Fredrikson & BYRON, P.A.

October 11, 2018

<u>VIA ELECTRONIC FILING</u>

Ms. Patricia Van Gerpen
Executive Secretary
South Dakota Public Utilities Commission
500 E Capitol Ave
Pierre, SD 57501-5070

RE: In the Matter of the Application by Prevailing Wind Park, LLC for a Permit of a Wind Energy Facility in Bon Homme County, Charles Mix County and Hutchinson County, South Dakota, for the Prevailing Wind Park Project Docket EL18-026

Dear Ms. Van Gerpen:

In connection with the above-referenced matter, enclosed please find the following documents and a Certificate of Service:

- Exhibit A36: *Williams v. Invenergy, LLC*, 2016 WL 1275990 (D. Oregon, April 28, 2016);
- Exhibit A37: Ownership Structure of Prevailing Wind Park, LLC;
- Exhibit A38: Turbine Number Key;
- Exhibit A39: Michaud et al., Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep (2016);
- Exhibit A40: Hearing and Vibrotactile Thresholds Table; and
- Updated Exhibit I-29, Attachment 4-2 Project Layout.

If you have any questions, please contact me.

Sincerely,

/s/ Lisa Agrimonti

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Enclosures
cc: Certificate of Service/Service List

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2016 WL 1725990
Only the Westlaw citation is currently available.
United States District Court,
D. Oregon,
PORTLAND DIVISION.

Daniel Brian Williams, Plaintiff,
v.
Invenergy, LLC, an Illinois Corporation;
and Willow Creek Energy, LLC, a
Delaware Corporation, Defendants.

Case No.: 2:13-CV-01391-AC
|
Signed 04/28/2016

OPINION AND ORDER

ACOSTA, Magistrate Judge.

***1** Plaintiff Daniel Brian Williams ("Williams") brings claims for private nuisance alleging Defendants Invenergy, LLC ("Invenergy") and Willow Creek Energy, LLC ("Willow Creek") (collectively "Defendants") are denying him the use and enjoyment of his home in Morrow County, Oregon. Williams contends Defendants' wind-turbine facility (the "Willow Creek Wind Facility"), which is situated near Williams's home, emits audible noise, vibration, light, and low-frequency infrasound which causes him anxiety and disturbs his sleep. Defendants move for partial summary judgment and, in the alternative, move to exclude the testimony of Williams's expert witnesses to the extent they intend to testify that low-frequency infrasound causes adverse health effects in humans. Upon careful review of the record, the court grants in part and denies in part Defendants' motion to exclude Williams's expert testimony. The court also grants in part and denies in part Defendants' motion for partial summary judgment.

Background

I. Factual Background

In early 2005, the Morrow County Planning Board ("Morrow County") granted Defendants a conditional use permit ("CUP") to build and operate the Willow Creek Wind facility. (Declaration of Steven Rizzo in Support of Defendants' Motion for Partial Summary Judgment ("Rizzo PSJ Decl.") Ex. 1 at 1.) Defendants were required to comply with twenty-one conditions to operate the Willow Creek Wind Project. (Rizzo PSJ Decl. Ex. 2 at 1.) Notably, the CUP required Defendants to "[c]omply with OAR 340 Division 35 standards relative to wind facilities and the appropriate sections of the Morrow County Noise Ordinance." (*Id.*)

The wind farm went operational in early 2008, and individuals with homes nearby immediately began complaining about the noise and vibration produced by the wind turbines. (McCandlish PSJ Decl. Ex. 2, 3, 4.) Shortly after the wind turbines began generating power, Williams started experiencing health problems. (Rizzo PSJ Decl. Ex. V.) Although Williams's primary complaint was sleep disturbance, he also experienced irritability, anxiety, nausea, dizziness, headaches, and at least one anxiety attack. (*Id.* at 2.) Williams primarily linked his symptoms to the deep, "pulsating, throbs of intermittent and constant audible sound" generated by the wind turbine. (*Id.* at 4.) He alternatively described the sound as "like a jet/train that isn't coming or going. Just there." (*Id.*) Eventually, Williams moved out of his home to escape the wind turbine noise. (*Id.* at 5.)

Upon learning of the complaints, Defendants met on several occasions with Williams and other local residents to discuss the local residents' concerns about the manner Defendants' were operating the wind-turbine facility. At these meetings, the parties discussed how much audible noise the turbines could lawfully produce while remaining in compliance with the CUP. (McCandlish PSJ Decl. Ex. 2 at 2.) Defendants initially expressed their belief that the applicable noise ceiling was 50 dB. Williams and the other concerned residents disagreed; they contended the state-imposed limit was 36 dB and urged Defendants to comply with that standard. Eventually, Defendants' agreed to conduct a noise test at properties surrounding the Willow Creek Wind Facility to determine whether they were in compliance with relevant noise standards. (McCandlish PSJ Decl. Ex. 17.) The "preliminary noise level survey" found regular, albeit minor, noise exceedences at various locations near the wind farm, particularly at wind speeds of 9 meters per second or more. (McCandlish PSJ Decl. Ex. 17.)

II. Procedural Background

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***2** Upon learning that Defendants were out of compliance with the conditional use permit, Williams and the other local residents instituted administrative proceedings with the Morrow County Planning Board in an attempt to have the violations remedied. (Rizzo PSJ Decl. Ex. 9 at 2.) Initially, the Morrow County Planning Board determined Defendants were in violation of the noise limitations in the CUP at multiple residences near the wind facility, and concluded Defendants "should have six months to bring the facility into compliance." (*Id.* at 3.) The parties appealed the board's decision to a Morrow County court, who remanded the case back to the Morrow County Planning Commission so the commission could "adopt findings in support of its decision and specify a procedure by which Invenergy could bring the Willow Creek Energy Facility into compliance with the noise standards within the six month deadline." (*Id.*)

On remand, the planning commission found:

> (1) that the evidence shows the facility violates the noise standard at times at three petitioners' residences (Eaton, Williams and Mingo) and at a fourth residence in some wind conditions (Wade), (2) the wind standard is an objective standard rather than a subjective standard and is either met or not met, "black and white," (3) future data collection should be done by a third party with Invenergy paying the cost, (4) Invenergy should have six months to bring the facility into compliance, and (5) to comply with the noise standard, total noise (combined noise from background sources and the facility) may not exceed 36 decibels (dBA).

(*Id.* at 4.) The parties again appealed the planning board's decision to a Morrow County Court, who adopted the planning board's decision in full. (*Id.*) In turn, the parties appealed the court's decision to the Oregon Land Use Board of Appeals ("LUBA"), which concluded the county court's decision was not supported by adequate findings or substantial evidence. (*Id.*) LUBA also concluded there were two separate methods for establishing whether Defendants complied with relevant noise standards, either of which were applicable to gauge compliance with the state noise standards. LUBA remanded the case back to the Morrow County court because "[b]oth the planning commission's and the county court's decision had erroneously suggested that, in defending against the allegations of noise standard violations, Invenergy is limited" to one method. (*Id.* at 4-5.)

On remand, the Morrow County Court concluded that Defendants violated the noise standards only at Williams's home, "but that those violations were not serious or significant enough to warrant either revoking the [CUP] or taking further action to require that those violations be corrected." (*Id.* at 5.) Williams and his neighbors again appealed to LUBA, who affirmed the county court's decision in full. (*Id.* at 20-21.)

On August 9, 2013, Williams filed a complaint in this court for common law trespass, common law nuisance, and nuisance per se. (Dkt. No. 1.) His complaint asks for an award of $5,000,000 in non-economic damages, $171,000 in economic damages, $5,000,000 in punitive damages, fees and costs, and a "permanent injunction enjoining Invenergy from creating noise exceedences." (Dkt. No. 1 at 13.) Defendants moved to dismiss Williams's claims for failure to state a claim. *Williams v. Invenergy, LLC,* Civ. No. 3:13-cv-01391-AC, 2014 WL 7186854, at *1 (D. Or. Dec. 16, 2014). In a December 16, 2014 Opinion and Order, the court concluded Williams failed to state claims for trespass and nuisance *per se*, but held his common-law nuisance claim could proceed based on his theory that the wind turbines created audible noise, low-frequency infrasound, light, and vibration which interfered with Williams's use and enjoyment of his property. *Id.* at *21.

Defendants have now filed a motion for partial summary judgment and a *Daubert* motion to exclude testimony by three of Williams's expert witnesses.

III. Overview of Williams's Expert Opinions

***3** Williams retained four experts to testify in this case. Defendants move to exclude only three from offering their testimony. The following section contains a brief description of the Rule 26 expert report for each contested expert.

A. James Report

Upon filing his lawsuit, Williams retained Richard James ("James") as an expert witness to assist in

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taking measurements in and around Williams's home, to determine the audible noise and infrasound, or wave phenomena "sharing the physical nature of sound but with a range of frequencies below that of human hearing," present and attributable to the wind turbines. (Declaration of Steven Rizzo in Support of Motions for Summary Judgment and for Alternative Request for a *Daubert* Hearing ("Rizzo Daubert Decl.") Ex. A at 1; *Infrasound*, THE AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE (5th ed. 2000)) Williams also retained James to testify regarding the general causal relationship between acoustic outputs produced by wind turbines and adverse health effects in humans. (*Id.*)

James's report begins with an introduction wherein James states his credentials and briefly describes his findings regarding the low-frequency sound emitted by the Willow Creek wind turbines. (*Id.*) James explains that the turbines emit a "sound signature" consisting of "a series of tones that start in the very low infrasound range below 1Hz at a frequency that is linked to the rotation speed of the turning hub and blades." (*Id.*) He further explains that "the blade pass tone has harmonics that also appear as tones" which accompany the tone immediately produced by turbine. (*Id.*)

After James describes his testing methods and instrumentation, James states three opinions related to Williams's case. (*Id.*) First, James opines that, "there is sufficient information from ... studies to associate the operation of utility scale wind turbines that produce strong ... blade pass tones and harmonics inside a home as a cause of the reported adverse health effects or inability to remain in one's home." (*Id.* at 3.) In support of this conclusion, James cites two documents. First, he cites the minutes from the "Wisconsin Brown County Board of Health's [October] 14, 2014 hearing which summarizes the supporting research conducted by this author and others for the Shirley Wind utility ...." (*Id.*) Second, James cites "peer reviews" of the Cape Bridgewater Acoustic Testing Program ("Cape Bridgewater ATP"), "a study conducted in Australia by Steve Cooper" which purportedly "linked the cause of the complaints and sensations not associated with audible sounds experienced by the test subjects while in their homes in the presence of the wind turbine signature (WTS)." (*Id.*) In particular, he cites two documents produced by Acoustician Steve Schomer which summarize the Cape Bridgewater ATP and discuss the implications thereof. (*Id.*)

James's second opinion is that, based on review of the topography surrounding Williams's home, "there is a clear line of sight (sound) from the region of the blades where sounds are emitted and the Williams's home and property where the immissions are received." (*Id.* at 4.) James based this conclusion on information obtained from Willow Creek, the Federal Aviation Administration, and Google Earth. (*Id.*) Lastly, James opines in his third opinion that the measurements taken in Williams's home evidence the presence of a Wind Turbine Signature ("WTS"), including low-frequency infrasound. (*Id.*) According to James, these sound-pressure levels are similar to those produced by other wind farms, and "supports [James's] opinion hat the infrasound associated with the WTS is sufficient to cause a person who is sensitive to these adverse health effects to similarly vacate his or her home as Mr. Williams has also done." (*Id.*)

B. Punch Report

***4** Williams also retained audiologist Jerry Punch ("Punch") as an expert witness in this case. (Rizzo Daubert Decl. Ex. T.) Pursuant to his duties as an expert, Punch submitted a Rule 26 expert-witness report (the "Punch Report"). (*Id.*) In that report, Punch recounts his lengthy career and comprehensive list of publications. Punch thereafter explains that, based on his pre-existing knowledge, his review of a symptom questionnaire completed by Williams, and his review of portions of the evidentiary record, including depositions and the James Report, he came to twelve conclusions regarding the effect of industrial-scale wind turbines. (*Id.* at 4.) Punch concludes that wind turbines:

> (1) produce low-frequency noise and infrasound that is acoustically unique and more disturbing than other sources of industrial or transportation noises,??
>
> (2) produce noise low-frequency noise and infrasound [*sic*] that cannot be easily masked by wind noise, closed windows, external noises such as fans, hearing protection devices or sleeping in a typical residential basement,??
>
> (3) produce infrasonic energy whose harmful effects on humans can be explained by physiological mechanisms

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of the inner ear, even though infrasound is not perceived as sound,??

(4) result in complaints of annoyance in substantial percentages of persons who live near them, which, in turn, can lead to stress, sleep disturbance, and other health disorders, with sleep disturbance being the most frequent health complaint,??

(5) result in symptoms of nausea or motion sickness in some people,??

(6) produce noise that results in a wide variety of health effects for a non-trivial percentage of residents,??

(7) produce adverse health effects that are not typically well correlated with A-weighted sound levels,??

(8) emit noise levels that exceed 32-35 dBA, which according to the World Health Organization (WHO, 2009), is a threshold level above which sleep disturbance and other adverse health effects occur in a substantial portion of the population (See Exhibit E),??

(9) lead to health effects that cannot be explained by either visibility or psychological expectations alone, and??

(10) can result in physiological responses directly linked to stress, changes in hormonal levels, slight alterations in brain-wave (EEG) activity, notable alterations in inner-ear physiology, and cardiovascular illnesses,??

(11) at Wisconsin's Shirley Wind project have been declared a human health hazard by the Brown County Board of Health, and??

(12) have been shown at the Cape Bridgewater Wind Farm in Melbourne, Victoria, Australia, to produce unpleasant sensations in exposed residents; those sensations, which include headache, dizziness, and nausea, were synchronized with operational conditions of the turbines, following a period of non-operation in which the sensations subsided.

(*Id.*) Punch attached to his report the symptom questionnaire, a document published by the World Health Organization regarding the relationship between audible noise levels and human behavior, including sleeping, the Schomer review of the Cape Bridgewater ATP, and a lengthy reference list.

C. Ironside Report

Williams's third expert is Dr. Keith Ironside, Jr. ("Dr. Ironside"), a medical doctor and board certified sleep specialist who operates the Oregon Sleep Center in Hermiston, Oregon. (Rizzo Daubert Decl. CC at 1, 8.) Dr. Ironside interviewed Williams about his symptoms and the circumstances surrounding those symptoms. (*Id.* at 1.) In his report, Dr. Ironside observes that Williams experienced "loss of sleep when he hears the wind turbines" and "awakens on days the wind mills are going feeling anxious." (*Id.*) Dr. Ironside further writes that Williams's sleep disturbances were often associated with "a fast heart rate." (*Id.* at 2.)

***5** Dr. Ironside assessed that Williams was a "non-sleepy person" due to his score of 2 out of 24 on the "Epworth sleepiness scale." (*Id.* at 3.) After consulting the International Classification of Sleep Disorders, 3rd edition, Dr. Ironside diagnosed Williams with "short-term insomnia disorder." (*Id.* at 6.) Williams's insomnia, Dr. Ironside opined, could not "be explained in this case purely by inadequate opportunity to sleep," but was properly attributed to "the noise of the wind turbines ...." (*Id.*) Dr. Ironside also concluded that vibrations produced by the wind turbines had an effect "on his autonomic nervous system ...." (*Id.*)

At deposition, Dr. Ironside testified that he had is "not an expert in infrasound or ... an audiologist," and had little experience with infrasound. (Rizzo Daubert Decl. Ex. DD at 6.) When asked whether it was his expert opinion that infrasound caused Williams's insomnia, Dr. Ironside responded, "I can't differentiate from infrasound and plain sounds based on [Williams's] history." (*Id.*) In fact, Dr. Ironside admitted at deposition that he has read about infrasound "only in passing," but has experienced infrasound twice in his life, once when a lion roared in his ear as a child and later when he experience tachycardia immediately preceding an earthquake in San Francisco. (*Id.* at 6.) However, following his deposition, Dr. Ironside reviewed the James Report and penned a letter to Williams's attorney in which he decisively concludes that "it is my opinion that to a reasonable degree of medical probability within my field of sleep medicine that the infrasound generated by industrial wind turbines operating closest to Mr. Williams'[s] home is a substantial contributing factor to Mr. Williams'[s] insomnia." (Rizzo Daubert Decl. Ex. EE at 1-2.)

Legal Standards

I. Motion to Exclude under *Daubert*
The Federal Rules of Evidence ("Rules") provide:

> A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if: (a) the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue; (b) the testimony is based on sufficient facts or data; (c) the testimony is the product of reliable principles and methods; and (d) the expert has reliably applied the principles and methods to the facts of the case.

