BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION

DOCKET EL19-027

IN THE MATTER OF THE APPLICATION OF CROWNED RIDGE WIND II, LLC FOR A PERMIT OF THE CROWNED RIDGE II WIND FARM IN CODINGTON, GRANT AND DEUEL COUNTIES, SOUTH DAKOTA

Direct Testimony of David M Hessler
On Behalf of the Staff of the South Dakota Public Utilities Commission
December 5, 2019

EXHIBIT
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Q. Please state your name and business address.

A. My name is David M. Hessler. The address of my company's administrative offices is 38329 Old Mill Way, Ocean View, Delaware 19970, and my personal office is located at 5096 N Silver Cloud Dr., St. George, Utah 84770.

Q. Mr. Hessler, by whom are you employed and in what capacity?

A. I have been employed for over 28 years by Hessler Associates, Inc., as Vice President and a Principal Consultant. Hessler Associates, Inc. is a family run engineering consulting firm that specializes in the acoustical design and analysis of power generation facilities of all kinds, including wind energy projects.

Q. Please describe your educational background and your professional experience?

A. I received a Bachelor of Science degree in Mechanical Engineering in 1997, *Summa cum Laude*, from the A. James Clark School of Engineering, University of Maryland, College Park, Maryland, and a Bachelor of Arts degree, 1982, from the University of Hartford, Hartford, Connecticut. I am a registered Professional Engineer (P.E.) in the Commonwealth of Virginia and I am a member of the Institute of Noise Control Engineering (INCE). My professional specialization is the measurement, analysis, control and prediction of noise from both fossil fueled and renewable power generation facilities. I have been the principal acoustical designer and/or test engineer on hundreds of power station projects all over the world and on roughly 70 industrial scale wind energy projects. I wrote the chapter on measuring and analyzing wind turbine noise in the book "Wind Turbine Noise"[1], which was published in 2011. I also drafted a set of best practices guidelines[2] for siting new wind turbine projects and testing them once completed for the National Association of Regulatory Utility Commissioners (NARUC). My resume, which contains a list of the cases where I have testified as an expert witness, is also attached for reference as Exhibit DMH-1.

Q. What is the purpose of your testimony in this case?

A. I have been asked by the Staff of the South Dakota Public Utilities Commission to review and independently evaluate the adequacy of the sound study carried out by EAPC Wind Energy in support of the Crowned Ridge II Wind Farm Project (CRII) and to review the testimony of other parties concerning noise.

Q. What materials have you reviewed in this matter?

A. I have reviewed Appendix I of the Application, which is the original (July 7, 2019) sound study for the Project prepared by EAPC Wind Energy and its later revision dated September 18, 2019. I have also reviewed the direct and supplemental testimony of Jay Haley, who was the author of the sound study, Richard Lampeter and the supplemental direct testimony of Christopher Ollson and Dr. Robert McCunney.

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[1] Bowdler, D., and Leventhall, G., Editors, "Wind Turbine Noise", Multi-Science Publishing Company, Brentwood, Essex, UK, 2011.

[2] Hessler, D., "Assessing Potential Impacts from Proposed Wind Farms & Measuring the Performance of Completed Projects", National Association of Regulatory Utility Commissioners, U.S. Department of Energy, October 2011.

Q. Can you please summarize your overall opinion of the sound study submitted on behalf of the project?

A. In general, the quality of the work and noise modeling is perfectly satisfactory and consistent with good industry practice. I agree with the modeling methodology and believe that the predictions are realistic, if not somewhat conservative because an explicit 2 dB uncertainty factor was added to the maximum turbine sound power level. However, I would fault the study for focusing exclusively on regulatory compliance rather than the minimization of potential community noise impacts. The project layout appears to have been aggressively devised, through careful placement and the now universal use of low noise trailing edge blades, to get the maximum number of turbines into the Project area while maintaining a predicted sound level at all non-participants of less than the Deuel and Grant County Ordinance limit of 45 dBA. In many cases the calculated sound level at non-participants is only an insignificant one or two tenths of decibel below that limit, which is still precariously close to the maximum allowable sound level even if the 2 dB uncertainty factor is neglected.

Q. Do you believe compliance with a 45 dBA noise limit is sufficient in and of itself to ensure that project noise will be considered acceptable to everyone?

A. No. Based on my experience and numerous studies by others, any time wind turbine sound levels higher than about 40 dBA are predicted at residences annoyance and complaints become much more likely. In this case, I gather from the latest sound study report that there are 96 non-participants throughout the Project area where a mean sound level above 40 dBA is predicted. If one were to back out the explicit 2 dB design margin, the number of non-participants above 40 dBA (i.e. a predicted level of 42 dBA or greater) would still be 49. Those are large numbers and percentage of residents highly annoyed by sound levels above 40 dBA will not be zero - despite the argument to the contrary advanced by Mr. Ollson in his supplemental testimony.

Q. What did Mr. Ollson say about predicting annoyance?

A. Mr. Ollson argues that annoyance and complaints cannot be correlated to sound level. He illustrates this in part by reproducing an excerpt from a table (Table IV) from a 2012 paper by Michaud, et al. (Exhibit CO-S-2) that shows that the distribution of 'formal complaints' was fairly uniform across all receptor sound levels from below 30 to more than 45 dBA. However, the same table also shows that those reporting a "high (very or extreme) level of annoyance" goes from 1% at sound levels between 30 and 35 dBA to nearly 14% for sound level in the 40 to 46 dBA range. Mr. Ollson also refers to another table (Table 7) in a paper by Bakker, et al. (Exhibit CO-S-5) to make the point that the people in the study more commonly experienced sleep disturbance from noises other than wind turbines. Table 6 in that same paper, not mentioned in Mr. Ollson's testimony, shows that for a quiet, rural area 82% of the study participants were not annoyed by the adjacent wind project when the sound level at their house was in the 36 to

40 dBA range but that 45% were slightly to highly annoyed when the sound level increased into 41 to 45 dBA range.

