Ex. A4

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY DEUEL HARVEST WIND ENERGY LLC FOR ENERGY FACILITY PERMITS OF A WIND ENERGY FACILITY AND A 345-KV TRANSMISSION LINE IN DEUEL COUNTY, SOUTH DAKOTA FOR THE DEUEL HARVEST NORTH WIND FARM

SD PUC DOCKET NO. ________________

PRE-FILED DIRECT TESTIMONY OF MICHAEL HANKARD
ON BEHALF OF DEUEL HARVEST WIND ENERGY LLC

November 30, 2018

I. INTRODUCTION AND QUALIFICATIONS

Q. Please state your name, employer, and business address.

A. My name is Mike Hankard. I am the president and principal of Hankard Environmental, Inc. ("Hankard Environmental"). My business address is 211 East Verona Avenue, Verona, Wisconsin 53593.

Q. Briefly describe your educational and professional background.

A. I have been measuring, analyzing, researching, and reporting on environmental noise levels for 27 years. My focus over the last eight years has been noise from utility-scale wind turbines, but I also have extensive experience with noise from mining operations, industrial plants, roadways, rail lines, commercial developments, and a host of other sources. I have worked on projects across the United States, as well as internationally, and have been principally responsible for noise measurements, analysis, and control on over 500 projects. I have interacted with a wide cross-section of project participants, including the public, local and state agencies, owners, operators, designers, and planners. I have a B.S. in electrical engineering from the University of Maine with a specialization in acoustics. I am a full member of the Institute of Noise Control Engineering and a member of the Acoustical Society of America. My statement of qualifications is attached as Exhibit 1.

Q. Expand on your professional expertise regarding sound from wind turbines, and how it is relevant to these proceedings.

A. I have conducted some of the most in-depth noise measurement studies of operating wind turbines in the United States. This experience has allowed me to spend many nights at residences located within wind farms listening to and measuring turbine noise and has given me a first-hand understanding of the characteristics of wind turbine noise emissions. In addition, I have spent hundreds of hours reviewing measured noise levels, listening to audio recordings, and have developed time- and frequency-based methods for separating wind turbine noise from that of wind in the trees, traffic, and insects/frogs. I used the results of my real-world studies to validate the accuracy of the noise model I employed to predict noise emissions from the Deuel Harvest North Wind Farm. Thus, the model of wind turbine noise emissions I use is accurate and is calibrated to predict the maximum wind turbine noise level over a one-hour period that is expected to occur at each turbine. Finally, I have participated in public and agency hearings regarding wind turbines at which the full spectrum of wind turbine noise issues was debated. This includes audible noise, low frequency noise, and infrasound. In preparation for these proceedings, I have read major research papers on these subjects published by acoustical consultants, government agencies, university researchers, and health professionals.

II. PURPOSE OF TESTIMONY

Q. What is your role with respect to the Deuel Harvest North Wind Farm Project ("Project")?

A. Hankard Environmental was retained to conduct noise modeling for the Project. I conducted acoustic modeling of the Project's proposed layout and prepared an associated Pre-Construction Wind Turbine Noise Analysis ("Noise Analysis"), which is provided in Appendix D of the Project's Facility Permit Application ("Application").

Q. What is the purpose of your Direct Testimony?

A. The purpose of my testimony is to discuss the methodology and results of the acoustic modeling Hankard Environmental conducted for the Project. In addition, I will discuss how the modeling demonstrates that the Project will comply with applicable acoustic regulations.

Q. What exhibits are attached to your Direct Testimony?

A. The following exhibits are attached to my Direct Testimony:

- <u>Exhibit 1</u>: Statement of Qualifications

Q. **Please identify the sections of the Application that you are sponsoring for the record.**

A. I am sponsoring the following portions of the Application:

- Section 15.3: Sound
- Appendix D: Pre-Construction Wind Turbine Noise Analysis

III. WIND TURBINE SOUND AND APPLICABLE STANDARDS

Q. **Please provide an overview of the sound that may be generated by modern utility-scale wind turbines, such as those that will be used by the Project.**

A. Wind turbines generate noise by means of two general mechanisms. First, noise is produced at the nacelle by mechanical equipment such as gearboxes, drive motors, and pumps. Second, "aerodynamic noise" is produced by the blades passing through the air. When turbines are operating near or at full power, it is the latter that is most important at residences located near the Project. Aerodynamic noise is produced by a number of mechanisms; primary among these is trailing edge noise (noise produced at the trailing edge of the blade, particularly on the down stroke) and noise from tip vortices. The amount of noise produced is dependent on the tip speed of the blade, the design of the blade, blade angles during operation, and atmospheric conditions.