FED. R. EVID. 702. Under Rule 702, the district court is tasked with the gate-keeping function assigned by *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993) ("*Daubert I*"), to determine the admissibility of expert witness testimony. *Kumho Tire Co., Ltd. v. Carmichael*, 526 U.S. 137, 141, 147 (1999). "Faced with a proffer of expert scientific testimony, then, the trial judge must determine at the outset ... whether the expert is proposing to testify to (1) scientific knowledge that (2) will assist the trier of fact to understand or determine a fact in issue. This usually entails a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue." *Daubert I*, 509 U.S. at 592-93 (footnote omitted). An expert's "bald assurance of validity is not enough." *Daubert v. Merrell Dow Pharm., Inc.*, 43 F.3d 1311, 1316 (9th Cir. 1995) ("*Daubert II*"). *Daubert*, which originally applied only to the testimony of "scientists," has been extended to apply to the testimony of engineers and other experts who possess technical and specialized knowledge. *Kumho Tire*, 526 U.S. at 141.

***6** In *Daubert I*, the Supreme Court articulated factors to consider when determining if an expert's testimony is admissible under Rule 702. Trial courts undertaking the *Daubert* analysis must determine: (1) whether the theory, technique, and background knowledge the expert applies is generally accepted in the relevant scientific community; (2) whether the research supporting the expert's conclusion has been subjected to peer review and publication; (3) whether the expert's theory can be and has been tested; (4) whether standards exist to control the operations of the expert's methods; and (5) whether the known or potential rate of error is acceptable. *Daubert I*, 509 U.S. at 593-94. The inquiry, however, is a flexible one, with the focus solely on the principles and methodology used, not on the conclusions they generate. *Id.* at 594; *see also Claar v. Burlington N. R. Co.*, 29 F.3d 499, 502 (9th Cir. 1994) (the district court is "both authorized and obligated to scrutinize carefully the reasoning and methodology" underlying the expert's testimony); *Tyson v. Ore. Anesthesiology Group, P.C.*, Case No. 03-1192-HA, 2008 WL 2371420, at *15 (D. Or. June 6, 2008) (finding inadmissible expert conclusions that were "vague and inadequately supported with specific, relevant statistical analysis").

However, the court's analysis is not constrained to an inflexible application of *Daubert* factors. *Daubert I*, 509 U.S. at 594; *Kumho Tire*, 526 U.S. at 147-153. As the Supreme Court observed, *Daubert's* factors "may or may not be pertinent in assessing reliability.... The conclusion, in our view, is that we can nether rule out, nor rule in, for all cases and for all time the applicability of the factors mentioned in *Daubert*.... Too much depends upon the particular circumstances of the particular case at issue." *Id.* at 150 (citations and internal quotations omitted). As a result, the court may consider other factors germane to the expert's opinion, and the factors listed in *Daubert* may not be reasonable measures of reliability of expert testimony in a particular case. *Id.*

A threshold question in determining the admissibility of expert testimony is whether the proffered testimony will assist the trier of fact. *Daubert I*, 509 U.S. at 592. Expert witness testimony is unnecessary unless the subject matter "is beyond the common knowledge of the average lay person." *U.S. v. Hanna*, 293 F.3d 1080, 1086 (9th Cir. 2002) (quotation marks omitted). Rulings on the admissibility of expert testimony under Rule 702 are committed to the sound discretion of the trial court. *Gen Elec. Co. v. Joiner*, 522 U.S. 136, 141-42 (1997). Thus, "even if [the expert] testimony may assist the trier of fact, the trial court has broad discretion to admit or exclude it."

Beech Aircraft Corp. v. U.S., 51 F.3d 834, 842 (9th Cir. 1995) (per curiam) (quotation marks omitted).

II. Motion for Summary Judgment

A court should grant a motion for summary judgment "if the movant shows that there is no genuine dispute as to any material fact and the movant is entitled to judgment as a matter of law." FED. R. CIV. P. 56(a). The moving party bears the burden of establishing that no issue of fact exists and that the nonmovant cannot prove one or more essential elements of a claim or defense. *Celotex Corp. v. Catrett*, 477 U.S. 317, 324 (1986). If the movant meets his burden, the nonmovant must "go beyond the pleadings [ ] by her own affidavits ... [to] designate specific facts showing that there is a genuine issue for trial." *Id.* (internal quotation marks omitted). On summary judgment, the court is bound to view all facts in a light most favorable to the nonmovant and must draw all justifiable inferences in the nonmovant's favor. *Narayan v. EGI, Inc.*, 616 F.3d 895, 899 (9th Cir. 2010).

Discussion

Defendants move for summary judgment, for partial summary judgment, and for exclusion of Williams's expert testimony. Williams opposes Defendants' motions and argues that, even if the court excludes his expert testimony, his nuisance claims survive. The court will first address Defendants' *Daubert* motion. Thereafter, the court will consider whether Defendants are entitled to summary judgment on Williams's claim for private nuisance. If his claims survive summary judgment, the court will then address whether he is barred as a matter of law from recovering injunctive relief and punitive damages.

I. Motion to Exclude under *Daubert*

***7** Defendants move to exclude the expert opinions of James, Punch, and Ironside. According to Defendants, the anticipated testimony of these three experts is not based on scientific knowledge and is not reliable under the test articulated in *Daubert I*. Williams contends his experts have reliably applied generally accepted scientific principles to establish causation in his case. After careful review of the record, the court grants in part and denies in part Defendants' *Daubert* motion, and will exclude all expert testimony regarding the causal link between turbine-generated infrasound and adverse human health effects.

A. James

Williams engaged James to testify primarily about two issues. First, James will testify that the windmills near Williams's home produce audible noise and infrasound which is measurable inside Williams's home. Second, James will testify regarding the general causal element of Williams's infrasound claim: that the noise and infrasound produced by the wind turbines caused Williams adverse health effects and annoyance which drove him to move out of his home.

Defendants move to exclude James's opinion under *Daubert*. They argue: (1) The materials upon which James relies lack scientific reliability; (2) James is not qualified to testify on causation; (3) James did not employ reliable methodology to reach his conclusions; and (4) James's opinion that infrasound is harmful to humans lacks scientific reliability. Williams disputes each of Defendants' arguments and contends James's scientific methods are reliable in theory and application.

1. Reliability of Foundational Materials

Defendants argue the materials upon which James relies to inform his causation testimony lacks scientific reliability. Because James's opinion lacks the requisite reliability required of expert testimony, Defendants contend the court should exclude James's testimony in its entirety. Specifically, Defendants contend the Brown County Board of Health Meeting Minutes, the Cape Bridgewater ATP, the Schomer review of the Cape Bridgewater ATP, and the N.D. Kelley Paper do not exhibit "good science" which may be relied upon to form opinions about the affect of wind farms on humans. Williams argues James is a seasoned expert in the field of acoustics who has encountered reliable scientific literature throughout his career which informs his opinions in this case. Because this is typical in scientific and academic fields of study, Williams contends James's testimony should be admitted.

The primary goal of the *Daubert* analysis is to determine whether the expert witness's testimony reflects "scientific knowledge." *Daubert II*, 43 F.3d at 1315. Proponents typically meet their burden of demonstrating "scientific

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knowledge" by showing that their methods constitute "good science." *Id.* Moreover, to the extent the witness's opinions arise out of pre-existing research or knowledge, the expert must "explain precisely how they went about reaching their conclusions and point to some objective source — a learned treatise, the policy statement of a professional association, a published article in a reputable scientific journal or the like — to show that they have followed the scientific method, as it is practiced by (at least) a recognized minority of scientists in their field." *Id.* at 1319. Due to the requirements of Rule 702, assuring the reliability of the expert's foundational knowledge, experience, and research is an essential aspect of the court's gatekeeping function on a *Daubert* motion. FED. R. EVID. 702. As such, the court must occasionally go beyond the expert's own research and scrutinize the foundational studies and literature which inform the expert's conclusions. *See Daubert II*, 43 F.3d at 1315 (stressing the importance of "scientific knowledge" based on "reliable treatises" and scientific research which predates the litigation in which the expert testifies).

a. Brown County Board of Health

***8** Attached to James's expert report as Exhibit 2(a) is a document entitled "Minutes of Brown County Board of Health meeting including Motion" (the "Brown County Minutes"). (Rizzo Daubert Decl. Ex. B.) The Brown County Minutes are the written minutes for an October 14, 2014 meeting of the Board of Health for Brown County, Wisconsin. (*Id.*) The primary topic of the meeting is to consider taking action against the "Shirley Wind Project" near Glenmore, Wisconsin due to the alleged health effects experienced by individuals living in the area. The meeting begins with members of the board of health reciting portions of a study performed by James on the Shirley Wind Project, including the following conclusion:

> [I]t is reasonable to conclude that the adverse health effects reported by members of the Shirley community are linked to the operation of the Shirley Wind Project wind turbines. While there may still be debate about the precise mechanism that causes these sounds to induce the symptoms; it is clear from this study, and others conducted in different parts of the world by other acousticians, that acoustic energy emitted by the operation of modern utility scale wind turbines is at the root of the adverse health effects.
>
> Following the Precautionary Principle, it is concluded that operation of the Shirley Wind [P]roject is exposing the community members to acoustic energy that can be linked to the reported adverse health effects, is similar to other historical problems with other infrasound noise sources, and that the only method available to protect the community's health is to not operate wind turbines close to homes. For that to occur, either the utility must terminate operations or it should operate with a buffer zone between the wind turbines and the closest residential properties. Given that the recent study shows people reporting adverse health effects at distances of four miles this could require purchase of many of the properties in the community.

(Rizzo Daubert Decl. Ex. B at 3.) James's data associated with his research on the Shirley Wind Project is not attached to or otherwise contained in the minutes. (*Id.*) Following recitation of portions of James's study, the board opened the meeting up to hear comments from the public. (*Id.* at 3.) The relevant portion of the meeting concluded with approval of a parliamentary motion, "[t]o declare the Industrial Wind Turbines at Shirley Wind Project in the town of Glenmore, Brown County, WI a human health hazard for all people (residents, workers, visitors, and sensitive passerby) who are exposed to infrasound/low frequency noise and other emissions potentially harmful to human health." (*Id.* at 13.)

Defendants contend this is not a scientific document which may serve as a foundation for scientific knowledge, and that the portions of James's study referenced in the Brown County Minutes may not serve as foundational scientific knowledge because no data is attached from which a third party could confirm or disprove James's conclusions. Williams, however, declares Defendants' argument a "straw man" and contends the Brown County Minutes were never intended to be a "scientific paper" or "demonstration of science." Instead, Williams contends the Brown County Minutes were "included as a demonstration of how medical practitioners, including a medical doctor trained and experienced in clinical work with patients, use their personal knowledge and skills to associate complaints to a cause." (James Decl. ¶ 11.)

The court agrees with Defendants that the Brown County Minutes do not constitute "scientific knowledge" and may not serve as a foundational document to explain the conclusions James reaches in his expert report. In James's

Rule 26 report, he cites the Brown County Minutes to support the proposition that a causal relationship exists between industrial wind turbines and adverse health effects in humans. However, James's data is not included in the Brown County Minutes, and the Minutes do not reflect any other scientific method which demonstrates the type of "good science" which should form the basis for an expert witness's knowledge. The Minutes are not a published scientific paper subject to the scrutiny of the scientific community. Nor are the Minutes properly described evidencing medical diagnosis or clinical decision making where medical professionals make unbiased treatment decisions to address the symptoms of individual patients. The Brown County Minutes are best described as the documenting the political process surrounding an issue of public concern in Brown County, Wisconsin. This is particularly evident given that a majority of the minutes are devoted to documenting public comments by concerned citizens at the meeting. As such, the Brown County Minutes are not scientific knowledge which may serve as a foundational basis for James's expert opinion.

b. The Schomer Review of Cape Bridgewater ATP

***9** In support of his opinion on general causation, James also cites "two statements issued by Dr. Paul Schomer" which he describes as "peer reviews of a study conducted in Australia by Steve Cooper ...." (Rizzo Daubert Decl. Ex. A at 3.) The first statement ("Schomer I"), briefly describes the "Cape Bridgewater Acoustic Testing Program" case study conducted by Steve Cooper in Victoria, Australia. (McCandlish Daubert Decl. Ex. 1 at 30.) Schomer then proclaims, with little explanation or additional reasoning, that the study conclusively proves the causal relationship between wind turbine operations and adverse health effects in humans. (*Id.*) Thereafter, Schomer warns that "some will undoubtedly argue that a correlation does not show cause and effect." (*Id.*) He labels this argument as "groundless" and "creative logic" which relies on the postulation that "some other thing like an unknown 'force' that simultaneously causes the wind turbine power being generated and symptoms such as nausea, vertigo, and headaches to change up and down together." (*Id.*)

The second document, which Schomer issued on February 20, 2015, serves as a response to certain criticisms of the Cape Bridgewater study and Schomer I. (Declaration of Attorney James E. McCandlish in Support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment or Alternative Request for a *Daubert* Hearing ("McCandlish Daubert Decl.") Ex. 1 at 32.) Among other criticisms, Schomer responds to the critique that the Cape Bridgewater study was not a "medical study," and that Schomer is not qualified to opine on the epidemiological relationship between acoustic stimuli created by wind turbines and adverse health effects in humans. (*Id.*) Schomer contends this criticism is unwarranted, and that he and the author of the Cape Bridgewater ATP are not holding out their conclusions as "medical conclusions." (*Id.*) He proceeds to analogize the causal relationship shown in the study to the relationship between some individuals' consumption of beans and the digestive gas created by those individuals thereafter:

> The Cooper study is a variation of how one "discovers" the relationship: beans in – gas out. Cooper examines three possible inputs: sound level of the receivers (six subjects), the vibration levels at the receivers, and the power output of nearby turbines. Cooper's outputs are the periodic observations by each subject as to the degree by which they feel they are being affected by wind turbines, specifically at the time they are giving these observations. The cause and effect is found between the input, the turbine power, and the outputs, subject's judgments as to the degree they are being affected at the time.... [T]he processes inside the body are not explained; [so] nothing "medical" is dealt with.

(*Id.*)

The court agrees with Defendants that the Schomer documents do not represent reliable "scientific knowledge" which James may use as a foundation for his expert conclusions. First, the Schomer documents are not a scientific study. Schomer includes no independent data or analysis of the Cape Bridgewater ATP. Instead, he summarizes the study and offers a brief defense of Cooper's work without critical analysis or any discussion of the study's limitations. There is no evidence Schomer's

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documents were published in a reputable journal or have otherwise been peer reviewed by respected acousticians in the scientific community. Third, the opinions expressed by Schomer are not "scientific." They are not supported by citation to corroborating studies or even explained in much detail. Schomer's thoughts, as expressed in these documents, consists primarily of unsupported conclusions which are not suitable to serve as a basis for "scientific knowledge."

Because the Schomer's review documents lack scientific reliability, they do not establish a definitive causal relationship between infrasound and adverse health effects. Thus, to the extent James bases his causal theory on the Schomer documents, those opinions lack scientific reliability and are not helpful to the court, and will be excluded.

c. Cape Bridgewater Acoustic Testing Program

***10** Although James does not cite directly to it in his expert report, Defendants move to exclude James's causation testimony to the extent it relies on the Cape Bridgewater ATP. (Rizzo Daubert Decl. Ex. F.) Defendants argue that the Cape Bridgewater ATP lacks scientific reliability because the author's methods were not scientific, and the author himself concedes that the study has too many limitations to conclusively establish causation.

In the Cape Bridgewater ATP, acoustician Steven Cooper ("Cooper") was retained by the company operating a wind-turbine project in Victoria, Australia to study the effects of the wind turbines on six local residents. (*Id.*) Cooper began by taking broad-spectrum sound and sound-pressure measurements in and around three homes located between 650m and 1600m from a wind turbine. (*Id.*) He then compared that data to operations data provided by the company operating the wind turbines to identify the audible and inaudible frequencies associated with the turbines' operation (the "Wind Turbine Signature"). (*Id.*) Finally, Cooper had six test subjects who self-reported turbine-associated symptoms record their experiences in a diary every few hours. (*Id.*)

The subjects were instructed to record their observations over the course of ten weeks regarding the observable noise and vibration produced by the wind turbines. (*Id*) They were also instructed to record the type and severity of the "sensation" they felt at the time of the diary entry. (*Id.*) The author defined "sensation" as (1) headache; (2) pressure in the head, ears, or chest; (3) ringing in the ears; (4) tachycardia; and (5) a sensation of heaviness. (*Id.*) Ultimately, statistical comparisons of the three sets of data showed an association with subjects experiencing a "high severity" of sensation when one of the following conditions was present: (1) "when the turbines were seeking to start (and therefore could drop in and out of generation);" (2) "an increase in power output of the wind farm in the order of 20%;" (3) "a decrease in the power output of the wind farm in the order of 20%;" and (4) " ... when the turbines were operating at maximum power and the wind increased above 12 m/s." (*Id.* at 167.) However, there "were at times other instances of high severity of [sensation] not fitting the above four scenarios." (*Id.*) Moreover, the author was able to find no association between the subjects' feeling of "sensation" with the decibel measurements intended to capture the audible volume of the noise produced by the turbines. (*Id.*) Based on that comparison, the author surmised that the "sensation" among subjects was caused not by audible noise, but by low-frequency infrasound which is below the human hearing threshold. (*Id.*)

i. Acoustic Outputs and WTS

James relies on the Cape Bridgewater ATP for two scientific propositions. First, he cites the Cape Bridgewater ATP in his rebuttal report for the proposition that, through broad-spectrum sound-pressure measurements, one can demonstrate the existence of a Wind Turbine Signature ("WTS"). The Wind Turbine Signature is the set of acoustic outputs and the associated harmonic frequencies created by the operation of a particular type of wind turbine. The court concludes this is reliable scientific knowledge under *Daubert*. First, the method of identifying the frequencies emitted by a wind turbine appears to be generally accepted in the field of acoustic sciences. James, Schomer, Salt, and even Defendants' expert have utilized some form of the methods applied by Cooper in the Cape Bridgewater ATP for determining the WTS of other wind turbines.

