Ex. A4

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY SWEETLAND WIND FARM, LLC FOR FACILITY PERMITS OF A WIND ENERGY FACILITY AND A 230-KV TRANSMISSION FACILITY IN HAND COUNTY, SOUTH DAKOTA FOR THE SWEETLAND WIND FARM PROJECT

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PRE-FILED DIRECT TESTIMONY OF ROBERT O'NEAL
ON BEHALF OF SWEETLAND WIND FARM, LLC

March 6, 2019

I. INTRODUCTION AND QUALIFICATIONS

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

A. My name is Robert O'Neal and I work for Epsilon Associates, Inc. ("Epsilon"), located at 3 Mill & Main Place, Suite 250, Maynard, Massachusetts 01754.

Q. Briefly describe your educational and professional background and your current work for Epsilon.

A. I have more than 30 years of experience in the areas of community noise impact assessments, meteorological data collection and analyses, and air quality modeling. My noise impact evaluation experience includes design and implementation of sound level measurement programs nationwide, modeling of future impacts, conceptual mitigation analyses, and compliance testing. I am a nationally recognized acoustics expert in the wind energy field, having performed noise impact assessments in over 25 states across the U.S. and Canada, and have also directed and reviewed shadow flicker studies for wind energy projects. I have provided expert witness testimony on noise impact studies, shadow flicker issues, and air pollution modeling in front of local boards and courts of law, and in adjudicatory hearings.

I have a B.A. in Engineering Science from Dartmouth College, and an M.S. in Atmospheric Science from Colorado State University. I am a Certified Consulting Meteorologist, a member of the American Meteorological Society, a member of the Acoustical Society of America, and Board Certified by the Institute of Noise Control Engineering ("INCE"). A copy of my curriculum vitae is provided as **Exhibit A4-1**.

Q. What is Epsilon's role with respect to the Sweetland Wind Farm Project ("Project")?

A. Epsilon conducted sound level and shadow flicker modeling analyses of the Project's proposed layout, and prepared a Sound Level Assessment Report

(“Sound Assessment”) and a Shadow Flicker Analysis Report (“Shadow Flicker Analysis”), which are provided in Appendices L and M, respectively, of the Sweetland Wind Farm, LLC’s (“Applicant” or “Sweetland”) Application for Energy Facility Permits (“Application”) for the Project.

II. OVERVIEW

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to discuss the methodology and results of the sound level assessment and shadow flicker modeling analysis Epsilon conducted for the Project. In addition, I will discuss how the modeling demonstrates that the Project will comply with applicable acoustic and shadow flicker regulations and/or commitments made by Sweetland.

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

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

- Section 15.3: Sound
- Section 15.5: Shadow Flicker
- Appendix L: Sound Level Assessment Report
- Appendix M: Shadow Flicker Analysis Report

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 for the Project.

A. Wind turbine noise can originate from two different sources: mechanical sound from the interaction of turbine components, and aerodynamic sound produced by the flow of air over the rotor blades. In addition to the turbines, the transformer located at a wind project’s substation will also emit sound.

Due to advances in wind turbine design, mechanical noise has been greatly reduced in modern turbines and does not contribute significantly to sound levels outside of the nacelle. Aerodynamic noise has also been reduced due to slower rotational speeds and changes in materials of construction.

Q. How are wind turbine sound levels measured?

A. While sound (noise) levels are measured and quantified in several ways, all of them use the logarithmic decibel ("dB") scale to accommodate the wide range of sound intensities found in the environment. A property of the decibel scale is that the sound pressure levels of two or more separate sounds are not directly additive. For example, if a sound of 50 dB is added to another sound of 50 dB, the total is only a 3-decibel increase (53 dB), which is equal to doubling in sound energy but not equal to a doubling in decibel quantity. Thus, every 3 dB change in sound level represents a doubling or halving of sound energy, and a change in sound levels of less than 3 dB is generally imperceptible to the human ear. Also, if one source of noise is at least 10 dB louder than another source, then the total sound level is simply the sound level of the higher-level source. For example, a sound source at 60 dB plus another sound source at 47 dB is equal to 60 dB.

A sound level meter is a standardized instrument used to measure sound. It contains "weighting networks" (e.g., A-, C-, Z-weightings) to adjust the frequency response of the instrument. Frequencies, reported in Hertz ("Hz"), are detailed characterizations of sounds, often addressed in musical terms as "pitch" or "tone." The most commonly used weighting network is the A-weighting 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, which reports in decibels designated as "dBA," is the accepted scale used for community sound level measurements.

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

- L_{90}, which is the sound level in dBA exceeded 90 percent of the time during a measurement period. The L_{90} 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.
- L_{eq}, 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 L_{eq} 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 L_{eq} is mostly determined by occasional loud noises.