Q. What do believe the Project should have done to address the potential for community disturbance?

A. Rather than attempt to dismiss annoyance as something that doesn't exist or wave it away as something that can't be quantified very well, I would have liked to have seen more of an effort on the Applicant's part to go beyond simple regulatory compliance and reduce the density of turbines, use fewer higher output turbines or otherwise optimize the layout so that the sound levels at all non-participating residences were as close to 40 dBA as reasonably possible. While the recent upgrade of all units to have low noise trailing edge blades would appear to be a step in the right direction, the number of non-participants with predicted sound levels above 40 dBA (96) has not, by my count at least, changed from the original July 7 modeling analysis. As it is, the actual sound levels at many non-participants produced by the currently proposed layout will exceed 45 dBA at times because wind turbine sound levels are highly variable with wind and atmospheric conditions and commonly fluctuate by +/- 5 dBA or more around the modeled sound level, which may be regarded as a long-term mean level. Consequently, it is good practice to attempt to keep the predicted project sound levels as far below the regulatory limit as is reasonably feasible.

Q. Do you see any specific layout changes at this point that might reduce the noise impact of the project?

A. Yes. According to Appendix B of the most recent revision of the sound study, which is a tabulation of the turbine coordinates and status, there are currently 6 alternate turbine locations: Turbines 94, 97, 103, 113, 134 and Alt6. In general, all of these sites are relatively far from non-participating residences and could be used as places to beneficially relocate units that are currently causing the sound levels at non-participants to exceed 40 dBA.

Q. Which, in your opinion, would be best candidates for relocation to the alternate turbine sites?

A. Unfortunately, there are a quite a few that I would like to see moved – many more than 6 – but the following 21 units, listed by the sound contour map inset section, would be at the top of my list.

Contour Map Enlargement Section	Turbines recommended for relocation to alternate sites.
A1	Alt4, 104, 125, 129
A2	98, 102
B1	72, 77, 81
B2	Alt5, 53, Unit South of 98 (number illegible)
C1	13
C2	3, 6, Alt9, Unit South of Alt9 (number illegible), 24, 30, 38, Unit South of 38 (number illegible)

I would urge the Applicant to review and enact these suggested relocations to the extent feasible or explain why they are not possible.

Q. **Do you agree with the noise limits and sound testing protocol proposed on behalf of the Applicant by Richard Lampeter?**

A. Yes. I agree that at a bare minimum the sound emissions from the entire project, in all three counties, should be limited as a permit condition to the Grant County Ordinance level of no more than 45 dBA at all non-participating residences and 50 dBA at participating residences. Short of a radical enlargement in the project footprint and/or a shift to higher MW units, I don't see any reasonable way of rearranging the project to realistically meet a lower acoustical design goal while still maintaining required PPA output. I also generally agree with the sound test procedure as proposed, especially the requirement that a minimum of 10 on/off tests be carried out to accurately quantify the concurrent background level allowing the project-only sound level to be determined with some confidence through logarithmic subtraction.

Q. **There are two other wind projects in the vicinity of the Crowned Ridge II site: Crowned Ridge I Wind and the Deuel Harvest Wind Project. How should their sound emissions be factored into or possibly excluded from any operational sound test of the Crown Ridge II Project?**

A. The nearest Deuel Harvest turbines are over 5 miles away from any of the proposed new units, so the two projects have no acoustical interaction and the Deuel Harvest Project may be ignored as an influence on any test.

The Crowned Ridge II Project (CRII), on the other hand, will essentially become a southern extension of the Crowned Ridge I Project (CRI) with no significant separation. Consequently, the two projects must be considered one project for the purposes of any testing at Crowned Ridge II; i.e. sound measurements made at the northern end of CRII must be taken with all turbines in the area operating, irrespective of which project they actually belong to, and any shutdowns associated with the on/off tests within at least 1 mile of the CRII units must also include the southernmost CRI units within at least 1 mile of the test site. Exhibit DMH-2 is a proposed revision of Richard Lampeter's sound test protocol that is slightly modified to consider the pre-existing Crowned Ridge I units as part of the Crowned Ridge II Project for sound testing purposes.

Q. Questions were raised at the August public input meeting about adverse effects from low frequency noise and the Applicant brought in additional consultants, Mr. Ollson and Dr. McCunney, to rebut those concerns. What is your opinion of their testimony on this matter?

A. In general, I agree with their assessments, backed up by a number of valid technical papers, that no adverse health effects are likely to result from either the infrasonic or low frequency sound emissions from the Project. While I sympathize with those that I have met complaining of "wind turbine syndrome" symptoms, the preponderance of the current evidence, research and mainstream expert opinion indicates that there is no link between the extremely low levels of low frequency sound generated by wind turbines and any adverse health outcomes.

Q. In your testimony in several previous wind turbine dockets before the SDPUC you indicated that you thought a tiny minority of people were sensitive to the infrasonic blade passing pulsation produced by wind turbines, but that this sensitivity was so extremely uncommon, based on the large number of operating wind projects without this problem, that the risk of it occurring was essentially negligible. Has your position on this evolved?