***11** Second, although other portions of the Cape Bridgewater ATP have not been subjected to meaningful peer review, the methods Cooper applies to show the

WTS have been subject to “true peer review.” Legal commentators have articulated two types of peer review, “true peer review,” and “editorial peer review.” *See* *Valentine v. Pioneer Choir Alkali Co., Inc.*, 921 F. Supp. 666, 675 (D. Nev. 1996) (citing Effie J. Chan, *The “Brave New World” of Daubert: True Peer Review, Editorial peer Review, and Scientific Validity*, 70 N.Y. U. L. Rev. 100 (1995) (note)). “Editorial peer review” is the process by which reputable scientific journals choose which articles it will publish. *Valentine*, 921 F. Supp. at 675. Editorial peer review is not necessarily a good measure of the scientific reliability for a study, as “the average [peer-reviewing] referee spends less than two hours assessing an article submitted” to a journal. *Id.* Moreover, the editorial peer review process is rife with the internal politics of academia. *Id.*

“True peer review” on the other hand, is the process by which an author's peers review the author's methods and attempt to replicate the results through retesting. *Id.* Some have labeled true peer review “the essence of science.” *Id.* Here, Cooper's methods for measuring the acoustic outputs of the Cape Bridgewater wind turbines, and his articulation of the WTS, have been reviewed by acousticians around the world and successfully replicated. It is clear that, due to its replicability, this method has become generally accepted in the acoustician community.

Third, Cooper's methods are capable of empirical verification as demonstrated by their continued use in the acoustician community. Finally, Defendants do not contend that the margin of error lies within an unacceptable limit. Therefore, the court will accept James's testimony about measuring acoustic outputs of wind turbines and creation of a WTS to the extent that testimony is based on the Cape Bridgewater ATP.

ii. Causation

James also cites the Cape Bridgewater ATP for his opinion that wind turbine acoustic outputs have a causal relationship to human adverse health effects, but the author of Cape Bridgewater ATP articulated significant shortcomings of the study as it relates to proving causation. First, the study's methods were not scientifically rigorous and are not generally accepted in the scientific community. The author of the study concedes that there were significant reporting abnormalities which affected the reliability of some data. At first, the test subjects did not understand their duty to fill out diaries every one-to-two hours. It was only part of the way through the study that they began filling out their diaries as intended. Moreover, the author noted that there “were significant issues in terms of instrumentation,” and cautioned future researchers against relying on manufacturers data to record measurements. (*Id.* at 170.) Second, the subject pool was small, and the individuals in the subject pool were not selected at random. Instead, the subjects of the study were self-selected based on their own pre-existing reactions to wind turbines. Thus, “the findings must be considered as **preliminary** and warrant[ ] further detailed studies of the scientific rigor necessary for the purpose of confirming/verifying” the study's findings. (*Id.* at 185) (emphasis original).

In addition, when analyzing “sensation” data, the author failed to analyze large amounts of data. Of the data collected, Cooper wrote only about the reports of level four and level five “sensations.” (Rizzo Daubert Decl. Ex. F at 126.) Subjects reported “441 Sensations classified as severity ranking 4, and 81 as severity ranking 5.” (*Id.*) Cooper analyzed 323 level 4 and 5 responses against the turbine power output data. However, Cooper did not analyze the level four data against the noise and infrasound data because “the degree of time involved in analysing [*sic*] the data ... would be significant.” (*Id.*) Moreover, thirty of the eighty-one level-five responses were not analyzed because the corresponding noise measurements were unavailable. (*Id.*) Due to the statistical methods involved, most notably the analysis of only six self-selected participants with pre-existing symptoms, Cooper specifically recognizes that it is not a reliable scientific basis to establish causation, and specifically provides that there “is not enough data from this study to justify any change in regulation.” (*Id.* at 230.) Another limitation noted by Cooper was that this “study did not include any testing in relation to sleep disturbance or health effects.” (*Id.* at 229.)

***12** Here, the *Daubert* factors weigh against accepting James's causation opinion to the extent it is premised on the Cape Bridgewater ATP. As the court has discussed, the statistical and methodological abnormalities present in this study show Cooper's methods were not generally accepted in the scientific community to definitively prove causation. Instead, Cooper's study is best described as a “case study,” which does not provide sufficient statistical

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reliability to constitute scientific evidence. *Casey v. Ohio Medical Prod.*, 877 F. Supp. 1380, 1384 (N.D. Cal. 1995). The existence of statistical and methodological abnormalities also lessens the importance of the study's replicability. Even though it is replicable, the replicating study would lack scientific reliability. Further, there is no evidence Cape Bridgewater ATP has been published in a reputable scientific journal. James contends that the Schomer documents constitute a "peer review" of the study, but the court is not convinced that Schomer's non-critical and non-analytical endorsement of the Cooper study constitutes the type of rigorous peer review which lends itself to scientific reliability. Accordingly, the court will not admit James's opinion on causation to the extent it is based on the findings of the Cape Bridgewater ATP.

d. N.D. Kelley Paper

Defendants move to exclude James's causation testimony to the extent it is premised on the paper "A Proposed Metric for Assessing the Potential of Community Annoyance from Wind Turbine Low-Frequency noise Emissions" by N.D. Kelley (the "Kelley Study"). In the Kelley Study, Kelley sought to quantify the "annoyance" felt by subjects when they were exposed to extremely low-frequency sound. (Rizzo PSJ Decl. Ex. J at 1.) Kelley placed the subjects in a room and in an adjacent room, put a speaker which would emit sounds below the range of audible frequencies in humans. (*Id.* at 5-6.) He also put measures in place to prevent associated audible noise from confounding the results. The subjects then recorded their "annoyance" level as they were exposed to various frequencies. (*Id.*)

Kelley found that "people do indeed react to a low-frequency noise environment" and registered "annoyance" for very low frequencies, even when the standard, A-weighted decibel level was low. (*Id.* at 8.) As a result, he concluded that the standard A-weighted decibel "measurements are not an adequate indicator of annoyance when low frequencies are dominant." (*Id.*)

However, like James's other sources, the Kelley study has significant scientific shortcomings. First, Kelley takes data from only seven subjects. He admits that the "experiment would have to be repeated with a much larger number of evaluators (population) to confirm" his results as scientific knowledge. (*Id.* at 8.) Moreover, there is no evidence the Kelley study was published in a reputable scientific journal or that it was subject to any manner of peer review. Finally, even if these methodological deficits were not present, the Kelley study would not be reliable scientific evidence of a causal relationship between wind turbine infrasound and adverse health effects in humans because Kelley studied only whether low frequencies produce "annoyance" in those exposed to them. The study does not support the proposition that wind-turbine infrasound is capable of producing broader adverse health effects, including anxiety, panic attacks, and sleeplessness.

Because James does not cite any foundational literature which supports his causation opinion, the court concludes James's opinion lacks the indicia of scientific knowledge necessary for the court to consider it under Rule 702. Therefore, the court will exclude James's conclusions regarding the causal relationship between infrasound produced by wind turbines and adverse health effects.

2. Qualification to Testify on Causation

Defendants next argue that, because James does not have the qualifications to opine on causation based on his education and work experience, the court should exclude his causation testimony. Williams disagrees, and contends James's long career as an acoustician who studies sound-pulses produced by industrial equipment qualifies him to opine on general causation. The court agrees with the Defendants.

***13** James received a Bachelor's degree in mechanical engineering from General Motors Institute with a focus on "Noise Control Engineering." (McCandlish Daubert Decl. Ex. 1 at 8.) He served as an adjunct instructor at Michigan State University from 1985 to 2013, and as an adjunct professor at Central Michigan University from 2012 to 2015. (*Id.*) Currently, James is the principal consultant and founder of E-Coustic Solutions. (*Id.*) He has a long career studying the noise and sound-pressure produced by industrial wind turbines. However, he is not a doctor or epidemiologist. As a result, he does not have the training to opine that the infrasound and audible noise created by wind turbines activates physiological mechanisms in the body which produce adverse health effects.

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3. Reliability of Methodology

Defendants also move to exclude James's testimony regarding three additional opinions: (1) that wind turbines produce broad-spectrum sound pressure, including audible noise and infrasound; (2) that generally accepted scientific methods may be applied to measure those acoustical outputs; and (3) that James was able take measurements inside Williams's home to capture the acoustical output, or Wind Turbine Signature of the wind turbines located nearby. The court disagrees, and concludes James has the qualifications and experience to offer each opinion, and that he reliably applied reliable scientific methods in this case to take acoustical readings inside Williams's home.

James has the qualifications and experience to opine on acceptable methods for measuring the broad-spectrum sound pressure and identifying the Wind Turbine Signature. James testifies in his Declaration that "the methodologies I use, full-spectrum recordings using instruments with appropriate sensors for the type of sound to be recorded and subsequently analyzed have been used by acousticians for at least 40 to 50 years." (James Decl. ¶ 8.) These methods are utilized in each study and case study cited in the record, including the Cape Bridgewater ATP and others. (*See* McCandlish Daubert Decl. Ex. 1 at 76-213.) It is clear these methods are capable of repetition, and that they are based on objective measures (Hz and dB, among others) which lend to its scientific reliability. Defendants offer no reason to reject James's opinions regarding the fact of turbines' acoustical output, or that those outputs may be measured and quantified. Therefore, the court will allow James to offer his opinions on those subjects.

Defendants last contend James did not apply reliable methods in this case to take accurate acoustic measures in Williams's home. Specifically, they contend James did not visit the property, did not set up the equipment, and cannot establish a "chain of custody" for his instrumentation which suggests the data could have been manipulated. The court disagrees.

James thoroughly explains in his declaration that, due to the nature of the instruments used, the data would reflect any manipulation of the equipment. He testifies that "[s]afety/security features are part of he system," including a "GPS component that logs the location" of the testing equipment. (James Decl. ¶ 10.) "Any attempt to relocate the system would be documented in a time stamped log file." (*Id.*) Moreover, James instructed Williams to set the equipment up in an empty bedroom where it would be undisturbed by the noise associated with people moving around the room. (*Id.*) Aside from speculation, Defendants offer no evidence that James's methods led to abnormalities or anomalies in the data. Therefore, this portion of their motion is denied.

4. Conclusions

After careful review of the record and briefs, the court concludes that James may testify: (1) that wind turbines produce broad-spectrum acoustic outputs, including audible noise and infrasound, that can be measured; and (2) that he reliably applied generally-accepted methodology to measure the broad-spectrum sound pressure present in Williams's home. James's testimony on these points is based on generally-accepted methods and reliable scientific knowledge; the methodology is testable and replicable; and to the extent acousticians have repeatedly replicated these methods, they have been subject to "true peer review" in the scientific community. Moreover, there is no indication that these methods were applied in an unreliable fashion by James.

***14** However, the court concludes James may not testify that these broad-spectrum acoustic stimuli produce adverse health effects in humans. James is neither a medical professional nor an epidemiologist, and the sources he cites in his Rule 26 report do not constitute reliable treatises or contain "objective, verifiable evidence ... based on 'scientifically valid principles" linking turbine-created infrasound to adverse health effects. *Daubert II*, 43 F.3d at 1138. Nor does James cite material which has "been subjected to normal scientific scrutiny through peer review and publication." *Id.* He relies exclusively on case studies, which at least one court in this district concluded "are universally regarded as an insufficient scientific basis for a conclusion regarding causation because case reports lack controls." *Hall v. Baxter Healthcare Corp.*, 947 F. Supp. 1387, 1411 (D. Or. 1996) (citing *Casey*, 877 F. Supp. at 1384, among others). While "[c]ausation can be proved even when we don't know precisely *how* the damage occurred," James does not come forward in this case with "sufficiently

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compelling" scientific proof to support his opinions on causation. *Daubert II*, 43 F.3d at 1314.

It is wholly possible that the adverse health effects articulated in the literature James cites are caused by infrasound and other acoustic outputs of wind turbines. However, the court does not concern itself during a *Daubert* analysis on the accuracy of the expert's results. Instead, the court must consider whether the methods used and sources relied upon are "scientifically reliable." The record before the court does not support Williams's contention that James's causation opinion is scientifically reliable. Therefore, the court excludes James's opinions on general causation.

B. Punch

Defendants move to exclude Punch from testifying regarding the general causal connection between wind-turbine acoustic outputs and adverse health effects in humans. They contend Punch: (1) did not apply reliable methodology to assess Williams's symptoms; and (2) based his opinions on unreliable and unscientific literature. Williams contends Punch applied reliable methodology, and has thoroughly justified his opinions by citing to dozens of studies and papers.

1. Reliable Methodology

Defendants argue Punch did not apply reliable methodology because he based his opinions in part on Williams's explanation of his symptoms in a questionnaire, which Defendants describe as unreliable. Punch used an eight-page questionnaire to "understand Williams'[s] complaints, what they were, the circumstances as to when they arose, when they subsided, frequency, duration and intensity ...." (Punch Decl. ¶ 3(a).) The questionnaire is eight pages long and is divided into three sections. (Rizzo Daubert Decl. Ex. V.) The first section asks the participant to check a box next to any of seventy-two symptoms that "have begun, or have become noticeably worse, after the industrial wind turbine project began operation" and asks the participant to describe the symptoms in detail on a separate page. (*Id.*) "Section 2" of the questionnaire asks the subject to answer a series of questions about the subject's symptoms, the subject's belief in the cause of those symptoms, and whether certain variables lessen or enhance the subject's symptoms. (*Id.* at 3-5.) "Section 3" contains a set of "miscellaneous" questions. (*Id.* at 6-8.)

Punch did not personally interview Williams or any other witness in this case, but he reviewed other data on the record. (Punch Decl. ¶ 3.) He reviewed the deposition testimony of Williams, Williams's neighbor, and Williams's ex-girlfriend, which Punch cross-checked against Williams's responses in the questionnaire. (Punch Decl. ¶ 3(a).) Punch also reviewed the acoustic data collected by James and Invenergy's expert, Robert O'Neal. (Punch Decl. ¶ 15(b).)

The Defendants contend the questionnaire is unreliable because it is "designed to encourage the subjective reporting of non-specific symptoms" which may be attributable to other causes and "does not permit wind farm complainants to express a difference in symptoms when wind turbines were on or off." The court disagrees with both critiques. First, there is nothing suggestive or leading about the questionnaire. Section 1 of the questionnaire allows the subject to pick from among seventy-two symptoms. No emphasis is placed on any one symptom or group of symptoms, and nothing in the explanations that precede the checklist or the or questions that follow are suggestive of which symptoms the subject should "check." In fact, aside from the fact it was developed by Punch and James, Defendants identify nothing in the questionnaire which shows it is suggestive or unreliable.

***15** Defendants also argue the questionnaire is unreliable because it "does not permit wind farm complainants to express a difference in symptoms when wind turbines were on or off." Again, the court disagrees. The second page of "Section 1" provides a space for the subject to describe their symptoms in detail. (Rizzo Daubert Decl. Ex. V at 2.) Moreover, the questions in Section 2 and Section 3 allow ample opportunity for the subject to explain differences in symptomatology during operation or non-operation of the wind turbines. (*Id.* at 3-6.) Williams even explains in question (a) that "[s]leep losses start and stops [*sic*] when I am around the turbines and they are turning. See my deposition." (*Id.* at 3.) Therefore, the court will not exclude the questionnaire or Punch's opinions thereof.

To the extent Defendants sought to argue that questionnaires are an unreliable methodology for documenting a subject's complaints, the court also

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disagrees. Punch testifies that "though a survey interview is not considered experimentation, it is regarded by the scientific community as a form of standard self-report research that is useful in gathering information about an individual's attitudes, opinions, symptoms, personal experiences or traits and beliefs." (Declaration of Jerry Punch, PHD, in support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment or Alternative Request for a *Daubert* Hearing ¶ 15.) Defendants offer no reason to discount this testimony or otherwise reject the use of questionnaires in general. Therefore, Defendants' motion is denied on this point.

