 250, 500, 1K, 2K, 4K, & 8K Hz), one-third octave band analysis is encouraged
b. L_{ave}, L_{10}, L_{50}, and L_{90}, in dBA
c. L_{ave}, L_{10}, L_{50}, and L_{90}, in dBC
d. A narrative description of sounds audible during each measurement

A note indicates 16 Hz data may be beyond the capabilities of the sound level measurement apparatus.

Development of the PSC Wind Noise Measurement Protocol was based, in part, on ASTM E1686-1996, "Environmental Noise Measurement Methods and Criteria." The active version is ASTM E1686-2023 and the PSC Wind Noise Measurement Protocol should be reviewed against the active version to determine if an update is warranted. ASTM E1686-2023 does not specifically address measurement of infrasound frequencies. While some of the standard's information may also apply to infrasound, a different standard will be required, if available, to support development of a new infrasound measurement protocol. The new infrasound measurement protocol will likely need to be more prescriptive than the current protocol, defining minimum requirements for the measurement apparatus and procedures. The following Acoustical Society of America (ASA) standard was identified by title: ASA/ANSI S12.9 PART 7 2016 Edition, April 25, 2016, "Quantities and Procedures for Description and Measurement of Environmental Sound, Part 7: Measurement of Low-frequency Noise and Infrasound Outdoors and in the Presence of Wind and Indoors in Occupied Spaces.

[122] Available at: https://psc.wi.gov/SiteAssets/WindNoiseProtocol.pdf