A. Yes. As mentioned above, I have met with people seriously affected by what they feel is the low frequency sound from wind turbines and it is impossible to be dismissive or incredulous of their plight, which led me to have an open mind as to whether some link may be possible through some unknown and potentially unknowable mechanism. A research paper by Cooper in 2017[3] seemed to empirically demonstrate that those known to have a sensitivity to this type of sound could identify it when it was inaudibly reproduced in a laboratory setting. However, after talking about this study with colleagues at the most recent wind turbine noise conference in Lisbon last June I was made aware of a flaw in the study where the higher frequencies in the sample recording (of wind turbine sound inside a house at an Australian wind farm) were not completely inaudible as claimed in the text of the paper, nor was it clear if the reproduced sound actually contained the key low frequency content below 40 Hz, which is beyond the capability of conventional speakers to produce. Consequently, I had to

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[3] Cooper, S and Chan, C, "Subjective perception of wind turbine noise – The stereo approach", 174th Meeting of the Acoustical Society of America, New Orleans, December 2017.

dismiss this study as evidence that infrasonic sound from wind turbines is perceptible to certain people.

Moreover, a large number of additional new papers on the subject were presented at the conference that all overwhelmingly concluded that any link between the low frequency sound emissions of wind turbines and adverse health effects was either highly unlikely or impossible. Consequently, while I continue to maintain an open mind on the subject, I would now concur with Mr. Ollsson and Dr. McCunney that this or any wind project poses no significant health risk due to infrasound.

Q. How would you then explain the complaints of those who claim adverse effects?

A. The situation is still not entirely clear and may never be fully understood, but an interesting hypothesis by Crichton[4] (Exhibit DMH-3) and others is that such negative outcomes are related to negative expectations stemming largely from exposure to the large amount of rather frightening, non-scientific, anti-wind propaganda on the internet. In a nutshell, Crichton's experiment at the University of Auckland exposed two randomly selected groups of students to video presentations, one with anti-wind content from the internet and another that suggested low frequency sound was therapeutic[5], while also exposing both

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[4] Crichton, F. et al., "The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound", *Health Psychol* (2013), 33:1588-92. Doi:10.1037/hea0000037.

[5] It is believed by some that this may actually be the case. Crichton:

> We found that alternative medicine practitioners have explored the therapeutic impact of infrasound (e.g., Yount, Taft, West, & Moore, 2004) and therapeutic infrasound producing

groups to recordings of sound from a wind project. Not surprisingly, the first group reported such things as headaches, ear pressure, tiredness, etc. while second group actually felt rejuvenated.

Q. Does this conclude your testimony?

A. Yes.

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devices are now marketed to the public. These devices have been promoted as alleviating the very symptoms infrasound exposure from wind farms is said to trigger (Haneke, Carson, Gregorio, & Maull, 2001).

CURRICULUM VITAE

DAVID M. HESSLER

Title:

Principal Consultant, Vice-President
Hessler Associates, Inc.

Professional Affiliations:

Professional Engineer (P.E.), Commonwealth of Virginia
Member Institute of Noise Control Engineering (INCE)

Education:

Bachelor of Science in Mechanical Engineering (B.S.), 1997
Summa cum Laude
A. James Clark School of Engineering
University of Maryland, College Park, MD

Bachelor of Arts (B.A.), 1982
University of Hartford, Hartford, CT

Employer:

Hessler Associates, Inc.
38329 Old Mill Way, Unit 8
Ocean View, DE 19970

Years in present position: 28

Office Location:

St. George, UT

Current Job Description:

Acoustical engineer specializing in the prediction, assessment and mitigation of environmental noise from new and existing power generation and industrial facilities. Typical tasks include:

- Field measurement studies of existing ambient sound levels in the vicinity of proposed project sites
- Computer noise modeling of new facilities prior to construction
- Environmental impact assessments for new projects
- Noise mitigation design studies of new facilities
- Verification measurements of completed facilities
- Diagnostic studies of facilities with existing noise problems
- Design and specification of noise mitigation measures
- Educational lectures on noise issues for private corporations
- Expert witness testimony

General Experience:

As an outside consultant to nearly all the major power industry EPC contractors, developers and OEM's, I have been the principal acoustical designer of over 400 power plants and industrial facilities worldwide ranging from a 3900 MW power station in Saudi Arabia to numerous combustion turbine combined cycle plants to refineries and wind turbine projects. Typically, the focus of the work on these projects was to anticipate potential noise impacts at sensitive receptors near the project and recommend practical noise abatement measures to avoid them. In addition, extensive verification measurements in and around the completed power plants and wind farms have been performed to confirm that the design recommendations have been successfully executed.

Wind Turbine Experience:

Over the past 16 years I have performed noise impact evaluations and siting optimization studies for roughly 70 large wind turbine projects in the United States, Canada and the Caribbean, involving nearly all current makes and models of wind turbines. I have developed test protocols and conducted long-term field measurement surveys of numerous newly completed wind projects to evaluate compliance with applicable permit conditions, to investigate complaints and/or to verify the accuracy of pre-construction noise modeling. I have carried out field tests of wind turbine sound power level in strict accordance with the IEC 61400-11 test methodology. I have carried out field measurement studies of operating wind turbines to evaluate their low frequency sound emissions, nacelle noise sources and radial directivity characteristics. I have testified as an expert witness at permitting hearings for proposed wind projects. I have attended six bi-annual Wind Turbine Noise conferences organized by INCE Europe.

Representative Papers and Publications:

“Wind Turbine Noise”, Chapter 7 *Measuring and Analyzing Wind Turbine Sound Levels*, Multi-Science Publishing Co., Brentwood, Essex, UK, Jan. 2012. Comprehensive book on all aspects of wind turbine noise. Each chapter written by a recognized expert in that subject.

Teleseminar “Wind Turbine Siting and Best Practices”, National Regulatory Research Institute (NRRI), Invited speaker, Jan. 2012.

“Best Practices Guidelines for Assessing Sound Emissions from Proposed Wind Farms and Measuring the Performance of Completed Projects”, Prepared for the Minnesota Public Utilities Commission under the auspices of the National Association of Regulatory Utility Commissioners (NARUC), Oct. 2011.