2. Scientific Reliability of Causation Opinion

Defendants challenge the scientific reliability of Punch's opinion on general causation. Their arguments can be grouped into two rough categories. First, they argue Punch does not have the qualifications to opine on general causation without resorting to documentary and empirical support. Second, Defendants argue the support Punch cited in and attached to his expert report does not constitute "scientific knowledge." Because Punch does not cite to adequate scientific sources to support his opinions on causation, the court should exclude his expert opinion on that point under *Daubert*.

a. Qualifications

Defendants contend Punch may not opine on causation solely on the basis of his qualifications. The court agrees. Punch's qualifications are impressive, to be sure. After earning his bachelors degree in psychology from Wake Forrest University, he earned a masters degree in Audiology and Speech Pathology from Vanderbilt University and a Ph.D. in Audiology from Northwestern University. (McCandlish Daubert Decl. Ex. 2 at 7.) He has served as a clinical audiologist, an assistant professor at two universities, an associate professor at Indiana University School of Medicine, a tenured associate professor at Michigan State University, Chair of the Audiology and Speech Sciences at Michigan State University, and director of the research division at the American Speech-Language-Hearing Association, among other positions. (*Id.* at 8.) Punch has also taught a litany of classes at the university level and written many published, editorially peer-reviewed articles. (*Id.* at 8-12.) However, Punch is neither a medical doctor nor an epidemiologist who could opine on the cause of Williams's symptoms solely on the basis of these qualifications. Therefore, for Punch's causation testimony to be admissible under *Daubert*, he must support his causation opinion with reference to foundational literature which establishes the causal relationship through the application of "scientific knowledge."

b. Support from Scientific Literature

Defendants next contend Punch's causation opinion is not supported by "scientific knowledge" because the literature on which he bases that opinion consists of unreliable case studies and unproven hypotheses which have not been peer reviewed. In particular, they question the scientific reliability of three documents: (1) the 2009 book *Wind Turbine Syndrome*, by Nina Pierpont ("Pierpont"); (2) "A Theory to Explain Some Physical Effects of the Infrasonic Emissions at Some Wind Farm Sites," by Schomer, Edreich, Pamidighantam, and Boyle (2015) ("Schomer et al."); and (3) "Responses of the Ear to Low Frequency Sounds, Infrasound and Wind Turbines" by Salt and Hullar (2010). Williams contends these articles are but a small portion of the literature which supports Punch's conclusions, and the court should deny Defendants' motion.

***16** The court already has explained that the Brown County Minutes, the Schomer Critique, and the Cape Bridgewater ATP are scientifically unreliable and do not prove causation. Similarly, the Pierpont and Schomer et al publications do not constitute "scientific knowledge." For both pieces, the authors collected anecdotal data on the symptoms of self-selected individuals living near wind turbines who had already reported symptoms the subjects themselves had linked to the presence of wind turbines. In the case of Pierpont's case study, the author "chose a cluster of the most severely affected and most articulate subjects [she] could find." (Rizzo Daubert Decl. Ex. X at 16.) She cautioned that her sample size and methods cannot establish a "gradient of effects with a gradient of exposure" and "is not an epidemiologic sample." (*Id.*) Similarly, Schomer et al caution that "[t]his paper presents a theory upon which needed investigations can go forward," and although the authors present an interesting theory regarding the physiological mechanisms which could cause the health

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effects purportedly associated with exposure to industrial wind turbines, there is no accompanying statistical analysis which demonstrates causation to any degree of scientific reliability. Without comparing the statistical prevalence of adverse health effects near wind turbines to that of the broader community, or to data taken before the wind turbines became operational among the same study participants, the court cannot conclude that Williams's experts adequately demonstrate causation.

The Ninth Circuit's analysis in *Daubert II* is instructive on this point. 43 F.3d at 1313. There, the plaintiff sued Dow Pharmaceuticals claiming that her child's birth defects were caused by the plaintiff's use of Bendectin, an anti-nausea drug manufactured by the defendant. *Id.* The Plaintiff submitted expert-witness reports which opined that a causal relationship existed between the drug and the birth defects. *Id.* Thus, the court was tasked with determining whether the expert-witness reports reflected "scientific knowledge." *Id.* The court began its analysis by observing that "[c]ausation can be proven even when we don't know precisely *how* the damage occurred, if there is sufficiently compelling proof that the agent must have caused the damage *somehow.* One method of proving causation in these circumstances is to use statistical evidence." *Id.* (emphasis original). The court explained further:

> To evaluate the relationship between Bendectin and [birth defects], an epidemiologist would take a sample of the population and compare the frequency of birth defects in children whose mothers took Bendectin with the frequency of defects in children whose mothers did not. *See DeLuca,* 911 F.2d at 946. The ratio derived from this comparison would be an estimate of the "relative risk" associated with Bendectin. *See generally* Joseph L. Fleiss, *Statistical Methods for Rates and Proportions* (2d ed. 1981). For an epidemiological study to show causation under a preponderance standard, "the relative risk of limb reduction defects arising from the epidemiological data ... will at a minimum, have to exceed '2.' " *DeLuca,* 911 F.2d at 958. That is, the study must show that children whose mothers took Bendectin are more than twice as likely to develop limb reduction birth defects as children whose mothers did not.

Daubert II, 43 F.3d at 1321 (footnote omitted).

Here, neither the Pierpont nor Schomer information constitutes an epidemiological study or shows a significant statistical relationship between turbine-generated infrasound and adverse health effects. The third article, by Salt and Hullar, supports its theory of causation by demonstrating that some low-frequency sounds simulate hair-cells in the cochleas of guinea pigs. However, the Salt and Hullar article, like Punch's other exhibits, fails to demonstrate the statistical relationship between low-frequency wind-turbine infrasound and human health effects. Similar to *Daubert II*, the court cannot ignore the lack of statistical or epidemiological evidence to prove Williams's theory of causation.

Williams also argues that the court should allow Punch to testify on causation because he was able to produce significant support for his opinion in his declaration. Punch's Declaration includes several string citations to various papers and studies which purportedly support his opinion. However, Punch did not cite these authorities in his expert witness report, and there is no evidence Invenergy was made aware of these sources prior to depositions. Rule 26 requires that an expert witness attach to his or her report "any exhibits that will be used to summarize or support" the expert's opinions. FED. R. CIV. P. 26(a)(2)(B) (iii). Failure to do so may be ground for exclusion because, as Judge Aiken reasoned in *McClellan v. I-Flow Corp*, 710 F. Supp. 2d 1092, 1029 (D. Or. 2010), "it is not defendants' responsibility to track down documents that purportedly support the opinion of plaintiffs' expert; it is plaintiff's duty to disclose the relevant documents or accept the consequences for failing to do so." The court agrees with Judge Aiken's observation, and concludes Punch's causation testimony should be excluded for failure to attach scientifically reliable supportive documents, or citations to such documents, to his expert report.

***17** In the absence of scientific evidence showing general causation, the court also concludes Punch may not testify about the hypotheses of Pierpont, Schomer et al, and Salt regarding the physiological mechanisms underlying the alleged causal relationship. Each author refers to their proposal as a "hypothesis" or "theory." However, none of these hypotheses or theories has been subject to experimental testing. As the Ninth Circuit reasoned in *Claar*, "scientists whose conviction about the ultimate conclusion of their research is so firm that they are willing to aver under oath that it is correct prior to performing the necessary validating tests could properly be viewed by the district court as lacking the objectivity that is

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the hallmark of the scientific method." 29 F.3d at 503. Therefore, the court concludes Punch may not opine on the relationship between wind-turbine infrasound and human adverse health effects or the prevailing hypotheses regarding the physiological mechanisms underlying that alleged causal relationship.

c. Admissible Subjects of Testimony

Although Punch may not testify that non-audible infrasound and other low-frequency sound pulses cause adverse health effects, Defendants do not challenge Punch's qualification or expertise to testify regarding the audible noise created by wind turbines and the causal relationship between that noise and sleep disturbance. Punch cites literature which discusses the link between audible noise levels and "annoyance" or disturbance, including the executive summary of a report issued by the World Health Organization ("WHO"). The WHO is a reputable organization, and Defendants produce no reason to question the scientific reliability of the WHO paper. Therefore, Punch may reference this "scientific knowledge" to support his opinion that wind turbines produce audible noise which may disturb individuals and interfere with sleep.

C. Ironside

Defendants challenge the opinion of Dr. Ironside that infrasound was a cause of Williams's short-term insomnia. They contend Dr. Ironside has neither the qualifications nor the expertise to offer such an opinion. The court agrees. Dr. Ironside admitted at deposition that he was not an expert in infrasound and could not parse the relative contribution of audible noise and infrasound to Williams's sleep disturbance. Dr. Ironside's anecdotal experience with infrasound produced by a lion's roar and an earthquake does not qualify him to opine on causation. The only outside source Ironside relied upon was the James Report. As the court discussed *supra*, James does not demonstrate in his report that his opinions on general causation between infrasound and adverse health effects reflect "scientific knowledge." Thus, the James report may not be relied upon by experts in other fields as authoritative evidence in support of a particular conclusion. Dr. Ironside's opinion that Williams's short-term insomnia was caused, in whole or in part, by infrasound produced by the wind turbines is not scientifically reliable and thus not helpful to the court. Accordingly, it is excluded under *Daubert*.

However, Defendants do not move to exclude Dr. Ironside's testimony to the extent he intends to testify regarding the causal relationship between audible noise produced by the wind turbines and Williams's sleep disturbances. Given Dr. Ironside's speciality in sleep medicine and the typical factors associated with sleep disturbance, the court concludes he may provide this opinion to the court.

II. Motion for Summary Judgment

Defendants contend they are entitled to summary judgment or partial summary judgment in three ways. First, they contend Williams cannot prove a prima facie case of nuisance without his expert witnesses's testimony on causation. Second, they argue Williams's nuisance claim predicated on the turbine's flashing lights is preempted and otherwise not legally cognizable. Third, Defendants argue Williams cannot recover punitive damages and injunctive relief as a matter of law.

A. Proof of Causation

***18** Defendants argue that, because the court granted their *Daubert* motion in part, they are entitled to summary judgment because Williams cannot prove the causal element of his claim. Williams contends he can establish his claims even without expert testimony.

"Any person whose property or personal enjoyment thereof is affected by a private nuisance, may maintain an action for damages therefor." OR. REV. STAT. § 105.505. Whether an activity constitutes a nuisance "depends upon its effect upon an ordinary reasonable man, that is, a normal person of ordinary habits and sensibilities." *York v. Stallings*, 217 Or. 13, 20-21 (1959). The "interference with the use and enjoyment of land is not actionable unless it is substantial and unreasonable." *Aldridge v. Saxey*, 242 Or. 238, 243 (1965). However, "all that need be established is that the annoyance is regarded as harmful to the health or comfort of ordinary people." *Seagraves v. Portland City Temple*, 269 Or. 28, 32 (1974). To determine whether the activity at issue constitute a nuisance, courts consider: (1) the location and character o the neighborhood; (2) the extent and frequency of the injury; and (3) the effect upon the enjoyment of life, health and property. *Aldridge*, 242 Or. at 243. However, a plaintiff may recover damages only for those injuries which are "causally linked" to the nuisance. *See* *Lunda v. Matthews*, 46 Or. App. 701, 709 (1980) (Awarding emotional distress damages because the nuisance would offend a reasonable person and "[a]ny anguish plaintiffs suffered is causally linked to their concern over the affects of the defendants' trespass and the resulting nuisance.").

Here, Williams contends that Defendants' operation of the Willow Creek Wind Facility have interfered with the use and enjoyment of his property because the audible noise, vibration, light, and infrasound emitted by the wind turbines causes him stress, anxiety, and loss of sleep. The court has already concluded that, under *Daubert*, Williams's experts may not opine on the causal relationship between low-frequency infrasound and adverse health effects in humans. Therefore, Williams cannot prove infrasound interferes with the enjoyment of his property and cannot prove his nuisance claim on that basis. Therefore, Defendants are entitled to summary judgment on Williams's nuisance claim to the extent it is premised on infrasound produced by the Willow Creek wind turbines.

However, Williams's claims are not based exclusively on nuisance caused by infrasound, and the record contains ample evidence to create a genuine issue of material fact on whether the audible noise, light, and vibration produced by the Willow Creek wind turbines constitutes a nuisance. Williams has introduced the testimony of both lay witnesses and expert witnesses which links audible noise, light, and vibration with Williams's sleep disturbance, stress, and anxiety.

To the extent Defendants contend Williams cannot prove his claims without expert testimony, they are mistaken. In *Seagraves*, the court rejected the defendant's argument that objective measurements or expert statements were necessary to prove a nuisance claim. 269 Or. at 32. The court continued, "[t]he cases are legion in which the extent of the interference with reasonable use and enjoyment attributable to a noise has been established by the evidence of witnesses describing the character and effect of the noise." *Id.* The same principle applies to vibration and light, which are readily perceptible to the ordinary person. Therefore, to the extent Defendants' moved for summary judgment on Williams's nuisance claim based on the audible noise and vibration, that motion is denied.

B. Nuisance based on "Flashing Lights"

***19** Defendants next argue Williams's nuisance claim based on the wind-towers' flashing lights is preempted by federal law and not cognizable under Oregon law. In response to Defendants' arguments, Williams withdrew his claim premised upon the disturbance caused by the flashing lights on the wind-turbine towers. Therefore, this claim is dismissed with prejudice.

C. Punitive Damages

Defendants next move for summary judgment on Williams's claims for punitive damages. They contend no reasonable jury could find Williams is entitled to punitive damages by the clear and convincing evidence because: (1) Williams cannot create a genuine issue of material of fact on whether Defendants acted with the requisite culpability; and (2) Defendants engaged in good-faith efforts to mitigate the alleged nuisance. Williams contends that, despite the heightened burden of proof, he can demonstrate a genuine issue of material fact on whether Defendants acted maliciously and deceptively, thus entitling him to punitive damages.

In Oregon, a plaintiff may prove he or she is entitled to punitive damages "by clear and convincing evidence that the party against whom punitive damages are sought has acted with malice or has shown a reckless and outrageous indifference to a highly unreasonable risk of harm and has acted with a conscious indifference to the health, safety and welfare of others." OR. REV. STAT. § 31.730. Although the type of conduct necessary to implicate a punitive damages award depends significantly on the type of case at issue, courts typically hold that an award of punitive damages is proper where the defendant acted with "malice," in an "aggravated" manner, or acted "willfully" "wantonly," or "recklessly." *Andor by Affatigato v. United Air Lines, Inc.*, 303 Or. 505, 512-513 (1987).

In nuisance actions, punitive damages are recoverable where the defendant acted with an "aggravated disregard of the rights of others and where the violation of societal interests is sufficiently great and of a kind that sanctions would tend to prevent." *Senn v. Bunick*, 40 Or. App. 33, 41 (1979) (internal quotation marks omitted). The defendant need not exhibit an intent to injure the plaintiff. *Id.* In fact, the Oregon Supreme Court has observed that:

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> punitive damages serve the function to deter enterprises from accepting the risks of harming other private or public interests by recklessly substandard methods of operation at the cost of paying economic compensation to those who come forward to claim it. Such operations may well be wholly impersonal with respect to any victim, indeed conducted with the hope that no harm will occur, and they may not involve a culpable attitude on the part of any one person responsible for the management of the enterprise; yet this court has held that such lack of managerial culpability alone does not foreclose punitive damages.

Andor by Affatigato, 303 Or. at 514 (quoting *Schmidt v. Pine Tree Land Dev.*, 291 Or. 462, 466 (1981) (internal citations omitted)). However, punitive damages are not available in cases where the defendant acted only in good faith. *Senn v. Bunick*, 40 Or. App. 33, 42 (1979). "Obviously, awarding punitive damages against a defendant who took pains to avoid encroachment [on the plaintiff's rights], and who honestly and reasonably believed he was not encroaching [on those rights], would not promote societal interests by deterring others in the future." *Id.*

***20** Here, Williams has introduced evidence which could suggest Defendants engaged in deception while dialoging with Williams and other concerned neighbors about the applicable noise limits, and continued to operate despite knowing they were violating ths state-mandated noise standards. Shortly after local residents complained to Invenergy about the audible noise produced by the wind turbines, Invenergy hired acoustic consultants to conduct a noise study of the residences surrounding the wind farm. The noise study demonstrated as early as March 25, 2009 that there were noise exceedences at Williams's home. (Declaration of Attorney James E. McCandlish in Support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment ("McCandlish PSJ Decl.") Ex. 16 at 2.) The evidence shows that Willow Creek continued to operate despite this knowledge.

Moreover, the evidence demonstrates that Willow-Creek representatives misrepresented the applicable standards in an attempt to convince them to drop their complaints against Willow Creek. David Iadarola, the Willow Creek project manager, testified that at the time he discussed the noise levels with residents, he was aware Defendants were required to comply with the state-mandated noise limit of 36 dB. (McCandlish PSJ Decl. Ex. 26 at 4.) However, Williams and his neighbor Michael Eaton testified that, at their meeting with Iadarola, he claimed Defendants needed only to keep the noise below the county-imposed limit of 50 dB. (McCandlish PSJ Decl. Ex. 25 at 6-7, Ex. 27 at 3.) The witnesses contend that, when they raised their concern that Defendants needed to comply with the 36 dB limit, Iadarola responded that he "didn't read it that way" and that "we got 50 [dB], County allows 50 [dB], we're at 50 ...." (McCandlish PSJ Decl. Ex. 27 at 3; Ex. 25 at 6.)