Q. Please explain what sound level metrics you believe are appropriate for a permit condition for sound?

A. The L_{eq} is the appropriate sound level metric for a permit condition for sound. The L_{eq} is directly comparable to the model output of the pre-construction predictive models since, by standard, the models use L_{eq} input sound data as provided by the manufacturers of wind turbines.

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

A. The sound levels at the base of a modern utility-scale wind turbine are typically between 55 and 60 dBA when the wind turbine is operating at full power. By comparison, normal conversation between two people is 55–65 dBA when they are about three feet apart. Therefore, one can hold a conversation at the base of an operating wind turbine. Sound levels decrease with distance away from a wind turbine. At 50 dBA, it would sound approximately half as loud as conversational speech, and between 30 and 40 dBA it is comparable to sound levels in a quiet rural area.

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

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

Q. Has Hand County established a sound level requirement for wind energy facilities to be located in that county?

A. Hand County has not adopted sound level requirements for wind farms and transmission facilities. However, Sweetland has entered into a Development Agreement with Hand County, which includes sound level requirements for the Project. Specifically, the Development Agreement provides that sound levels resulting from Project wind turbines will not exceed 50 dBA at the currently occupied residences of participating landowners and 45 dBA at the currently occupied residences of non-participating landowners, unless waived in writing by the owner of the occupied residence.

IV. ACOUSTIC ANALYSIS

Q. Was the Sound Assessment provided as Appendix L to the Application prepared by you or under your supervision and control?

A. Yes.

Q. What was the purpose of the acoustic modeling and assessment?

A. The purpose was to conservatively model the sound level to be produced by the Project and to confirm the Project will comply with applicable sound limits established pursuant to the Applicant's Development Agreement with Hand County.

Q. Who provided the turbine model, turbine layout, and receptors to be used when conducting the acoustic modeling for the Project?

A. Applicant provided the turbine model (General Electric ("GE") 2.82/127[1] with a hub height of 89 or 114 meters),[2] the proposed layout with up to 71 primary turbine locations and 15 alternate locations, and the receptor dataset (41 currently occupied residences in proximity of the Project).

Q. Are the turbine model and turbine layout the same as depicted in Figure A-2 of the Application?

A. Yes.

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

A. A conservative prediction of sound levels associated with the Project was made using Cadna/A noise calculation software, which is commonly used in the industry for sound modeling. This software incorporates the ISO 9613-2 international standard for sound propagation (Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation).

In addition to the turbine model specifications, proposed Project layout, and the receptor locations discussed above, inputs and significant parameters employed in the model included:

- <u>Project Layout:</u> All 86 possible turbine locations were modeled (including 71 primary turbine locations and 15 alternate turbine locations) as well as the two substation transformers. A total of 64 primary and 9 alternate turbines are proposed to have a hub height of 114 meters, and a total of 7 primary and 6 alternate turbines are proposed to have a hub height of 89

[1] Two of the turbines (Turbines 42 and 43 as shown on Figure A-2 of the Application) will be GE 2.82-127 Low Noise Trailing Edge ("LNTE") units.

[2] A total of 64 primary and 9 alternate wind turbines are proposed to have a hub height of 114 meters and a total of 7 primary and 6 alternate wind turbines are proposed to have a hub height of 89 meters.

meters. The hub height of each turbine in the layout is included in Appendix A of the Sound Assessment. Two of the turbines will be GE 2.82-127 LNTE units. Specific locations of the transformers were not provided, so Epsilon conservatively modeled them on the north side of the substation area closest to the nearest modeling receptor.

- Parcel Participation: A dataset containing property parcels in the proximity of the Project was provided by the Applicant. Parcels identified as Wind Energy Lease and Easement Agreement ("Controlled Land") and Good Neighbor Agreement ("GNA") within the dataset have been considered participating parcels and are indicated as such on Figure 5-1 of the Sound Assessment. Parcels containing wind turbines that were not identified as 'Controlled Land' or 'GNA' have been given "pending participation" status and are indicated as such on the figure. Parcels not indicated on that figure are considered non-participating properties.
- Modeling Location: Sound levels at receptors were modeled as discrete points at a height of 1.5 meters above ground level to correlate with the typical ear height of a standing person. Sound levels were also modeled throughout a large grid of receptor points, each spaced 20 meters apart to allow for the generation of sound level isolines, which are lines on a map depicting sound levels.
- Terrain Elevation: The terrain height contour elevations for the area modeled were generated from elevation information derived from the National Elevation Dataset ("NED") developed by the U.S. Geological Survey.
- Source Sound Levels: The expected sound power levels associated with the GE 2.82-127 turbine with hub heights of 89 or 114 meters were obtained from a GE technical report. The expected sound power levels associated with the GE 2.82-127 LNTE turbine were obtained from a GE technical report. The expected sound power levels for the Project substation were calculated based on information provided by the Applicant. The octave-band sound power levels calculated for the GE

2.82/127 and GE 2.82-127 LNTE turbines represent “worst-case” operational sound level emissions. The substation transformer sound power levels as presented in Table 5-1 of the Sound Assessment were input to the model. Further, all turbines were assumed to be operating simultaneously and at the design wind speed corresponding to the greatest sound level impacts. In addition, an uncertainty factor of 2.0 dBA was added to the sound power level for the proposed turbine to account for uncertainty in the manufacturer’s sound data.