“Accounting for Background Noise when Measuring Operational Noise from Wind Turbines”, Fourth International Meeting on Wind Turbine Noise, Rome, Italy, Apr. 2011.

“Recommended noise level design goals and limits at residential receptors for wind turbine developments in the United States”, *Noise Control Engineering Journal*, J.59 (1), January-February 2011.

“Wind tunnel testing of microphone windscreen performance applied to field measurements of wind turbines”, Third International Meeting on Wind Turbine Noise, Aalborg, Denmark, June 2009.

“Experimental study to determine wind-induced noise and windscreen attenuation effects on microphone response for environmental wind turbine and other applications”, *Noise Control Engineering Journal*, J.56, July-August 2008.

Expert Witness Cases:

Before the Washington State Energy Facilities Siting Board (EFSEC) on behalf of Bechtel and the Cherry Point Cogeneration Project, Bellingham, WA, 2003. Permitting support for a proposed combined cycle power plant facility.

Before the Public Service Commission of West Virginia on behalf of the Longview Power Project near Morgantown, WV, 2006. Permitting support for a proposed coal-fired power plant facility.

Before the Pennsylvania Department of Environmental Protection on behalf of Waste Management and the Alliance Sanitary Landfill in Taylor, PA, 2006. Support in defending against a Class Action Lawsuit brought by neighbors of the landfill.

Before the Office of the Attorney General of New York on behalf of the Hudson Valley Community College Cogeneration (Diesel) Plant. Support in defending against a Class Action Lawsuit brought by neighbors.

Before the Hanover County (VA) Board of Supervisors on behalf of Martin Marietta Materials and the Doswell Quarry, 2008. Permitting support for a proposed quarry expansion.

Before the New Hampshire Site Evaluation Committee on behalf of Granite Reliable Power, LLC, 2008. Docket No. 2008, July 2008. Permitting support for a proposed wind turbine project in Northern New Hampshire.

Before the Public Utilities Commission of Ohio, Ohio Power Siting Board on behalf of EverPower Renewables and the Buckeye Wind Project, 2008. Permitting support for a proposed wind turbine project in Ohio.

Before the Wisconsin Public Service Commission on behalf of Clean Wisconsin with regard to the proposed Highland Wind Farm in Forest, WI. Docket No. 2535-CE-100. Engaged as an independent expert to evaluate the Applicant’s sound studies and the testimony of opposition groups.

Before the Public Utilities Commission of Ohio, Ohio Power Siting Board on behalf of EverPower Renewables and the Buckeye II Wind Project, 2012. Permitting support for a proposed wind turbine project in Ohio.

Before the Maine State Government Energy, Utilities and Technology Committee on behalf of Patriot Renewables and the Beaver Ridge Wind Project, 2014. Peer review of operational sound testing by others.

Before the South Dakota Public Utilities Commission, serving as an outside expert to the PUC Staff reviewing the noise aspects of the Dakota Range Wind permit application, Docket EL 18-003, June 2018.

Before the South Dakota Public Utilities Commission, serving as an outside expert to the PUC Staff reviewing the noise aspects of the Prevailing Wind Park permit application, Docket EL 18-026, October 2018.

Before the Rhode Island Energy Facility Siting Board, serving as an outside expert to the Town of Burrillville, RI reviewing the noise aspects of the Clear River Energy Center permit application, Docket SB-2015-06, December 2018.

Before the South Dakota Public Utilities Commission, serving as an outside expert to the PUC Staff reviewing the noise aspects of the Deuel Harvest Wind Project permit application, Docket EL18-053, April 2019.

Exhibit_DMH-2

Proposed Post Construction Sound Protocol

[Revised to consider the Crowned Ridge I turbines as being part of the Crowned Ridge II Project]

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

If a field survey and monitoring data is requested by the Commission, the Project Owner shall submit the test protocol to the Commission prior to conducting the survey and sound monitoring for approval. The test protocol shall include and be implemented as follows:

a) The post-construction monitoring survey shall be conducted following applicable American National Standard Institute (ANSI) methods.

b) Sound levels shall be measured continuously for 14 days in an effort to capture a sufficient quantity of valid readings meeting the wind conditions delineated below in subpart (e). A sufficient quantity shall be defined as 0.5% of the total number of samples, or a minimum of 10 for a 14 day measurement period. As a precaution against the possibility that a sufficient number of valid readings are not automatically recorded during the chosen 14 day sampling period, 10 on/off tests shall be carried out during the survey period when both the CRII and CRI Projects are operating at full power production irrespective of the ground level wind speed. For the on/off tests, all units within *at least* 1 mile of the measurement position shall be shut down for a 10 minute period synchronized with the monitors clocks (starting, for example, at the top of the hour or 10 minutes after, 20 minutes after, etc.). The background level measured during the shutdown interval can then be subtracted from the average of the levels measured immediately before and after it to determine the project-only sound level. The results from these tests may be used to make up for any shortfall in collecting 10 samples measured when the ground level wind speed is low.

c) Measurements shall be conducted at a select number of non-participating and participating residences with the highest expected noise levels and/or at specific residences identified in the Commission's formal request. At least 6 measurement locations total should be selected.

d) Measurements shall be conducted using sound level meters meeting ANSI Type 1 specifications. An anemometer shall be placed within 20 feet of each microphone, and at a height of approximately 2 meters above the ground.

e) The measurement data shall be analyzed as follows:

i. At a minimum, the closest five wind turbines associated with the CRII and CRI Projects will be operating for evaluation periods and when at least the closest wind turbine is operating at a condition at full (within one decibel of maximum sound power levels) acoustic emissions.

ii. Discard those samples measured when the 10-minute average ground wind speed is greater than 5 m/s.

iii. Discard those samples measured during periods with precipitation.