Further, the record contains evidence which, when viewed in a light most favorable to Williams, could suggest Defendants employed deceptive and manipulative testing methods to determine the true noise levels at Williams's residence. First, Williams produces an email in which the consultant Invenergy hired to conduct noise tests wrote, "[w]e need to end up conducting a test which will demonstrate compliance with the particular standard ...." (McCandlish PSJ Decl. Ex. 10 at 1.) Although this statement is ambiguous, and alone may not demonstrate the culpability necessary to justify punitive damages, other emails between the consultant and Defendants' representatives tend to support the proposition that Defendants or their consultants manipulated reporting of sound-test data. In a June 12, 2009 email, the consultant writes:

> A quick plot of Eaton's L1 shows almost all L1's are less than the 75 dBA limit. There are a few exceedance [*sic*]. I agree that L1 has no place here from an acoustic standpoint. If you want to say something like "the wind turbine section of the code focuses on L10 and L50 and therefore L1 was not analyzed" –I am ok with that. Proceed that way?

(McCandlish PSJ Decl. Ex 18 at 1.) This email suggests that some sound-measurements were collected and analyzed, but Defendants or their agents chose not to report that data because, by their own admission, it was "going to give [them] heartburn." (*Id.*) When viewed in a light most favorable to Williams, the evidence on the record creates a genuine issue of material fact regarding whether Defendants exhibited "aggravated disregard" of Williams's right to use and enjoy his property.

Defendants argue Williams cannot recover punitive damages because he can prove only *de minimis* violations of the DEQ noise regulations. Although compliance with relevant regulations is evidence in the defendant's favor, the standard for whether a condition constitutes a nuisance is not tied directly to governmental standards governing noxious conditions. *See Lunda v. Matthews*, 46 Or. App, 701, 707 (1980) ("Conformance with pollution standards does not preclude a suit in private nuisance"). Instead, the primary question in a nuisance action is whether the allegedly noxious condition would interfere with a reasonable individual's ability to use and enjoy his or her property. *Id.* Similarly, whether Williams is entitled to punitive damages depends not on whether Defendants maliciously and recklessly violated the DEQ violations, but whether they maliciously and recklessly interfered with Williams's right to enjoy his property. *Id.*

***21** Lastly, Defendants contend Williams cannot prove the requisite state of culpability because they took good faith efforts to mitigate the noise, including a state-of-the-art system which automatically monitors the turbine noise levels and shuts down certain turbines in the event of a noise exceedence. Again, this is evidence which Defendants may use to rebut Williams's contention that Defendants acted recklessly and maliciously, but it is not determinative. *See McElwain v. Georgia-Pacific Corp*, 245 Or. 247, 252-254 (1966) (affirming an award of punitive damages against the operator of a mill where the defendant took significant remedial steps because they knew prior to constructing the mill "that the mill would cause damage to adjoining property"). Therefore, this portion of Defendants' motion is denied.

D. Injunctive Relief

Defendants argue they are entitled to summary judgment on Williams's claim for injunctive relief because it is an "extraordinary remedy" which should be granted only where the plaintiff cannot be sufficiently compensated by remedies at law. Alternatively, Defendants contend an injunction would be inappropriate in this case because the hardship created by an injunction would be disproportionate to the benefit resulting to Williams. The court disagrees.

In Oregon, the court may award injunctive relief only where there is a likelihood of substantial and immediate irreparable injury and there are insufficient remedies at law to compensate the plaintiff for his or her injury. *G.C. & K.B. Inv., Inc. v. Wilson*, 326 F.3d 1096, 1107 (9th Cir. 2003). In nuisance cases, an injunction should not be issued as a matter of course. *York v. Stallings*, 217 Or. 13, 22 (1959). Instead, whether to issue an injunction "is subject to the sound discretion of the court." *Id.* The Oregon Supreme Court has also established a "comparative injury doctrine," whereby the "court may refuse an injunction in certain cases where the hardship caused to the defendant by the injunction would greatly outweigh the benefit resulting to the plaintiff." *Id.*

However, injunctive relief is not an uncommon remedy in nuisance cases, and by their very nature, nuisance cases are seldom resolved through legal remedies alone. *Jewett v. Deerhorn Ent., Inc.*, 281 Or. 469, 479 (1978). As the Oregon Supreme Court held in *Jewett*, "[i]t would be unreasonable to require the plaintiffs to further endure the nuisance while the defendant experiments" with cost-effective remedial measures. *Id.* When issued, these injunctive remedies must be tailored to remedy the plaintiff's injury. *Lunda*, 46 Or. App. at 711. Notably, injunctive relief must "restrict defendants from operating [the alleged nuisance] at such times and in such manner as would unreasonably interfere with plaintiffs' use and enjoyment of their property." *Id.*

Here, the Defendants do not meet their burden of demonstrating they are entitled to judgment as a matter of law on Williams's claim for injunctive relief. First, they cite no evidence suggesting legal remedies would be sufficient to compensate Williams for his injury in the event he succeeds at trial. Defendants also fail meet their burden of showing that imposing an injunction would result in a burden disproportionate to Williams's benefit. They produce no testimony, financial analysis, or other evidence which shows an injunction would be at all burdensome. Therefore, this portion of their motion for summary judgment is denied.

Conclusion

For the aforementioned reasons, the court GRANTS in part and DENIES in part Defendants' Motion for Partial Summary Judgment and Alternative Request for

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a *Daubert* Hearing (Dkt. No. 97). The court GRANTS that motion to the extent it seeks to exclude expert testimony regarding the causal link between turbine-produced infrasound and adverse human health effects. Consequently, because Williams cannot create a genuine issue of material fact that infrasound impaired his ability to use and enjoy his land, his nuisance claim premised on the effects of infrasound is dismissed and the court GRANTS Defendants' motion for partial summary judgment on that issue. Williams's nuisance claims based on noise and vibration remain at issue.

***22** Further, pursuant to Williams's withdrawal of his nuisance claim based on the flashing lights on the wind-turbine towers, the court GRANTS Defendants' motion for partial summary judgment on that claim. The court DENIES Defendants' motion for partial summary judgment on Williams's claims for punitive damages and injunctive relief. Therefore, this case shall proceed to trial on Williams's claims for nuisance based on the audible noise and vibration produced by the Willow Creek wind turbines, punitive damages, and injunctive relief.

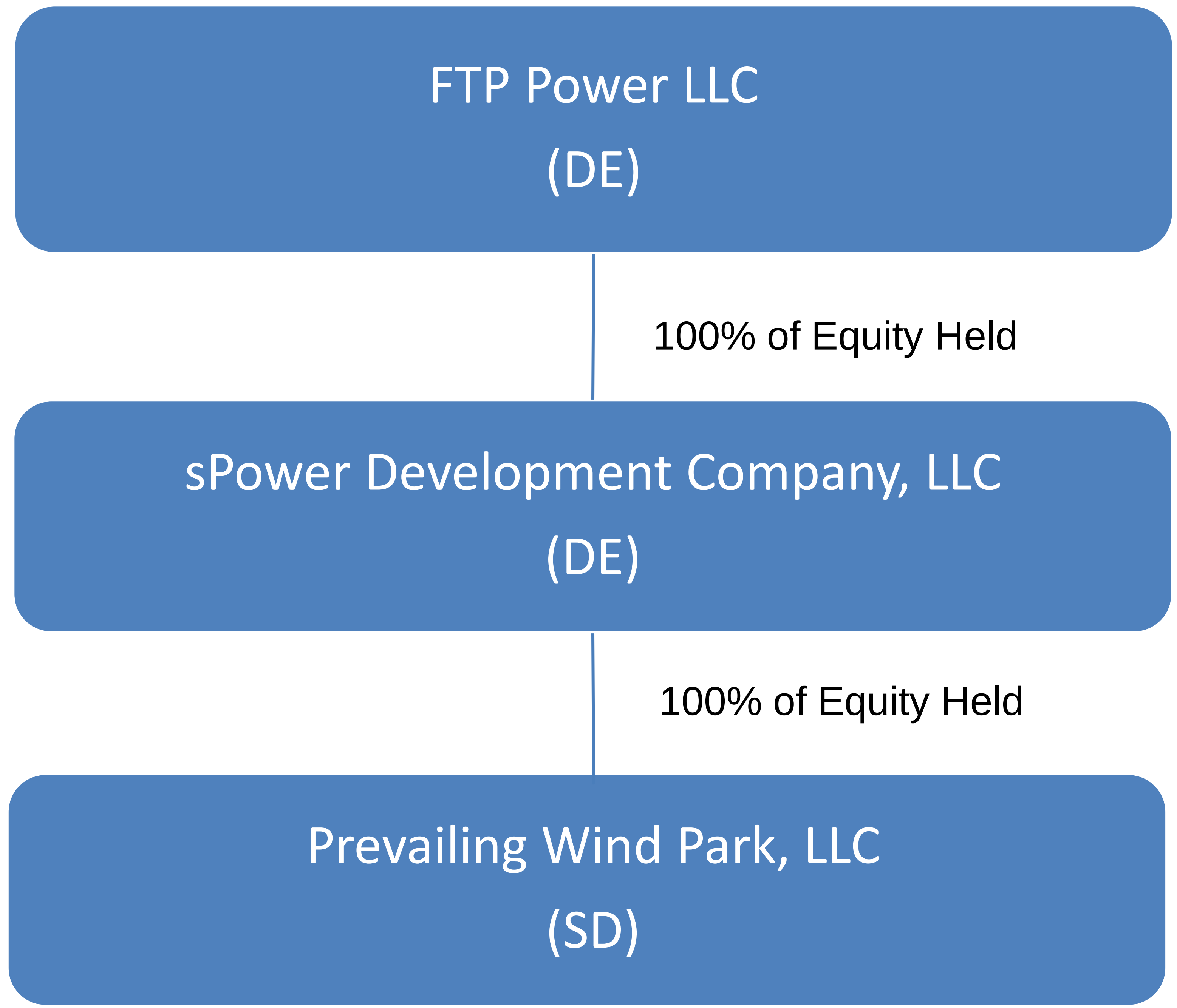
IT IS SO ORDERED.

This 28 th day of April, 2016.

All Citations

Not Reported in F.Supp.3d, 2016 WL 1725990

Ownership Structure of Prevailing Wind Park, LLC (formed 9/27/17)



Prevailing Wind Park Project
Turbine Number Key

Construction ID[1]	Turbine No.[2]
1A.01	21
1A.02	33
1A.03	54
1A.04	36
1A.05	50
1A.06	46
1A.07	47
1B.08	18
1B.09	20
1B.10	25
1B.11	51
1B.12	30
1B.13	56
1B.14	55
2A.15	5
2A.16	3
2A.17	1
2A.18	2
2A.19	6
2A.20	4
2A.21	13
2B.22	7
2B.23	12
2B.24	9
2B.25	8
2B.26	15
2B.27	22
2B.28	16
3A.29	17
3A.30	29
3A.31	23
3A.32	48
3A.33	57

[1] This column includes the turbine numbers included in Exhibit A3-2 (Updated Shadow Flicker Analysis) and Exhibit A10-2 (Updated Sound Study). These identifiers will be used during Project construction.

[2] This column includes the turbine numbers identified on Exhibit A14-2 (Revised Layout) Exhibit and I29, Attachment 4-2.

Prevailing Wind Park Project
Turbine Number Key

Construction ID[1]	**Turbine No.**[2]
3A.34	40
3A.35	32
3A.36	26
3B.37	24
3B.38	41
3B.39	45
3B.40	37
3B.41	39
3B.42	58
3B.43	49
4A.44	28
4A.45	10
4A.46	11
4A.47	34
4A.48	14
4A.49	31
4B.50	27
4B.51	52
4B.52	53
4B.53	35
4B.54	42
4B.55	44
4B.56	43
4B.57	38
5A.58	60
5A.59	61
5A.60	62
5A.61	63
5A.62	64

pii: sp-00087-15
http://dx.doi.org/10.5665/sleep.5326
EXHIBIT A39

Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep

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Study Objectives: To investigate the association between self-reported and objective measures of sleep and wind turbine noise (WTN) exposure.
Methods: The Community Noise and Health Study, a cross-sectional epidemiological study, included an in-house computer-assisted interview and sleep pattern monitoring over a 7 d period. Outdoor WTN levels were calculated following international standards for conditions that typically approximate the highest long-term average levels at each dwelling. Study data were collected between May and September 2013 from adults, aged 18–79 y (606 males, 632 females) randomly selected from each household and living between 0.25 and 11.22 kilometers from operational wind turbines in two Canadian provinces. Self-reported sleep quality over the past 30 d was assessed using the Pittsburgh Sleep Quality Index. Additional questions assessed the prevalence of diagnosed sleep disorders and the magnitude of sleep disturbance over the previous year. Objective measures for sleep latency, sleep efficiency, total sleep time, rate of awakening bouts, and wake duration after sleep onset were recorded using the wrist worn Actiwatch2® from a subsample of 654 participants (289 males, 365 females) for a total of 3,772 sleep nights.
Results: Participant response rate for the interview was 78.9%. Outdoor WTN levels reached 46 dB(A) with an arithmetic mean of 35.6 and a standard deviation of 7.4. Self-reported and objectively measured sleep outcomes consistently revealed no apparent pattern or statistically significant relationship to WTN levels. However, sleep was significantly influenced by other factors, including, but not limited to, the use of sleep medication, other health conditions (including sleep disorders), caffeine consumption, and annoyance with blinking lights on wind turbines.
Conclusions: Study results do not support an association between exposure to outdoor WTN up to 46 dB(A) and an increase in the prevalence of disturbed sleep. Conclusions are based on WTN levels averaged over 1 y and, in some cases, may be strengthened with an analysis that examines sleep quality in relation to WTN levels calculated during the precise sleep period time.
Keywords: actigraphy, annoyance, multiple regression models, PSQI, sleep, wind turbine noise
Citation: Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Murray BJ, Weiss SK, Villeneuve PJ, van den Berg F, Bower T. Effects of wind turbine noise on self-reported and objective measures of sleep. *SLEEP* 2016;39(1):97–109.

Significance
This study provides the most comprehensive assessment to date of the potential association between exposure to wind turbine noise (WTN) and sleep. As the only study to include both subjective and objective measures of sleep, the results provide a level of insight that was previously unavailable. The absence of an effect of WTN on sleep is based on an analysis of self-reported and objectively measured outcomes in relation to long term outdoor average sound levels. Knowledge in this area may be strengthened by future research to consider the potential transient changes in WTN levels throughout the night, which may influence subtle measures of sleep not assessed in the current study.

INTRODUCTION

Sleep loss has been implicated in a variety of negative health outcomes[1] including cardiovascular abnormalities,[2] immunological problems,[3] psychological health concerns,[4] and neurobehavioral impairment that can lead to accidents.[5] Sleep loss may be related to total sleep time restriction and/or reduced sleep quality in the sleep time obtained. Sleep disorders such as insomnia and obstructive sleep apnea are associated with an increased incidence of hypertension, heart failure, and stroke.[6,7]

Sleep can clearly be disrupted with noise.[8] It has long been recognized that electroencephalography (EEG) arousals can be induced with external environmental stimuli, but are modulated by sleep state.[9] The World Health Organization (WHO) Guidelines for Community Noise recommend that, for continuous noise, an indoor sound level of 30 dB(A) should not be exceeded during the sleep period time to avoid sleep disturbance.[10] More recently, the WHO's Night Noise Guidelines for Europe [11] suggest an annual average outdoor level of 40dB(A) to reduce negative health outcomes from sleep disturbance even among the most vulnerable groups.

Sleep can be measured by subjective and objective means[12] although due to the fundamental nature of unconsciousness in this state, people are unable to introspect on their sleep state. As such, an individual may surmise the quality of his or her sleep, with descriptions of what his or her presumed sleep was like, periods of awakening, and consequences of the state. However, sleep state misperception is a common clinical phenomenon, whereby patients with some degree of insomnia may report much worse quality of sleep than what actually occurred.[13] Subjective interpretation of sleep state is thus subject to biased reporting from the individual and therefore subjective and objective measures of sleep are frequently discordant. Therefore, objective physiological measures of sleep can provide a more accurate reflection of what actually happened during an individual's sleep and form the basis of an

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unprejudiced understanding of the actual biological effect of factors such as noise on sleep.

Although the current study is the first to include objective measures in the assessment of sleep quality in the context of wind turbine noise (WTN) exposure, the psychological experience of the individual must be considered, though this factor may be more prone to subjective interpretation. Numerous subjective scales of sleep have been devised. The Pittsburgh Sleep Quality Index (PSQI)[14] is a measure of the subjective experience of sleep that has had detailed psychometric assessment,[15] validation in numerous populations,[16–18] and is one of the most common subjective methodologies used in sleep research.