Q. **Please provide an overview of how humans perceive sound, and how perceived levels are measured.**

A. The human ear is sensitive primarily to the level (loudness) of a noise (sound), but also to its pitch (frequency). Sound consists of small changes in air pressure that our ears detect. The human ear is capable of detecting an incredibly large range of sound pressure changes, from about 20 micropascals (the "threshold of human hearing") to about 20 pascals (the "threshold of pain"). The frequency of a sound is the rate at which it fluctuates in time, expressed in Hertz ("Hz"), or wave cycles per second.

The compressive decibel scale is used to make the numbers more manageable for discussion. Sound is quantified using the decibel ("dB"), which can be weighted and expressed in different ways. The most common weighting scale used in environmental noise analysis and regulation is the A-weighted decibel ("dBA"). This weighting mechanism emulates the human ear's varying sensitivity to the frequency of sound. The human ear is much less sensitive to low frequencies, most sensitive to about 1,000 hertz ("Hz"), and not very sensitive to high frequencies. The A-weighted level represents the sum of the energy across the entire "audible frequency spectrum" (20 to 20,000 Hz), weighted by frequency as the human ear would do. This incorporates the frequencies where wind turbines produce most of their sound (250 to 1,250 Hz). This is a common range for other sources as well, including transportation, industrial, and agricultural equipment. Turbines do not emit much high frequency noise, and that which is emitted is attenuated by the atmosphere before it reaches even the closest residences.

Sounds in the environment vary with time, and the two sound level metrics that are commonly reported in community noise monitoring are:

- L90, which is the sound level in dBA exceeded 90 percent of the time during a measurement period. The L90 is close to the lowest sound level observed. It is essentially the same as the "residual" sound level, which is the sound level observed when there are no obvious nearby intermittent noise sources.
- Leq, the equivalent level, is the level of a hypothetical steady sound that would have the same energy (i.e., the same time-averaged mean square sound pressure) as the actual fluctuating sound observed. The equivalent level is designated Leq and is commonly A weighted. The equivalent level represents the time average of the fluctuating sound pressure, but because sound is represented on a logarithmic scale and the averaging is done with time-averaged mean square sound pressure values, the Leq is mostly determined by occasional loud noises.

A-weighting is the most appropriate weighting network here because it most closely approximates how the human ear responds to sound at various frequencies (in the 20 to 20,000 Hz range). The A-weighting network is the accepted scale used for community sound level measurements. Further, the applicable noise limit for comparison is A-weighted.

Q. How does the sound from wind turbines fit within the range of sound audible to humans?

A. Sound pressure levels at the base of a modern utility-scale wind turbine are typically between 55 and 60 dBA. For comparison, typical conversational speech between two people standing three feet apart is between 55 and 65 dBA, so one could hold a conversation at the base of a wind turbine. As sound spreads from a turbine, the sound level diminishes.

Q. Are you aware of any federal or state sound level regulations for wind energy conversion facilities located in South Dakota?

A. No. There are no federal noise regulations that apply to this Project. Also, it is my understanding that the State of South Dakota does not have statutes or rules governing sound level requirements for wind energy conversion facilities.

Q. Has Deuel County established sound level requirements for wind energy facilities?

A. Yes. The Deuel County Zoning Ordinance provides that the noise level from wind energy systems "shall not exceed 45 dBA average A-Weighted Sound pressure at the perimeter of existing residences, for non-participating residences." This is the only numerical noise limit applicable to wind energy systems in Deuel County, South Dakota.