iv. If measured (total) sound levels exceed the sound level limits, determine project only sound levels by removing transient background noise (i.e. occasional traffic, activities of residents, farming activities, and wind gusts) based upon audio recordings, excessive wind gusts, personal observations, and/or comparison of sound level metrics.

v. If measured (total) sound levels exceed the sound level limits, determine project only sound levels by removing, continuous background noise. This approach requires wind turbine shutdowns, where the background noise is measured directly. The background sound level shall be measured with all turbines within *at least* 1 mile of the measurement location temporarily shut down. This would include turbines that are part of the CRI Project for measurement positions in the northern part of the CRII Project. Background noise levels will be subtracted from total noise levels measured during these wind conditions to calculate turbine-only noise levels.

vi. As necessary, review of the frequency spectra of potential turbine-only samples to identify and remove outliers (spectral shape clearly differing from those samples measured under very low (less than 2 m/s) ground wind conditions, which are the samples most representative of turbine only noise).

f) Compare the resulting turbine-only noise levels to the 45 and 50 dBA limits. Compliance shall be demonstrated if all samples are less than the limits.

Exhibit_DMH-3
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Health Psychology

0278-6133/13/$12.00 http://dx.doi.org/10.1037/hea0000037

The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound

Fiona Crichton, George Dodd, Gian Schmid, Greg Gamble, Tim Cundy, and Keith J. Petrie
University of Auckland

Objective: Wind farm developments have been hampered by claims that sound from wind turbines causes symptoms and negative health reports in nearby residents. As scientific reviews have failed to identify a plausible link between wind turbine sound and health effects, psychological expectations have been proposed as an explanation for health complaints. Building on recent work showing negative expectations can create symptoms from wind turbines, we investigated whether positive expectations can produce the opposite effect, in terms of a reduction in symptoms and improvements in reported health. ***Method:*** 60 participants were randomized to either positive or negative expectation groups and subsequently exposed to audible wind farm sound and infrasound. Prior to exposure, negative expectation participants watched a DVD incorporating TV footage about health effects said to be caused by infrasound produced by wind turbines. In contrast, positive expectation participants viewed a DVD that outlined the possible therapeutic effects of infrasound exposure. ***Results:*** During exposure to audible windfarm sound and infrasound, symptoms and mood were strongly influenced by the type of expectations. Negative expectation participants experienced a significant increase in symptoms and a significant deterioration in mood, while positive expectation participants reported a significant decrease in symptoms and a significant improvement in mood. ***Conclusion:*** The study demonstrates that expectations can influence symptom and mood reports in both positive and negative directions. The results suggest that if expectations about infrasound are framed in more neutral or benign ways, then it is likely reports of symptoms or negative effects could be nullified.

Keywords: psychological expectations, symptom reporting, environmental risks, wind energy, infrasound

Sourcing renewable and sustainable energy is widely viewed as necessary to mitigate climate change and address the negative health impacts associated with fossil fuel consumption, such as mortality and morbidity due to cardiorespiratory diseases (Haines, Alleyne, Kickbusch, & Dora, 2012). To this end, harvesting wind power has become a key feature of clean energy development policies in many countries, with the aim of reducing greenhouse-gas emissions and related adverse health outcomes. Yet in many parts of the world wind farm implementation has been stalled by claims that living in the vicinity of wind farms may pose a health risk (Knopper & Ollson, 2011; Chapman, 2011). Given the importance of the role of wind energy in the attainment of clean energy targets worldwide, it is necessary to understand what could be causing reported health complaints and to explore approaches to address these complaints.

The type of health problems reported include a range of nonspecific physical symptoms, such as headache, nausea, ear problems, dizziness, and sleep dysfunction, as well as negative mood states, such as depression (e.g., Pierpont, 2009). Negative health effects from wind turbines have been attributed to the infrasound produced by the operation of wind turbines. Infrasound (sound between .01 and 20 Hz) is generally below the threshold of human hearing and is a common everyday phenomenon. Infrasound is produced by air turbulence and ocean waves, as well as by machinery such as air conditioners, and by internal physiological processes, such as respiration and heartbeat (Leventhall, 2007). Infrasound generated by wind turbines is subaudible and does not exceed typical levels of everyday infrasound exposure (Turnbull, Turner, & Walsh, 2012). Moreover, reviews of the scientific evidence have found the evidence does not support a direct pathophysiological link between the sound produced by wind turbine operations and the health of people living in the vicinity of wind farms (e.g., Ellenbogen et al., 2012; Fortin, Rideout, Copes & Bos, 2013; Knopper & Ollson, 2011).

Research has more recently focused on whether the health complaints by residents in the vicinity of wind farms could be due to psychological expectations. This work suggests that expectations could be established by media and Internet information asserting that adverse health effects are caused by exposure to infrasound produced by wind turbines. The expectations hypothesis is supported by a recent epidemiological analysis of health and noise complaints of Australian wind farms operating since 1993. This analysis shows that the majority of complaints commenced after 2009 and coincided with adverse health effects being promoted by groups opposed to the construction of wind farms

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Keith J. Petrie and Fiona Crichton, Department of Psychological Medicine, University of Auckland; George Dodd and Gian Schmid, Acoustic Research Centre, University of Auckland; Tim Cundy and Greg Gamble, Department of Medicine, University of Auckland.

Correspondence concerning this article should be addressed to Keith J. Petrie, Psychological Medicine, Faculty of Medical and Health Sciences, University of Auckland, Private Bag 92019, Auckland, New Zealand. E-mail: kj.petrie@auckland.ac.nz

(Chapman, St. George, Waller, & Cakic, 2013). Further support for the expectations hypothesis comes from a recent sham-controlled double-blind experimental study we conducted. The study showed that healthy volunteers, when given information designed to invoke either high or low expectations that exposure to infrasound causes symptom complaints, reported symptoms that were consistent with the level of expectation (Crichton, Dodd, Schmid, Gamble, & Petrie, 2013).