The PSQI has been administered in a study to compare subjective sleep quality among 79 subjects living near two different wind farms wherein it was reported that sleep quality was worse among the group living closer to the wind turbines.[19] Pedersen[20] found that self-reported sleep disturbance for any reason from any source was inconsistently related to the level of WTN. Bakker et al.[21] showed that self-reported sleep disturbance was correlated to WTN level, but when noise annoyance from wind turbines was brought into a multiple regression, sleep disturbance appeared to be highly correlated to the annoyance, but not to WTN level and only annoyance was statistically correlated to WTN level. This is consistent with the study by van den Berg et al.[22] wherein noise annoyance was reported as a better predictor of self-reported sleep disturbance than noise level for transportation, industrial, and neighbor noise.

Several studies have provided objectively measured assessments of transportation noise-induced sleep disturbance.[23–26] Although it is clear that noise is among the many factors that contribute to sleep disturbance [23,24,27,28] there has been no study to date that has provided an assessment of sleep disturbance in the context of WTN exposures using objective measures such as actigraphy.

The current study was designed to objectively measure sleep in relation to WTN exposure using actigraphy, which has emerged as a widely accepted tool for tracking sleep and wake behavior.[29,30] The objective measures of sleep, when considered together with self-report, provide a more comprehensive evaluation of the potential effect that WTN may have on sleep.

This study was approved by the Health Canada and Public Health Agency of Canada Review Ethics Board (Protocol #2012-0065 and #2012-0072).

METHOD

Sample Design

Target population, sample size, and sampling frame strategy

Several factors influenced the determination of the final sample size, including having adequate statistical power to assess the study objectives, and adequate time allocation for collection of data, influenced by the length of the personal in-dwelling interview and the time needed to collect the physical measures. Overall statistical power for the study was based on the study's primary objective to assess WTN-associated effects on sleep quality. Based on an initial sample size of 2,000 potential dwellings, it was estimated that there would be 1,120 completed survey responses. For 1,120 survey responses there should be sufficient statistical power to detect at least a 7% difference in the prevalence of sleep disturbances with 80% power and a 5% false positive rate (Type I error). There was uncertainty in the power assessment because the current *Community Noise and Health Study*, was the first to implement objectively measured endpoints to study the possible effects of WTN on sleep. How these power calculations applied to actigraphy-measured sleep was also unknown. In the absence of comparative studies, a conservative baseline prevalence for reported sleep disturbance of 10% was used.[31,32] Sample size calculation also incorporated the following assumptions: (1) approximately 20% to 25% of the targeted dwellings would not be valid dwellings (i.e., demolished, unoccupied seasonal, vacant for unknown reasons, under construction, institutions, etc.); and (2) of the remaining dwellings, there would be a 70% participation rate. These assumptions were validated (see response rates and sample characteristics related to sleep).

Study locations were drawn from areas in southwestern Ontario (ON) and Prince Edward Island (PEI) where there were a sufficient number of dwellings within the vicinity of wind turbine installations. The ON and PEI sampling regions included 315 and 84 wind turbines, respectively. The wind turbine electrical power outputs ranged between 660 kW to 3 MW (average 2.0 ± 0.4 MW). All turbines were modern monopole tower design with three pitch-controlled rotor blades (~80 m diameter) upwind of the tower and most had 80 m hub heights. All identified dwellings within approximately 600 m from a wind turbine and a random selection of dwellings between 600 m and 11.22 km were selected from which one person per household between the ages of 18 and 79 y was randomly selected to participate. The final sample size in ON and PEI was 1,011 and 227, respectively. Participants were not compensated in any way for their participation.

Wind turbine sound pressure levels at dwellings

Outdoor sound pressure levels were estimated at each dwelling using both ISO 9613-1[33] and ISO 9613-2[34] as incorporated in the commercial software CadnaA version 4.4.[35] The resulting calculations represent long-term (1 y) A-weighted equivalent continuous outdoor sound pressure levels (LAeq). Therefore, calculated sound pressure levels can only approximate with a certain degree of uncertainty the sound pressure level at the dwelling during the reference time periods that are captured by each measure of sleep. The time reference period ranges from 1–7 d (actigraphy), to 30 d for the PSQI and the previous year for the assessment of the percentage highly sleep disturbed. Van den Berg[36] has shown that, in the Dutch temperate climate, the long-term average WTN level for outdoor conditions is 1.7 ± 1.5 dB(A) below the sound pressure level at 8 m/sec wind speed. Accordingly, a best estimate for the average nighttime WTN level is approximately 2 dB(A) below the calculated levels reported in this study.

Calculations included all wind turbines within a radius of 10 km, and were based on manufacturers' octave band sound power spectra at a standardized wind speed of 8 m/sec and favorable sound propagation conditions. Favorable conditions assume the dwelling is located downwind of the noise source, a stable atmosphere, and a moderate ground-based temperature inversion. Although variations in wind speeds and temperature as a function of height could not be considered in the model calculations due to a lack of relevant data, 8 m/sec was considered a reasonable estimate of the highest noise exposure conditions. The manufacturers' data were verified for consistency using on-site measurements of wind turbine sound power. The standard deviation in sound levels was estimated to be 4 dB(A) up to 1 km, and at 10 km the uncertainty was estimated to be between 10 dB(A) and 26 dB(A). Although calculations based on predictions of WTN levels reduces the risk of misclassification compared to direct measurements, the risk remains to some extent. The calculated levels in the current study represent reasonable worst-case estimates expected to yield outdoor WTN levels that typically approximate the highest long-term average levels at each dwelling and thereby optimize the chances of detecting WTN-induced sleep disturbance. The few dwellings beyond 10 km were assigned the same calculated WTN value as dwellings at 10 km. Unless otherwise stated, all decibel references are A-weighted. A-weighting filters out low frequencies in a sound that the human auditory system is less sensitive to at low sound pressure levels.

In the current study, low-frequency noise was estimated by calculating C-weighted sound pressure levels. No additional benefit was observed in assessing low frequency noise because C- and A-weighted levels were so highly correlated. Depending on how dB(C) was calculated and what range of data was assessed, the correlation between dB(C) and dB(A) ranged from $r = 0.84$ to $r = 0.97$.[37]

Background nighttime sound levels at dwellings

As a result of certain meteorological phenomena (atmospheric stability and wind gradient) coupled with a tendency for background sound levels to drop throughout the day in rural/semi-rural environments, WTN can be more perceptible at the dwelling during nighttime.[38–41] In Canada, it is possible to estimate background nighttime sound pressure levels according to the provincial noise regulations for Alberta, Canada,[42] which estimates ambient noise levels in rural and suburban environments. Estimates are based on dwelling density per quarter section, which represents an area with a 451 m radius and distance to heavily travelled roads or rail lines. When modeled in accordance with these regulations, estimated levels can range from 35 dB(A) to 51 dB(A). The possibility that exposure to high levels of road traffic noise may create a background sound pressure level higher than that estimated using the Alberta regulations was considered. In ON, road noise for the six-lane concrete Highway 401 was calculated using the United States Federal Highway Administration (FHWA) Traffic Noise Model[43] module in the CadnaA software.[35] This value was used when it exceeded the Alberta noise estimate, making it possible to have levels above 51 dB(A).

Data Collection

Questionnaire administration and refusal conversion strategies

The questionnaire instrument included modules on basic demographics, noise annoyance, health effects, quality of life, sleep quality, sleep disorders, perceived stress, lifestyle behaviors, and prevalence of chronic disease. To avoid bias, the true intent of the study, which was to assess the community response to wind turbines, was masked. Throughout the data collection, the study's official title was: *Community Noise and Health Study.* This approach is commonly used to avoid a disproportionate contribution from any group that may have distinct views toward wind turbines. Data collection took place through in-person interviews between May and September 2013 in southwestern ON and PEI. After a roster of all adults aged 18 to 79 y living in the dwelling was compiled, a computerized method was used to randomly select one adult from each household. No substitution was permitted; therefore, if the targeted individual was not at home or unavailable, alternate arrangements were made to invite them to participate at a later time.

All 16 interviewers were instructed to make every reasonable attempt to obtain interviews, which included visiting the dwelling at various times of the day on multiple occasions and making contact by telephone when necessary. If the individual refused to participate, they were then contacted a second time by either the senior interviewer or another interviewer. If, after a second contact, respondents refused to participate, the case was coded as a final refusal.

Self-reported sleep assessment

Long-term self-reported sleep disturbance included an assessment of the magnitude of sleep disturbance experienced at home (of any type for any reason) over the past year. Participants were requested to describe their level of sleep disturbance at home over the past year using one of the following categories: "not at all," "slightly," "moderately," "very" or "extremely," where the top two categories were collapsed and considered to reflect "highly sleep disturbed." For the purposes of this analysis the bottom three categories reflect "low sleep disturbance." These categories and the classification of "highly sleep disturbed" is consistent with the approach adopted for annoyance[44] and facilitates comparisons to self-reported sleep disturbance functions developed for transportation noise sources.[45] Data were collected on prevalence of diagnosed sleep disorders. In addition, participants completed the PSQI, which provided an assessment of sleep quality over the previous 30 d. The seven components of the PSQI are scored on a scale from 0 (better) to 3 (worse); therefore the global PSQI is a score ranging between 0–21, where a value of greater than 5 is thought to represent poor sleep quality.[14,16–18]

Objectively measured sleep

An Actiwatch2® (Philips Healthcare, Andover, MA, USA) sleep watch was given to all consenting and eligible participants aged 18 to 79 y who were expected to sleep at their current address for a minimum of 3 of the 7 nights following the interview. There were 450 devices at hand that were cycled throughout the study. In order to receive the device, respondents also needed to have full mobility in the arm on which the watch was to be worn. Respondents were asked to wear the device on their wrist during all hours of the day and night for the 7 d following their interview. The Actiwatch2® provides key information on sleep patterns (based on movement), including timing and duration of sleep as well as awakenings, and has been compared with polysomnography in some patient samples,[46] but does not replace polysomnography due to imperfect sensitivity and specificity for detecting wake periods. However, this tool can provide reasonable estimates for assessing subjects objectively for more prolonged periods of time than conventional assessment tools, with minimal participant burden.[47] The devices were configured to continuously record a data point every 60 sec for the entire 7 d period. Data analysis was conducted using Actiware® Version 5.1[48] with the software set to default settings (i.e., sensitivity setting of medium and a minimum minor rest interval size of 40 min). With these settings an epoch of 40 counts (i.e., accelerometer activity above threshold) or less is considered sleep and epochs above 40 counts are considered wake. However, any given epoch is scored using a 5-epoch weighting scheme. This procedure weighs the 2 epochs adjacent to the epoch in question. The 5-epoch weighting is achieved by multiplying the number of counts in each respective epoch by the following: 1/25, 1/5, 1, 1/5, 1/25, whereby an average above 40 indicates "awake" for the central epoch. The sleep start parameter was automatically calculated by the Actiware® software determined by the first 10 min period in which no more than one 60 sec epoch was scored as mobile. An epoch is scored as mobile if the number of activity counts recorded in the epoch is greater than or equal to the epoch length in 15 sec intervals (i.e., in a 60 sec epoch an activity value of 4 or higher). Endpoints of interest from wrist actigraphy included sleep efficiency (total sleep time divided by measured time in bed), sleep latency (how long it took to fall asleep), wake after sleep onset (WASO) (the total duration of awakenings), total sleep time, and the number of awakening bouts (WABT) (during a sleep period). The WABT data was analysed as the rate of awakening bouts per 60 min in bed.

To help interpret the measured data, respondents were asked to complete a basic sleep log each night of the study. The log contained information about whether the respondent slept at home or not, presence of windows in the room where they slept, and whether or not the windows were open. After the 7 d collection period, respondents were asked to return the completed sleep log with the actigraph in a prepaid package.

Statistical Methodology

The analysis follows the description in Michaud et al.,[49] which provides a summary of the study design and objectives, as well as a proposed data analysis. Briefly, the Cochran Mantel-Haenszel chi-square test was used to detect associations between self-reported magnitude or contributing sources of sleep disturbance and WTN exposure groups while controlling for province. Because a cut-off value of 5 for the global PSQI score provided a sensitive and specific measure distinguishing good and poor sleep, the PSQI score was dichotomized with the objective to model the proportion of individuals with poor sleep quality (i.e., PSQI > 5).[14] As a first step to develop the best model to predict the dichotomized PSQI score, univariate logistic regression models only adjusting for WTN exposure groups and province were carried out. It should be emphasized that variables considered in the univariate analysis have been previously demonstrated to be related to the modeled endpoint and/or considered by the authors to conceptually have a potential association with the modeled endpoint. The analysis of each variable only adjusts for WTN category and province; therefore, interpretation of any individual relationship must be made with caution.

The primary objective in the current analysis was to use multiple regression models to identify the best predictors for (1) reporting a PSQI score greater than 5; and (2) the actigraphy endpoints. All explanatory variables that were statistically significant at the 20% level in the univariate analysis for each respective endpoint were considered in the multiple regression models. To develop the best model to predict each endpoint of interest, the stepwise method, which guards against issues of multicollinearity, was used for multiple regression models.

The stepwise regression was carried out in three different ways wherein the base model included: (1) WTN exposure category and province; (2) WTN exposure category, province, and an adjustment for individuals who reported receiving personal benefit from having wind turbines in the area; and (3) WTN category and province, stratified for those who received no personal benefit.

For the analysis of PSQI, multiple logistic regression models were developed using the stepwise method with a 20% significance entry criterion and a 10% significance criterion to remain in the model. The WTN groups were treated as a continuous variable, giving an odds ratio (OR) for each unit increase in WTN level, where a unit reflects a 5 dB(A) WTN category. The Nagelkerke pseudo R^2 is reported for logistic regression models.

Repeated-measures data from all wrist actigraphy measurements were modeled using the generalized estimating equations (GEE) method, as available in SAS (Statistical Analysis System) version 9.2 PROC GENMOD.[50–52] Univariate GEE regression models only adjusting for WTN exposure groups, province, day of the week, and the interaction between WTN groups and day of the week were carried out. The interaction between WTN and province was significant for the total sleep time outcome in the univariate models, but was no longer significant in the multiple GEE regression model. Therefore, the base model for the multiple GEE regression models included only WTN category, province, and day of the week. The same stepwise methodology that was applied to build the PSQI models was used to develop multiple GEE regression models for each actigraphy endpoint. The within-subjects correlations were examined with different working correlation matrix structures (unstructured, compound symmetry, and autoregressive of first order). An unstructured variance-covariance structure between sleep nights was applied to all endpoints with the exception of sleep latency, where compound symmetry was used. The advantage of the GEE method is that it uses all available data to estimate individual subject variability (i.e., if 1 or more nights of data is missing for an individual, the individual is still included in the analysis).

The wrist actigraphy endpoints of sleep efficiency and rate of awakening bouts do not follow a normal distribution, because one is a proportion ranging between 0 and 1 (sleep efficiency) and the other is a count (awakening bouts). Therefore, to analyze awakening bouts a Poisson distribution was assumed. The

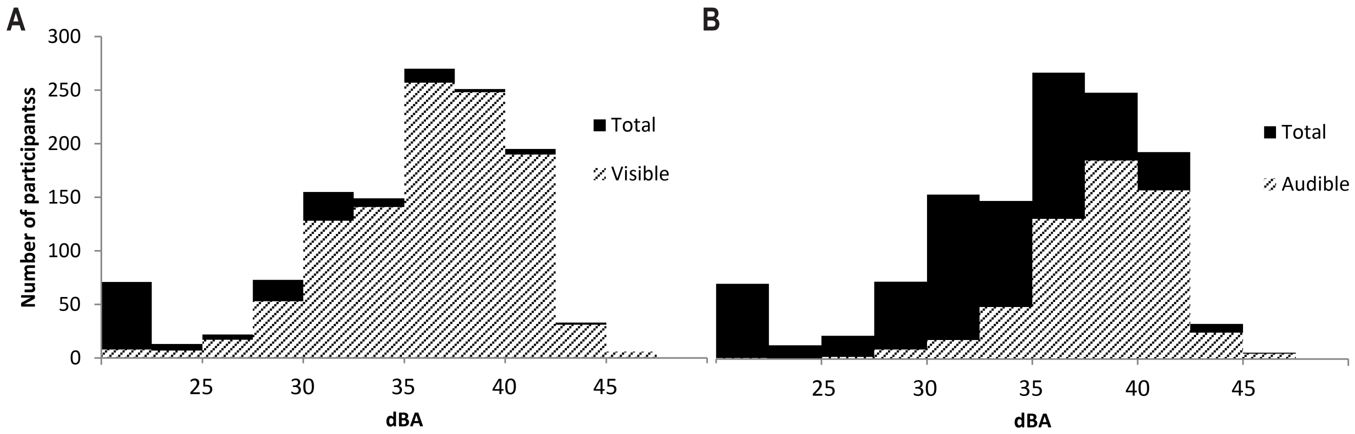

Figure 1—Histogram showing the distribution of participants as a function of calculated outdoor A-weighted wind turbine noise levels. **(A)** The number of participants who self-reported on the questionnaire that wind turbines were visible from anywhere on their property. **(B)** The number of participants who self-reported that wind turbines were audible from inside or outside their home.

number of awakening bouts was analyzed with respect to the total time spent in bed and is reported as a rate of awakening bouts per 60 min in bed. Sleep efficiency, sleep latency, and WASO were transformed in order to normalize the data and stabilize the variance.[53–55] In the GEE models, statistical tests were based on transformed data in order to satisfy the normality and constant variance assumptions. Because back-transformation was not possible for some endpoints, the arithmetic mean (least squares mean [LSM]) is presented for all endpoints.