IV. ACOUSTIC ANALYSIS

Q. What was the purpose of the acoustic modeling and analysis discussed in the Noise Analysis?

A. The purpose of the Noise Analysis was to conservatively model the sound level to be produced by the Project and determine through analysis whether the noise generated by the Project will comply with the applicable noise standard in Deuel County, which establishes a maximum dBA level. To ensure compliance with that requirement, my modeling was designed to assess the maximum sound level that could be generated by each turbine in any given hour (one-hour Leq). Consistent with these goals, the Noise Analysis describes the results of an acoustic modeling analysis we conducted, which demonstrates that Project sound levels will meet Deuel County's 45 dBA noise standard at the perimeter of existing, non-participating residences.

Q. Could you provide an overview of the methodology used in conducting the acoustic modeling analysis for the Project?

A. The modeling utilized conservative assumptions and was conducted in accordance with the international standard (ISO 9613-2), which is used for propagating outdoor sound levels from specific sources. There are several parameters in the ISO 9613-2 method, including the locations of the noise sources and receivers, noise source level and frequency characteristics, terrain and ground type, and atmospheric propagation conditions. Specifically, ISO 9613-2 assumes downwind sound propagation between every source and every receiver; consequently, all wind directions are taken into account. This is a conservative method because, in the model, each receiver is downwind of every source, a scenario that cannot physically occur. While the modeling did not include the turbine manufacturers' uncertainty factor, the modeling did apply a conservative ground factor of 0.0, which represents completely reflective ground material such as pavement or flat water, and results in a higher level of sound reaching a receptor. Actual ground conditions could at times be 0.0 when the ground is completely frozen, but would generally be closer to 0.5 when the ground is covered with new snow or crops, or when the ground is bare and unfrozen. These assumptions were made to maintain the inherent conservativeness of the model and to estimate the worst-case modeled sound levels.

Modeling was completed for both the GE 2.82-127 and GE 2.3-116 turbine models. The layout analyzed includes 111 units of GE 2.82-127 wind turbines and 13 units of GE 2.3-116 wind turbines, all fitted with Low Noise Trailing Edge ("LNTE") blades. Note that 12 of the GE 2.82-127 wind turbines included in the noise analysis are alternates.

Sound levels from the Project were calculated for each of the 122 non-participating and 109 participating residences (receptors) located within 2 miles of any turbine or main transformer. In accordance with ISO 9613-2, each receptor's height was set to 1.5 meters (5 feet) above the ground.

Further discussion of the methodology used is provided in the Noise Analysis (Appendix D of the Application).

Q. Could you summarize the results of the analysis?

A. Noise levels from the Project are predicted to be less than 45 dBA at all non-participating residences within 2 miles of the Project turbines and main transformers. At non-participating residences within the study area, noise levels range from 24 dBA to 44.9 dBA, with an average of 36 dBA. At participating residences, noise levels range from 28 dBA to 49.8 dBA. Thus, the results show the Project will comply with the Deuel County noise requirement.

Q. Are you aware of any post-construction noise studies for other wind farms that support the accuracy and conservativeness of the pre-construction noise modeling you conducted for the Project?

A. Yes. The noise level modeling method employed on this Project has been validated by many acoustical consultants, including Hankard Environmental. Hankard Environmental has conducted numerous wind turbine noise level compliance surveys, and routinely compares the results of these measurements with corresponding predicted levels using the same methods employed on this Project. The noise modeling method used in the Noise Analysis has been demonstrated by Hankard Environmental and other acoustical consultants to over-predict measured turbine only maximum one-hour Leq levels by at least 1 dBA. Comparatively, my predicted maximum one-hour Leq levels would be 3 dBA higher than an actual long-term average Leq level.

Q. How confident are you that actual noise levels will not be louder?

A. I am highly confident of this because I have routinely compared the results of my measurements of noise emissions from operating wind farms to models of those projects that I constructed using the same modeling methods employed here. Hankard Environmental has conducted many noise level measurement surveys at operating wind farms. We focus our analysis on those times when all nearby turbines were operating at full capacity, noise from other sources was at a minimum, and atmospheric conditions were conducive to sound propagation (mainly at night). We find that the maximum measured turbine noise levels are less than our predicted levels.

V. CONCLUSION

Q. Does this conclude your direct testimony?

A. Yes.

Dated this 30th day of November, 2018.

Mike Hankard

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