The provocative question that this research raises is that if negative expectations can create symptoms from wind turbines, can positive expectations produce a reduction in symptoms and improvements in reported health? To investigate this idea further we explored whether infrasound had ever been used as a therapy. We found that alternative medicine practitioners have explored the therapeutic impact of infrasound (e.g., Yount, Taft, West, & Moore, 2004) and therapeutic infrasound producing devices are now marketed to the public. These devices have been promoted as alleviating the very symptoms infrasound exposure from wind farms is said to trigger (Haneke, Carson, Gregorio, & Maull, 2001). We used this information to investigate whether positive health information about infrasound might create positive expectations leading to improved subjective health evaluation during exposure to wind farm sound. Such a finding would have the potential to inform interventions designed to safeguard against future symptom reporting and to reduce or reverse symptomatic experiences attributed to wind farms.

In this experimental study we tested whether the provision of either positive or negative health information about infrasound generated by wind turbines was reflected in participants' symptoms and health perceptions in response to wind farm sound. It was hypothesized that during listening sessions involving simultaneous exposure to audible wind turbine sound and infrasound, participants given negative expectations would experience an increase in the number and intensity of physical symptoms, an increase in negative mood, and a decrease in positive mood, and would evaluate exposure sessions as having adverse health impacts. In contrast, it was also hypothesized that participants given positive expectations would experience a decrease in the number and intensity of physical symptoms, a decrease in negative mood, and an increase in positive mood, and would evaluate exposure sessions as having health benefits.

Method

Sixty undergraduate participants (39 female, 21 male) with a mean age of 19.72 years (*SD* = 2.66) were recruited by flyers distributed at the University of Auckland. Following recruitment participants were randomly allocated to positive or negative expectation groups. All participants were told the purpose of the study was to investigate the effect of sound below the threshold of human hearing (infrasound) on the experience of physical sensations and mood. Experimental procedures were conducted in a listening room purpose built for subjective sound experiments to the standard set by the International Electrotechnical Commission (IEC268-13). Consistent with the cover story, the research was conducted in the Acoustic Research Centre, a facility associated with the School of Engineering.

Once baseline measurements were undertaken, participants viewed one of two 5-minute, 27-second DVD presentations, each of which contained wind turbine and health material available on the Internet. The negative health information DVD incorporated TV current affairs footage indicating that exposure to wind turbine sound, particularly infrasound, might pose a health risk. In contrast, the positive health information DVD framed wind turbine sound as containing infrasound, subaudible sound created by natural phenomena such as ocean waves and the wind, which had been reported to have positive effects and therapeutic benefits on health. Participants were contemporaneously and continuously exposed to infrasound (9Hz, 50.4dB) and audible wind farm sound (43dB), which had been recorded 1 km from a wind farm, during two 7-minute listening sessions. Both groups were made aware they were listening to the sound of a wind farm, and were being exposed to sound containing both audible and subaudible components and that the sound was at the same level during both sessions. Symptom and mood questionnaires were filled in at baseline and during each exposure period, prompted by a 2-second audible tone (middle C–262Hz) played 2 minutes into each session.

Symptoms and mood were assessed on a 7-point Likert scale ranging from 0 (*not at all*) to 6 (*extreme* or *extremely*). At baseline and during exposure sessions, participants evaluated their experience of 24 physical symptoms (e.g., headache, ear pressure, tiredness), and the extent to which they felt 12 positive mood items (e.g., relaxed, peaceful, cheerful) and 12 negative mood items (e.g., anxious, nervous, distressed). For each rating period a total symptom score was calculated as the number of symptoms experienced with a rating ≥ 1, and a total symptom intensity score was calculated as the sum of the ratings given for all symptoms experienced. Reliability of the symptom questionnaire was established in a previous study (Crichton et al., 2013). Further, for each rating period total positive mood and total negative mood scores were calculated. The symptom and mood scales all demonstrated good internal consistency (Cronbach's alpha for symptom intensity scale = .82; positive mood scale = .95; negative mood scale = .92). As a manipulation check to see if participants believed that exposure periods had influenced their symptoms, participants were asked whether they had experienced an improvement or worsening of symptoms during sessions on two 7-point Likert scales ranging from 0 (*not at all*) to 6 (*extreme*). Symptom improvement or worsening was assessed as a score ≥ 1. This assessment occurred in a room adjoining the listening room after experimental procedures had concluded.

Results

We first conducted mixed model analysis of covariance to assess within- and between-group differences in terms of change from baseline in symptom reporting during exposure session 1 and exposure session 2, controlling for baseline scores. These data are depicted in Figure 1. Results showed a significant interaction between expectation group and exposure session in relation to both symptom change scores, $F(1, 58) = 13.95$, $p < .001$, and symptom intensity change scores $F(1, 58) = 16.27$, $p < .001$. Tukey-Kramer post-hoc tests revealed that expectation group allocation differentially influenced symptom reporting during exposure sessions. There were significant differences between the negative expectation group and the positive expectation group in relation to symptom change scores during session 1 ($p = .005$) and session 2 ($p < .001$), and similarly, in relation