All regression models for PSQI and actigraphy endpoints were adjusted for provincial differences. Province was initially assessed as an effect modifier. Because the interaction was not statistically significant for any of the multiple regression models, province was treated as a confounder in the models with associated adjustments, as required. Statistical analysis was performed using SAS version 9.2. A 5% statistical significance level was implemented throughout unless otherwise stated and Tukey corrections were applied to account for all pairwise comparisons to ensure that the overall Type I (false positive) error rate was less than 0.05.

Actigraphy Data Screening

The sleep actigraphy file consisted of 4,742 nights of actigraphy measured sleep (i.e., sleep nights) data from 781 participants. The following adjustments to the file were made to account for data that could not be processed: removal of sleep nights with no data (n = 15), data where the dates from the sleep watch and sleep log diary did not match (n = 61), recordings beyond 7 d (representing data collected off wrist or during return shipment) (n = 56), nights with shift work (n = 630), and data related to sleep nights away from home (n = 132). Removal of these data supported the objective to relate sleep behavior to noise exposure from wind turbines at the participants' dwelling. Sleep starting after 05:00 with awakening on the same day before 18:00 was considered day sleep and removed from the analysis (n = 70). One participant was removed where there appeared to be a watch malfunction (i.e., indicated nearly constant sleep). The final sample size consisted of 3,772 sleep nights and 654 participants. Any sleep that started after midnight, but before 05:00 was re-coded and considered as sleep for the previous night to avoid having two sleep observations for the same night. For the remaining data, all available data was used whether the person wore the watch for 1 d or for the maximum 7 d.

RESULTS

Wind Turbine Sound Pressure Levels at Dwellings

Calculated outdoor sound pressure levels at the dwellings determined by ISO 9613-1[33] and ISO 9613-2[34] reached levels as high as 46 dB(A). Results are considered to have an uncertainty of ± 4 dB(A) within distances that would have the strongest effect on sleep (i.e., ~600 m). Figure 1 illustrates the distribution of participants as a function of WTN levels and identifies the number of participants who reported wind turbines were visible from anywhere on their property (panel A) and audible (panel B) while they were either outside or inside their dwelling.

Background Nighttime Sound Pressure Levels

Modeled background nighttime sound (BNTS) levels ranged between 35 and 61 dB(A) in the sample. Average BNTS was highest in the WTN group 30–35 dB(A) and lowest in areas where modeled WTN levels were between 40–46 dB(A).[37] In the univariate analysis of global PSQI, the proportion of people with poor sleep (i.e., global scores above 5) was statistically similar among the BNTS levels (P = 0.9727). For actigraphy, BNTS levels were only statistically significant for the endpoint WASO (P = 0.0059), where it was found that individuals in areas with louder BNTS levels tended to have longer durations of awakenings. WASO increased from 50.7 min (95% confidence interval [CI]: 46.9, 54.4) in areas with < 40 dB(A) BNTS to 67.2 min (95% CI: 57.0, 77.5) in areas with ≥ 55 dB(A) BNTS levels (see supplemental material).

Response Rates and Sample Characteristics Related to Sleep

A detailed breakdown of the response rates, along with personal and situational variables by WTN category, is presented by Michaud.[37] Of the 2,004 potential dwellings, 1,570 were valid and 1,238 agreed to participate in the survey (606 males,

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

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

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

Table 2—Summary of Pittsburgh Sleep Quality Index scores.

	Wind Turbine Noise, dB(A) < 25	25–30	30–35	35–40	40–46	Overall
Mean (95% CI)	6.22 (5.32, 7.11)	5.91 (5.05, 6.77)	6.00 (5.51, 6.50)	5.74 (5.33, 6.16)	6.09 (5.55, 6.64)	5.94 (5.72, 6.17)
n (%) score > 5[a]	40 (49.4)	45 (48.9)	138 (46.5)	227 (44.4)	106 (46.7)	556 (46.0)

[a]Pittsburgh Sleep Quality Index score above 5 is considered to represent poor sleep. CI, confidence interval.

632 females), resulting in a final overall response rate of 78.9%. Of the 1,238 participants, 1,208 completed the PSQI in its entirety (97.6%) and 781 participated in the sleep actigraphy portion of the study (63%). Sleep actigraphy participation rates were in line with projections based on an unpublished pilot study designed to assess different sleep watch devices and participant compliance. Participation rate was equally distributed across WTN categories.

The prevalence of reporting a diagnosed sleep disorder was unrelated to WTN levels (P = 0.3102).[27] In addition, the use of sleep medication at least once a week was significantly related to WTN levels (P = 0.0083). The prevalence was *higher* among the two lowest WTN categories (< 25 dB(A) and 25–30 dB(A)).[37] Factors that may affect sleep quality, such as self-reported prevalence of health conditions, chronic illnesses, quality of life, and noise sensitivity were all found to be equally distributed across WTN categories.[37,56] In response to the general question on magnitude of sleep disturbance for any reason over the past year while at home, a total of 757 participants (61.3%) reported at least a "slight" magnitude of sleep disturbance (includes ratings of "slightly," "moderately," "very" and "extremely"), with a total of 164 (13.3%) classified as "highly" sleep disturbed (i.e., either very or extremely). The levels of WTN were not found to have a statistically significant effect on the prevalence of sleep disturbance whether the analysis was restricted to only participants highly sleep disturbed (P = 0.4300), or if it included all participants with even a slight disturbance (P = 0.7535) (Table 1). When assessing the sources reported to contribute to sleep disturbance among all participants with even slight disturbance, reporting wind turbines was significantly associated with WTN categories (P < 0.0001). The prevalence was ≥ 15.1% among the participants living in areas where WTN levels were ≥ 35 dB(A) compared to ≤ 3.9% in areas where WTN levels were below 35 dB(A). However, wind turbines were not the only, nor the most prevalent, contributing source at these sound levels (see Table 1).

PSQI Scores

For the 1,208 participants who completed the PSQI in its entirety, the average PSQI score across the entire sample was

5.94 with 95% confidence interval (CI) (5.72, 6.17). The Cronbach alpha for the global PSQI was 0.76 (i.e., greater than the minimum value of 0.70 in order to validate the score). Table 2 presents the summary statistics for PSQI as both a continuous scale and a binary scale (the proportion of respondents with poor sleep; i.e., PSQI above 5) by WTN exposure categories. Analysis of variance was used to compare the average PSQI score across WTN exposure groups (after adjusting for provinces). There was no statistical difference observed in the mean PSQI scores between groups (P = 0.7497) as well as no significant difference between provinces (P = 0.7871) (data not shown). Similarly, when modeling the proportion of respondents with poor sleep (PSQI > 5) in the logistic regression model, no statistical differences between WTN exposure groups (P = 0.4740) or provinces (P = 0.6997) were observed (see supplemental material).

Effects of Personal and Situational Variables on PSQI Scores and Actigraphy

A univariate analysis of the personal and situational variables in relation to the PSQI scores (logistic regression) and actigraphy (GEE) was conducted. The list of variables considered was extensive and included, but was not limited to, age, sex, income, education, body mass index, caffeine consumption, housing features, diagnosed sleep disorders, health conditions, annoyance, household complaints, and personal benefit (i.e., rent, payments or other indirect benefits through community improvements) from having wind turbines in the area. The analysis of these and several other variables in relation to the endpoints has been made available in the supplemental material.

Multiple Logistic Regression Models for PSQI

Table 3 provides a summary of the variables retained in the multiple regressions for the PSQI and actigraphy endpoints. A detailed description of the statistical results, including the direction of change and the pairwise comparisons made among the groups within each variable is available in the supplemental material.

Table 4 presents the results from stepwise multiple logistic regression modeling of the proportion of respondents with "poor sleep" (i.e., scores above 5 on the PSQI). The final models for the three approaches to stepwise regression as listed in the Statistical Methods section produced nearly identical results to one another. Therefore, results are only presented for the regression method where the variables WTN category, province, and personal benefit were forced into the model that fit the data well (Hosmer-Lemeshow test, P > 0.05). Using stepwise regression, the predictive strength of the final model was 37%. There was no observed relationship between the proportion of respondents with poor sleep and WTN levels (P = 0.3165).

Participants who had improved sleep quality after closing their bedroom window were found to have the same odds of poor sleep when compared to those who did not need to close their window (P = 0.0565). Participants who stated that closing their window did not improve sleep quality had higher odds of poor sleep in comparison with both those who had improved sleep quality after closing windows and those who did not need to close windows (P ≤ 0.0006, in both cases). Unemployed individuals had higher odds of poor sleep compared with those who were employed (OR [95% CI]: 1.55 [1.12, 2.15]).

Long-term sleep disturbance (of any type by any source) was included in the study because dose-response relationships have been published for this measure in relation to other community noise sources[45] and this endpoint provides a longer time reference period than the previous 30 d assessed using the PSQI. Those who reported a very or extremely high level of sleep disturbance (i.e., percentage highly sleep disturbed) by any source while at home had 6 times higher odds of poor sleep assessed with the PSQI (OR [95%CI]: 6.28 [3.46, 11.40]) when compared to those with no, slight, or moderate reported sleep disturbance. Finally, participants suffering from migraines/headaches, asthma, arthritis and a diagnosed sleep disorder (e.g., sleep apnea or insomnia) had higher odds of poor sleep when compared to those not suffering from these health and chronic conditions.

Sleep Actigraphy

The majority of participants (56%) wore the watch for the full 7 nights (mean number of days 5.77, SD = 1.85). The frequency across the days of the week was equally distributed (data not shown). Response rates for the actigraph were equally distributed across WTN exposure groups (P = 0.5585), although a higher proportion of participants were noted in PEI, in comparison to ON (P = 0.0008).

Table 5 presents the summary data for each sleep actigraphy endpoint analyzed. Although mean values appear stable between one sleep night to the next within an endpoint, the standard deviation is observed to fluctuate between sleep nights (data not shown). The observed correlations between the PSQI and the actigraphy endpoints are presented as supplemental material.

Multiple GEE Regression Models for Actigraphy

Multiple regression models for the five sleep actigraphy endpoints were developed. Variables that were associated with each endpoint (i.e., significant at the 10% level) are summarized in Table 3. Specific information on these variables, including the direction of change, P values, and pairwise comparisons has been made available in the supplemental material. Table 6 presents the LSM and the P values for the exposure of interest, the WTN exposure categories, obtained from the GEE regression models for the sleep actigraphy endpoints. Unadjusted results reflect the base model (including WTN, province, day of the week, and the interaction between WTN and day of the week) whereas adjusted results come from the multiple regression models obtained through the stepwise method and take into account factors beyond the base model. The level of exposure to WTN was not found to be related to sleep efficiency (P = 0.3932), sleep latency (P = 0.6491), total sleep time (P = 0.8002), or the number of awakening bouts (P = 0.3726). There was an inconsistent association found between WASO and WTN exposure where there was a statistically significant reduction in WASO time observed in areas where WTN levels were 25–30 dB(A), in comparison with < 25 dB(A) and 40–46

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Table 3—Variables retained in multiple generalized estimating equations and multiple logistic regression models.

	Sleep Efficiency (%)	Sleep Latency (min)	Total Sleep Time (min)	WASO (min)	Rate of Awakening Bouts (per 60 min)	PSQI (scores > 5)
Base model						
WTN levels				++		
Province				+		+
Demographic variables						
Sex	++					
BMI group	+	++				
Age group		++				
Marital status					+	
Employment				++		++
Smoking status				++		
Caffeine consumption	++				+	
Education	++			++		
Situational variables						
Bedroom location				++		
Air conditioning unit in bedroom			++			
Bedroom on quiet side			+			
Bedroom window type			+			
Sleep improved by closing window						++
Closure of bedroom windows/other[a]		++				
BNTS level			++	++		
Audible rail noise						++
Audible aircraft noise				++		
Wind turbine related variables						
Complaint about wind turbines	+					
Personal benefits						++
Annoyance with blinking lights			++		++	
Personal and health related variables						
Self-reported sleep disturbance[b]						++
Sleep disturbed by pain			++		++	
Sleep disturbed by neighbors			++			
Sleep disturbed by other[c]						++
Annoyed by snoring						+
Sleep medication[d]				++		
Migraines						++
Dizziness						+
Chronic pain						+
Asthma		++				++
Arthritis						++
Diagnosed sleep disorder			+			++
Restless leg syndrome					++	

A summary of significant variables retained in multiple generalized estimating equations and multiple logistic regression models for objectively measured and self-reported sleep endpoints, respectively. The specific direction of change, level of statistical significance, pairwise comparisons between variable groups and full description of the variable names is provided in supplemental material. [a]The source identified by participants as the cause of closing bedroom windows to reduce noise levels was not road traffic, aircraft, rail or wind turbines. [b]Evaluates the magnitude of reported sleep disturbance at home from not at all to extremely, for any reason over the previous year. [c]The source identified by participants as contributing to their sleep disturbance was not wind turbines, children, pets or neighbors. [d]Use of sleep medication was note considered in the multiple regression model for PSQI since it is one of the seven components that make up the global PSQI score. +, ++ denotes statistically significant, $P < 0.10$, $P < 0.05$, respectively. BMI, body mass index; BNTS, background nighttime sound level; PSQI, Pittsburgh Sleep Quality Index; WTN, wind turbine noise.

Table 4—Multiple logistic regression model for Pittsburgh Sleep Quality Index.

Variable	Groups in Variable[b]	Model: WTN, Province, and Personal Benefit Forced in PSQI[a] P value[c]	OR (CI)[d]
		(n = 933, R^2 = 37%, H-L P = 0.9252)[h]	
WTN, dB(A)[e]		0.3165	0.93 (0.80, 1.07)
Province	PEI/ON	0.0810	1.46 (0.95, 2.25)
Personal benefit	No/Yes	0.0499	1.82 (1.00, 3.30)
Sleep improved by closing window (overall P value < 0.0001)	Yes	0.0565	1.41 (0.99, 2.00)
	No	< 0.0001	8.48 (3.11, 23.14)
	Did not need to close windows	Reference	
Employment	No/Yes	0.0085	1.55 (1.12, 2.15)
Audible rail noise	No/Yes	0.0380	1.56 (1.03, 2.37)
Reported cause for sleep disturbance			
Other[f]	Yes/No	< 0.0001	2.55 (1.86, 3.48)
Self-reported sleep disturbance[g]	High/Low	< 0.0001	6.28 (3.46, 11.40)
Annoyed by snoring	High/Low	0.0693	2.16 (0.94, 4.94)
Migraines	Yes/No	0.0062	1.76 (1.17, 2.64)
Dizziness	Yes/No	0.0696	1.46 (0.97, 2.20)
Chronic pain	Yes/No	0.0754	1.47 (0.96, 2.25)
Asthma	Yes/No	0.0166	2.01 (1.14, 3.56)
Arthritis	Yes/No	0.0497	1.45 (1.00, 2.10)
Diagnosed sleep disorder	Yes/No	0.0001	2.99 (1.71, 5.23)

[a]The logistic regression is modeling the probability of having a PSQI score above 5. [b]Where a reference group is not specified it is taken to be the last group. [c]P value significance is relative to the reference group. [d]OR (CI) odds ratio and 95% confidence interval based on logistic regression model. [e]The exposure variable, WTN level, is treated as a continuous scale in the logistic regression model. [f]The source identified by participants as the cause of closing bedroom windows to reduce noise levels was not road traffic, aircraft, rail or wind turbines. [g]Evaluates the magnitude of reported sleep disturbance at home from not at all to extremely for any reason over the previous year. [h]H-L P > 0.05 indicates a good fit. CI, confidence interval; H-L, Hosmer-Lemeshow test; ON, Ontario; OR, odds ratio; PEI, Prince Edward Island; PSQI, Pittsburgh Sleep Quality Index; WTN, wind turbine noise.

dB(A) WTN categories. This was because of a higher mean WASO time among participants from PEI living in areas where WTN levels were less than 25 dB(A) (data not shown).

DISCUSSION

The effects on health and well-being associated with accumulated sleep debt have been well documented.[1–5,57] The sound pressure levels from wind turbines can exceed the WHO recommended annual average nighttime limit of 40 dB(A) for preventing health effects from noise-induced sleep disturbance.[11] The calculated outdoor A-weighted WTN levels in this study reached a maximum of 46 dB(A), with 19% of dwellings found to exceed 40 dB(A). Within an uncertainty of approximately 4 dB(A), the calculated A-weighted levels in the current study can be compared to the WHO outdoor nighttime annual average threshold of 40 dB(A).[11,58] With the average façade attenuation with windows completely opened of 14 ± 2 dB(A),[58] the average bedroom level at the highest façade level, 46 dB(A), will be 32 ± 2 dB(A), which is close to the 30 dB(A) indoor threshold in the WHO's Guidelines for Community Noise.[10] Considering the uncertainty in the calculation model and input data, only dwellings in the highest WTN category are expected to have indoor levels above 30 dB(A) and thus sensitivity to sleep disturbance. However, with windows closed, indoor outdoor level difference is approximately 26 dB, which should result in an indoor level around 20 dB(A) in the current study.

Factors including, but not limited to, medication use, other health effects (including sleep disorders), caffeine consumption, and annoyance with blinking lights on wind turbines were found to statistically influence reported and/or actigraphically measured sleep outcomes. However, there was no evidence for any form of sleep disturbance found in relation to WTN levels. Studies published to date have been inconsistent in terms of self-reported evidence that WTN disrupts sleep,[59,60] and none of these studies assessed sleep using an objectively measured method. These inconsistent findings are

Table 5—Summary of Actiwatch2® data.

		Wind Turbine Noise, dB(A)				
		< 25	25–30	30–35	35–40	40–46
n (weekday, weekend)		(198, 78)	(200, 68)	(705, 273)	(1114, 420)	(526, 190)
Sleep Actigraphy Endpoint	**Sleep Night**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Sleep latency, min	Weekday	14.53 (23.31)	13.89 (23.08)	13.02 (26.14)	13.01 (23.05)	13.01 (22.83)
	Weekend	22.85 (37.01)	10.02 (15.86)	13.23 (22.47)	15.36 (36.13)	12.94 (26.96)
Sleep efficiency, %	Weekday	84.69 (6.59)	85.64 (7.84)	84.92 (7.56)	85.24 (7.83)	85.01 (7.03)
	Weekend	83.62 (7.93)	87.73 (5.46)	84.37 (8.39)	85.01 (7.96)	84.28 (8.47)
WASO, min	Weekday	58.58 (29.45)	50.43 (34.80)	54.99 (31.63)	52.63 (30.14)	55.50 (34.19)
	Weekend	60.49 (37.14)	48.57 (27.00)	58.28 (38.69)	54.11 (35.56)	56.60 (37.53)
Total sleep time, min	Weekday	455.24 (160.65)	447.70 (165.62)	448.88 (169.37)	445.76 (166.52)	448.38 (179.82)
	Weekend	468.12 (163.83)	462.21 (139.61)	457.15 (167.15)	448.63 (155.09)	442.85 (174.23)
Number of awakening bouts, count	Weekday	24.41 (9.49)	22.04 (10.04)	25.05 (13.53)	23.56 (9.86)	24.01 (9.81)
	Weekend	24.89 (10.00)	22.09 (8.76)	26.09 (13.01)	24.60 (10.54)	24.35 (10.22)
Time in bed, min	Weekday	536.05 (173.73)	521.39 (176.46)	526.53 (180.77)	520.55 (173.97)	524.48 (187.30)
	Weekend	559.85 (184.18)	526.99 (154.00)	540.13 (179.72)	527.18 (166.46)	522.57 (176.14)
Rate of awakening bouts per 60 min in bed	Weekday	2.83 (1.00)	2.64 (1.12)	2.94 (1.27)	2.82 (1.08)	2.89 (1.09)
	Weekend	2.77 (1.06)	2.60 (1.06)	2.97 (1.18)	2.87 (1.08)	2.93 (1.14)

SD, standard deviation; WASO, wake after sleep onset.

Table 6—Generalized estimating equations regression models for sleep actigraphy endpoints.

	Sleep Efficiency, %	Sleep Latency, min	Total Sleep Time,[d] min	WASO, min	Number of Awakening Bouts during Sleep
n	618	526	619	647	626
Sleep nights[c]	3,561	3,017	3,552	3,728	3,595
P value unadjusted[a]	0.2420	0.9051	0.7222	0.0655	0.2460
P value adjusted[b]	0.3932	0.6491	0.8002	0.0056	0.3726
Unadjusted[a] WTN, dB(A)	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**
< 25	84.71 (83.25, 86.17)	16.34 (11.40, 21.28)	458.00 (428.08, 487.93)	58.83 (52.78, 64.87)	24.26 (22.28, 26.25)
25–30	86.49 (85.12, 87.87)	12.34 (8.88, 15.80)	462.68 (427.47, 497.90)	49.11 (43.72, 54.50)	21.08 (19.14, 23.02)
30–35	84.82 (83.86, 85.78)	12.51 (10.54, 14.49)	464.00 (441.44, 486.57)	55.39 (52.04, 58.74)	24.57 (23.01, 26.14)
35–40	85.33 (84.60, 86.05)	13.02 (11.39, 14.65)	449.10 (433.95, 464.24)	53.08 (50.35, 55.80)	23.37 (22.40, 24.35)
40–46	85.01 (84.05, 85.98)	12.64 (10.50, 14.78)	445.78 (426.60, 464.96)	55.46 (51.45, 59.47)	23.84 (22.55, 25.13)
Adjusted[b] WTN, dB(A)	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**
< 25	85.62 (83.97, 87.28)	15.08 (10.03, 20.13)	462.41 (407.97, 516.84)	62.00 (55.14, 68.85)	23.19 (20.58, 25.79)
25–30	87.28 (85.55, 89.01)	10.88 (6.45, 15.32)	453.43 (401.10, 505.76)	51.67 (44.14, 59.20)	20.57 (17.87, 23.26)
30–35	85.82 (84.52, 87.13)	9.95 (7.02, 12.87)	455.22 (406.72, 503.72)	56.11 (50.81, 61.42)	24.00 (21.26, 26.75)
35–40	85.97 (84.86, 87.08)	10.71 (7.88, 13.54)	466.12 (416.21, 516.02)	57.80 (52.36, 63.24)	22.56 (20.57, 24.56)
40–46	86.16 (84.84, 87.48)	10.92 (7.01, 14.82)	472.95 (422.09, 523.81)	62.06 (55.64, 68.48)	22.85 (20.68, 25.02)

[a]The base model for the multiple generalized estimating equations (GEE) regression models for all endpoints included wind turbine noise (WTN) exposure groups, province, day of the week, and the interaction between WTN groups and day of the week. [b]A complete list of the other variables included in each multiple GEE regression model based on the stepwise methodology is presented in Table 3. [c]Sample size for the adjusted GEE regression models. [d]The base model for total sleep time includes the interaction between WTN groups and province. [e]LSM, least squares means, for each group after adjusting for all other variables in the multiple GEE regression model and corresponding 95% confidence interval (CI). P values for both the adjusted and unadjusted models are based on the transformed variable in order to satisfy model assumptions of normality and constant variance.

not entirely surprising considering that sleep disturbance reported as a result of transportation noise exposure occurs at sound pressure levels that exceed WTN levels calculated in the current study.[27,28,45] Study results concur with those of Bakker et al.,[21] with outdoor WTN levels up to 54 dB(A), wherein it was concluded that there was no association between the levels of WTN and sleep disturbance when noise annoyance was taken into account.

The current study employed a wide range of self-reported and objectively measured endpoints related to sleep to provide a comprehensive assessment of the potential effects that WTN exposure may have on sleep. Self-reported diagnosed sleep disorders[37] and self-reported highly sleep disturbed for any reason were factors found to be unrelated to WTN exposure. Furthermore, taking medication at least once per week was more commonly reported among participants living in areas where WTN levels were below 30 dB(A). Scores on the PSQI, either analyzed as a proportion above 5, or as a mean score, were also unrelated to WTN level. Actigraphy-measured sleep latency, sleep efficiency, the rate of awakening bouts, and total sleep time were all found to be unrelated to WTN exposure. The only statistically significant finding found between WTN level and actigraphy was a reduced wake time after sleep onset among participants living in areas where WTN levels were 25–30 dB(A) and this was because of a higher WASO time at the lowest WTN category among PEI participants. The results of the current study do not support conclusions that exposure to WTN up to 46 dB(A) has any statistically significant effect on self-reported or objectively measured sleep. However, annoyance with blinking lights on wind turbines (used as aircraft warning signals) may be related to a higher rate of awakening bouts and reduced total sleep time.

This study has some important limitations. Objective measures of sleep were assessed for up to 7 d, whereas the PSQI and the reported highly sleep disturbed outcomes represent time periods of 30 d and 1 y, respectively. The concern is that 7 d of actigraphy may not represent long-term average sleep patterns. However, the selected time frame for actigraphy measures is typical, and supported in the literature and considered more than adequate for evaluating sleep in a nonclinical study sample.[30,61] If there were situational factors (e.g. an ill child) that made sleep worse in the actigraphy-assessed week, it would not be expected to bias against the effect of wind turbines on sleep, and in fact, would overstate the effect of recent situational events as compared to the long-term theoretical concern about WTN-induced sleep disturbance. As previously discussed, the analysis of actigraphy results was based on nightly average sleep patterns in relation to long-term WTN levels. Although WTN calculations would be expected to produce the highest sound pressure levels at the dwelling, they do not take into consideration the influence that night-to-night variations in outdoor WTN levels may have had on actigraphy results. Similarly, an analysis based on long-term average sound level does not fully account for transient deviations in WTN levels that could potentially interfere with sleep. An analysis based on a time-matched comparison between operational turbine data and actigraphy would permit a more refined assessment of the possible effect that night-to-night variations in WTN levels may have on sleep. These limitations extend to the fact that fluctuations in indoor sound levels during sleep remain unknown.

The possibility that wind turbine operators may have intentionally altered the output of their turbines in order to reduce potential WTN effects on sleep has been one of the concerns raised during the external peer review of this paper. When the *Community Noise and Health Study* was originally announced several months preceding data collection the study locations were unknown. Although awareness of the precise study locations would have become greater as data collection commenced, the deployment of the sleep watches took place over several months among a subsample of participants across the entire study sample. Furthermore, the reference period time for self-reported sleep disturbance was over the previous year and previous 30 d (PSQI). Finally, the subsets of sound power measurements were consistent with manufacturer-supplied data. In the authors' opinion, there is no evidence to suggest that wind turbine operators intentionally altered the output of their turbines to minimize potential effects on sleep at any point in the study.

CONCLUSIONS

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

The WHO's[11] health-based limit for protecting against sleep disturbance is an annual average outdoor level of 40 dB(A). This level was exceeded in 19% of the cases, but by no more than 6 dB(A) and as such represents a limit to detecting a potential effect on sleep. It is therefore important to acknowledge that no inferences can be drawn from the current results to areas where WTN levels exceed 46 dB(A). Likewise, assuming a baseline prevalence of 10%, the study was designed so that the statistical power would be sufficient to detect at least a 7% difference in the prevalence of self-reported sleep disturbance. A larger sample size would be required to detect smaller differences. The statistical power of a study design is a limitation that applies to all epidemiological studies.

Although it may be tempting to generalize the current study findings to other areas, this would have required random selection of study locations from all communities living near wind turbines in Canada. Despite the fact that participants in the study were randomly selected, the locations were not and for this reason the level of confidence one has in generalizing the results to other areas can only be based on a certain level of scientific judgment regarding the level of exposure and the similarity between the current study sample and others. Despite limitations in generalizing the results of this analysis beyond the study sample, the current study is the largest and most comprehensive analysis of both self-reported and objectively measured sleep disturbance in relation to WTN levels published to date.

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ACKNOWLEDGMENTS

The authors acknowledge the support they received throughout the study from Serge Legault and Suki Abeysekera at Statistics Canada, and are especially grateful to the volunteers who participated in this study.

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Submitted for publication February, 2015
Submitted in final revised form August, 2015
Accepted for publication August, 2015
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DISCLOSURE STATEMENT

This was not an industry supported study. The study was funded by Health Canada. The authors have indicated no financial conflicts of interest.

EXHIBIT A40

Close

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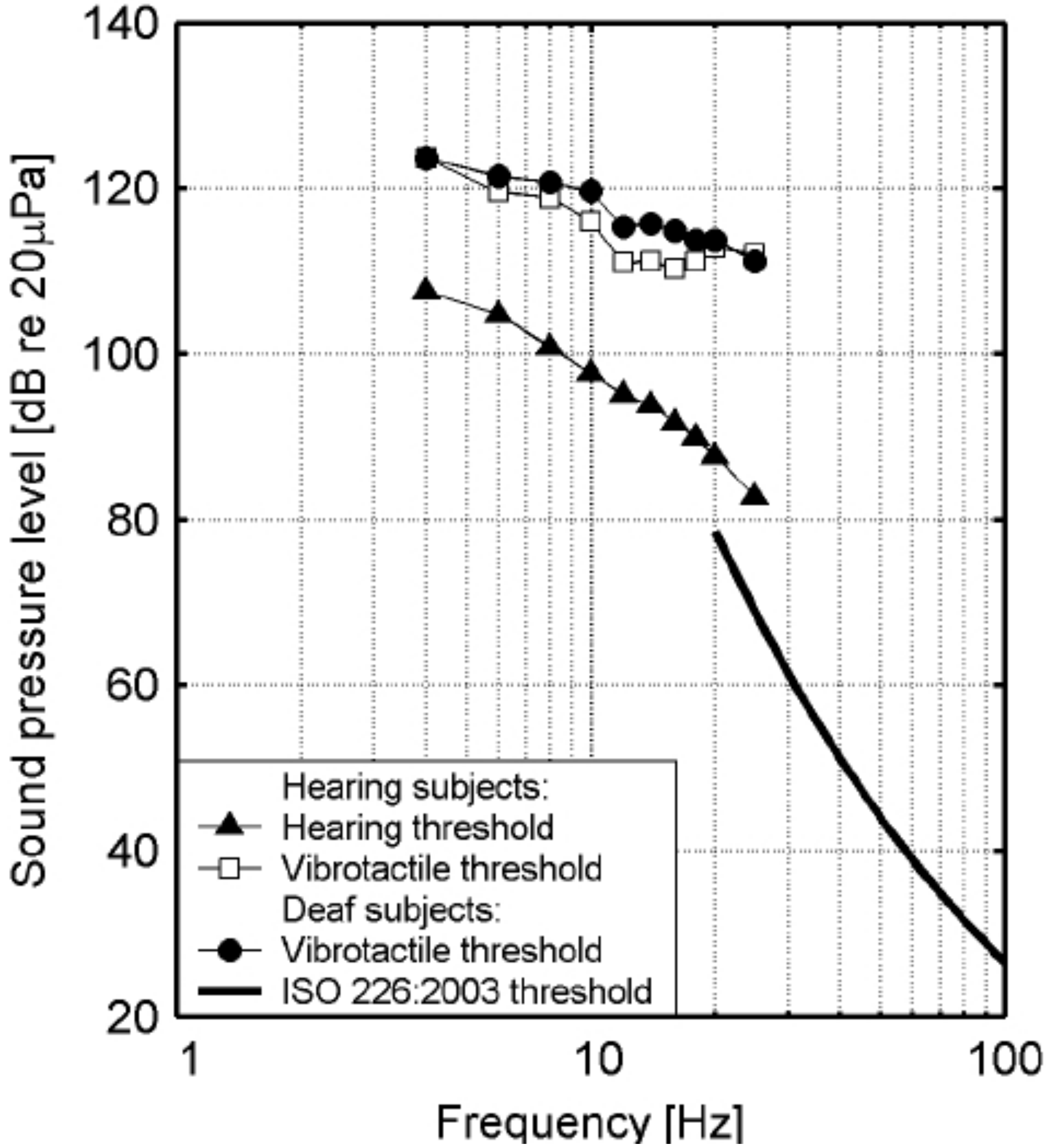
Hearing and vibrotactile thresholds as measured for hearing and deaf subjects by Landström et al. (1983).



PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC, FOR A WIND ENERGY FACILITY PERMIT FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * * *	**CERTIFICATE OF SERVICE** **EL18-026**

Bridget Duffus, of Fredrikson & Byron, P.A., hereby certifies that on the 11th day of October, 2018, true and correct copies of the following documents and this Certificate of Service were served electronically on the persons listed below:

- Exhibit A36: *Williams v. Invenergy, LLC*, 2016 WL 1275990 (D. Oregon, April 28, 2016);
- Exhibit A37: Ownership Structure of Prevailing Wind Park, LLC;
- Exhibit A38: Turbine Number Key;
- Exhibit A39: Michaud et al., Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep (2016);
- Exhibit A40: Hearing and Vibrotactile Thresholds Table;
- Updated Attachment 4-2 to Exhibit I-29: Project Layout; and
- Filing letter.

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