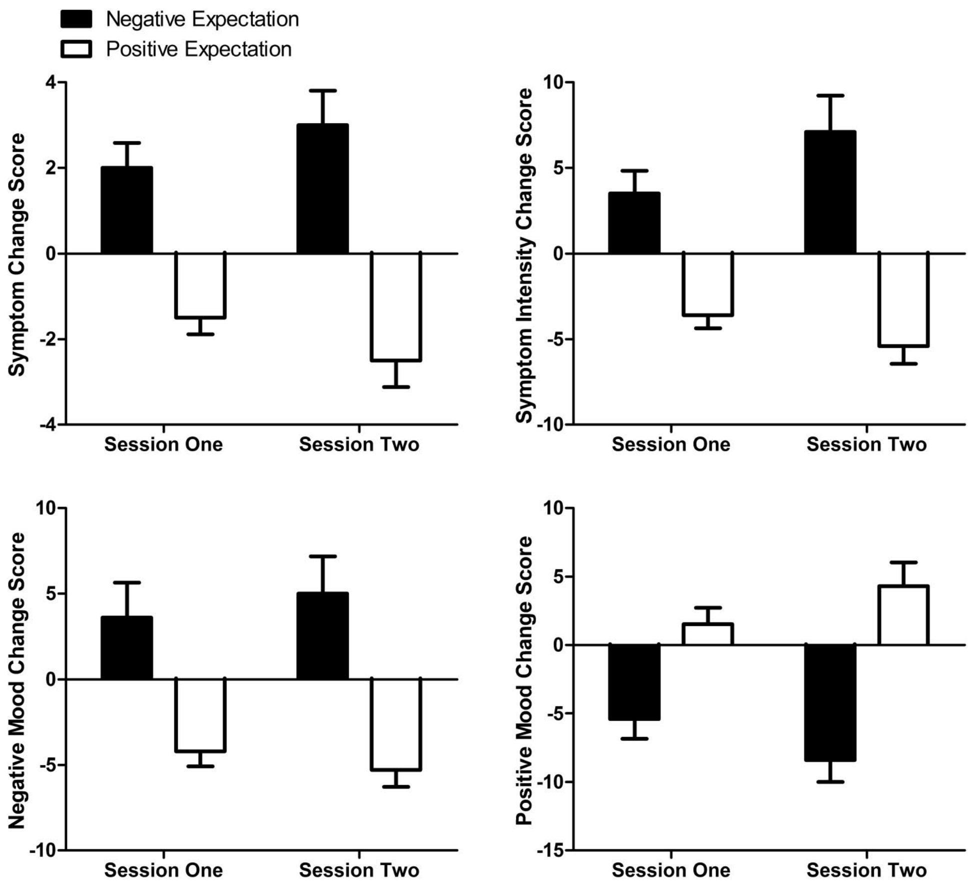

Figure 1. Changes in symptoms, symptom intensity, and mood in negative and positive expectation groups.

to symptom intensity change scores during session 1 (p = .01) and session 2 (p < .001). There were also within group differences in symptom reporting in the negative expectation group during session 1 and session 2 in respect of symptom change scores (p = .037) and symptom intensity change scores (p = .002). Thus negative expectation group participants became more symptomatic over time, suggesting that experiences during the first exposure session reinforced symptom expectations leading to heightened symptomatic experiences.

To check whether the manipulation had also triggered a significant symptomatic change from baseline, we conducted repeated measure ANOVAs, using Greenhouse-Geisser correction when the assumption of sphericity had been violated, on mean symptom and symptom intensity scores recorded at baseline, during Session 1, and during Session 2, as reported in Table 1. Results showed that participants in the negative expectation group recorded a significant increase from baseline in the number of symptoms experienced $F(1.36, 39.45) = 12.12$, $p < .001$, $\eta_p^2 = .30$. Analysis revealed there were significant increases from baseline in the number of symptoms reported during both session 1 (p = .002) and during session 2 (p = .001). This pattern was also seen in relation to symptom intensity, whereby, an increase in symptom intensity was recorded from baseline $F(1.32, 38.35) = 9.57$, p = .002, η_p^2 = .25, and analysis showed significant increases in symptom intensity from baseline reported both during session 1 (p = .013) and during session 2 (p = .002). As predicted, in the positive expectation group there were significant decreases from baseline in the reported experience of both the number of symptoms $F(1.31, 37.92) = 14.56$, $p < .001$, $\eta_p^2 = .34$ and symptom intensity $F(1.25,36.26) = 23.72$, $p < .001$, $\eta_p^2 = .45$.

In terms of the number of symptoms, there were decreases from baseline during session 1 (p = .001) and session 2 (p < .001). This pattern was also reflected in relation to reported symptom intensity, whereby there was a decrease from baseline during session 1 (p < .001) and session 2 (p < .001).

Table 1
Mean (SD) Symptom and Mood Scores in the Negative Expectation (NE) and Positive Expectation (PE) Groups

	N	Group	Baseline	Session 1	Session 2
Symptom score	30	NE	5.2 (2.8)	7.2 (3.1)	8.2 (3.6)
	30	PE	6.7 (3.2)	5.2 (2.9)	4.2 (3.3)
Symptom intensity score	30	NE	9.1 (5.8)	12.7 (6.3)	16.3 (10.0)
	30	PE	11.8 (7.4)	8.2 (5.2)	6.4 (4.7)
Negative mood score	30	NE	7.5 (6.8)	11.1 (10.4)	12.5 (11.0)
	30	PE	9.3 (10.7)	5.1 (8.1)	4.1 (6.8)
Positive mood score	30	NE	37.0 (10.1)	31.5 (13.3)	28.6 (14.1)
	30	PE	34.4 (9.3)	35.9 (9.7)	38.7 (10.4)

We further performed a mixed model analysis of covariance to assess within and between group differences in terms of change in positive and negative mood from baseline during exposure session 1 and exposure session 2, controlling for baseline scores. These data are also illustrated in Figure 1. In terms of change in negative mood from baseline, there was a significant main effect of group allocation, $F(1, 57) = 18.26$, $p < .001$. In relation to change in positive mood from baseline, analysis revealed a significant interaction between group and session, $F(1, 58) = 17.59$, $p < .001$. Tukey-Kramer post-hoc tests showed differences between the groups in relation to positive mood change scores during session 1 ($p = .011$) and during session 2 ($p < .001$). Further, there were within-group differences, such that from session 1 to session 2 there was a significant decrease in positive mood in the negative expectation group ($p = .016$), and a significant increase in positive mood in the positive expectation group ($p = .03$).

To assess whether mood during exposure sessions was significantly different from baseline assessment, we also conducted repeated measures ANOVA. Mood scores are also presented in Table 1. In relation to the negative expectation group, analysis revealed an increase in negative mood $F(1.48, 43.0) = 3.77$, $p = .043$, $\eta_p^2 = .12$, and a decrease in positive mood $F(1.46,42.18) = 20.48$, $p < .001$, $\eta_p^2 = .41$ from baseline. The increase in negative mood from baseline occurred during session 2 ($p = .031$). In relation to positive mood, there was a decrease from baseline during session 1 ($p = .001$) and session 2 ($p < .001$). In the positive expectation group there was a decrease from baseline in negative mood $F(1.66,48.12) = 21.54$, $p < .001$, $\eta_p^2 = .43$, and an increase in positive mood $F(1.46,42.31) = 4.99$, $p < .05$, $\eta_p^2 = .15$. Analysis showed a significant decrease from baseline in negative mood during session 1 ($p < .001$) and session 2 ($p < .001$). The significant increase in positive mood occurred during session 2 ($p = .02$).

In terms of the evaluation of perceived health impacts of infrasound exposure, 90% of the positive expectation group reported an improvement in physical symptoms after the listening sessions had concluded compared to 10% of the negative expectation group (χ^2 $(1, n = 60) = 16.48$, $p < .001$, $phi = -.52$). Consistent with this finding, 77% of the negative expectation group reported a worsening of symptoms during exposure, compared to 10% of the positive expectation group (χ^2 $(1, n = 60) = 27.15$, $p < .001$, $phi = .67$).

Discussion

In this study the experience of symptoms and mood during exposure to audible windfarm sound and infrasound was influenced by the type of expectations provided prior to the listening sessions. Participants randomized to the negative expectation group showed significant increases in the number and intensity of symptoms when exposed to windfarm sound, while participants given positive expectations about the sound showed the opposite pattern, with a significant reduction in the number and intensity of symptoms. The effect of expectations on mood following exposure to wind farm sound showed a very similar pattern with increases in negative mood in the negative expectation group and increases in positive mood in the positive expectation group.

The finding that negative expectations about windfarm sound prompted increased symptom reporting during exposure to infrasound is consistent with earlier research. In a previous sham-controlled experiment, the information that infrasound exposure has been reported to cause symptoms created elevated concern about the health effects of windfarms and triggered symptoms during exposure to both sham and genuine infrasound. The study demonstrated that symptom reports were provoked by expectations rather than any effect of actual infrasound (Crichton et al., 2013). The results are also consistent with other research indicating health warnings may elicit health complaints, even when the risk itself is purely one of perception and no genuine risk is posed (Colloca & Miller, 2011; Faasse, Gamble, Cundy, & Petrie, 2012; Faasse & Petrie, 2013). In one such study, viewing a TV report about purported health risks associated with exposure to electromagnetic fields produced by WiFi was shown to increase the likelihood of experiencing symptoms following sham exposure to a WiFi signal (Witthöft & Rubin, 2013). Evidence indicates that such information can increase anxiety and create related symptom expectations, which trigger later increased symptom reports (Faasse & Petrie, 2013).

It is important to note that this is the first study to demonstrate that participants exposed to wind farm sound experienced a placebo response elicited by positive pre-exposure expectations. Participants reported positive health effects during exposure to wind farm sound if they were given expectations that infrasound produced health benefits. These findings are consistent with previous work showing participants exposed to white noise, within a context designed to produce therapeutic expectations, evaluated the exposure as significantly more pleasant, relaxing, and beneficial than participants simply exposed to white noise without expectations (Kendrick & Elkins, 2012). The malleability of symptom reporting has also been demonstrated in an experiment where participants placing their finger on a rough vibrating surface interpreted the experience as pleasurable, painful or neutral, depending upon the way in which the stimulus was described prior to the experiment (Anderson & Pennebaker, 1980).

The study has two important implications. First, it provides further evidence that information easily accessible on the Internet concerning the health effects of wind turbines can create symptom expectations that are reflected in symptom and health reports. The fact that negative expectations in the current study were formed by viewing TV material sourced from the Internet suggests that a pathway for symptom reports attributed to wind farms could be via expectations created by media coverage about purported health effects. Second, the study demonstrates that if information about infrasound were framed in more neutral or benign ways, then reports of symptoms or negative health effects are likely to be nullified.

It should be noted that the study is limited by the fact that discrete sound exposure periods in a listening room may not entirely duplicate the experience of sound in the locale of a wind farm. However, the study has added ecological validity in that exposure was to audible sound recorded from a wind farm, overlaid with infrasound, and the health expectations were constructed using material easily available on the Internet. It should also be noted that it cannot be conclusively determined whether negative experiences triggered by negative health expectations can be reversed or alleviated by the later provision of positive information, or whether positive health information can protect against the future effects of exposure to negative health information, such as is often circulated in communities where wind farms are proposed or operating (Chapman, 2011). This issue is of importance given that current media coverage has been shown to incorporate fright factors that may induce fear, anxiety, and concern about the health risk posed by wind farms (Deignan, Harvey, & Hoffman-Goetz, 2013). Future research should investigate whether positive expectations can change symptomatic experiences in participants previously made aware of negative health information, or provide a buffer against the influence of the later delivery of negative expectations. As part of this research, it will be important to discuss the ethical implications of using placebo effects as part of a public health strategy to counteract the effect of negative expectations. Such research could provide further evidence useful to inform strategies designed to reduce anxiety and symptom reporting in those living in the vicinity of wind farms.

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