- Ground Attenuation: Spectral ground absorption was calculated using a G-factor of 0.5, which corresponds to “mixed ground” consisting of both hard and porous ground cover. No additional attenuation due to tree shielding, air turbulence, or wind shadow effects was considered in the model.
- Meteorological Assumptions: Meteorological conditions were selected to minimize atmospheric attenuation in the 500 Hz and 1 kHz octave bands where the human ear is most sensitive. The model also assumed favorable conditions for sound propagation, corresponding to a moderate, well-developed ground-based temperature inversion, as might occur on a calm, clear night or equivalently downwind propagation.

Q. Could you summarize the results of the Sound Assessment?

A. A sound model was first performed using all 86 wind turbines as GE 2.82-127 units with regular blades. Results showed that sound levels at two participating residences would exceed the Hand County Development Agreement limits. The sound modeling was changed to include LNTE turbine blades on two turbines, which produce lower sound levels compared to the standard blade counterparts. With use of the LNTE units on the two turbines identified in the Sound Assessment, sound levels at the two participating receptors would be reduced to 50 dBA, which would meet the Hand County Development Agreement limit for participating landowners. It is Epsilon’s understanding that Sweetland has committed to using LNTE turbine models to reduce sound levels at these two participating residences.

The sound levels range from 35 to 50 dBA at participating receptors and from 27 to 43 dBA at nonparticipating receptors. The highest modeled sound level at a non-participating residence is 43 dBA. Accordingly, the Project will comply with the Hand County Development Agreement sound limits of 50 dBA at occupied residences of participating landowners and 45 dBA at occupied residences of non-participating landowners.

Q. How accurate is your analysis of the anticipated sound levels that will be generated by the Project?

A. The Massachusetts Clean Energy Center's Research Study on Wind Turbine Acoustics ("RSOWTA"),[3] showed that the same parameters used in the Sound Report resulted in model results (L_{eq1hr}) that were nearly identical (within one dBA) to the monitoring results, with the exception of one outlier. Another study showed that for sites with similar topography to the Project, the same modeling parameters used in the Sound Assessment resulted in measured sound levels one dBA less than the modeled sound levels.[4]

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

A. The conservative set of modeling assumptions for this analysis has been verified through post-construction sound level measurement programs at five different operating wind energy facilities in the RSOWTA. According to the RSOWTA, ISO 9613-2 model with mixed ground (G=0.5) with +2 dB added to the results was most precise and accurate at modeling the hourly L_{eq}. In addition, a post-

[3] RSG et al, "Massachusetts Study on Wind Turbine Acoustics," Massachusetts Clean Energy Center and Massachusetts Department of Environmental Protection, 2016.

[4] Cooper, J. and T. Evans, "Accuracy of noise predictions for wind farms," Proceedings of the 5th International Conference on Wind Turbine Noise, Denver, CO, 2013.

construction measurement program conducted by Epsilon in the Rocky Mountain region found measured sound levels met the predicted sound level under worst-case operating conditions.

V. SHADOW FLICKER AND APPLICABLE STANDARDS

Q. Could you please explain what shadow flicker is?

A. With respect to wind turbines, shadow flicker is an intermittent change in the intensity of light in a given area resulting from the operation of a wind turbine due to its interaction with the sun. While indoors, an observer experiences repeated changes in the brightness of the room as shadows cast from the wind turbine blades briefly pass by windows as the blades rotate. In order for this to occur, the wind turbine must be operating, the sun must be shining, and the window must be within the shadow region of the wind turbine, otherwise there is no shadow flicker.

Q. Are you aware of any federal, state, or local shadow flicker regulations for wind energy facilities located in South Dakota?

A. Shadow flicker is not currently regulated in applicable local, state or federal law.

Q. Please describe the shadow flicker requirement agreed to by the Applicant pursuant to its Development Agreement with Hand County.

A. Sweetland's Development Agreement with Hand County limits shadow flicker resulting from Project wind turbines at currently occupied residences to 30 hours per year or less, unless waived in writing by the owner of the occupied residence.

Q. Is the 30-hour per year (absent a waiver agreement) standard agreed to by the Applicant and Hand County a common standard in the industry and, if so, why?

A. Typically there are no regulations for shadow flicker. As more areas see wind energy projects, some jurisdictions are trying to implement a guideline or limit on the amount of shadow flicker from wind turbines. The most common limit is 30 hours per year. This number arose from a German court case which deemed 30 hours per year of flicker acceptable.[5]

VI. SHADOW FLICKER ANALYSIS

Q. Was the Shadow Flicker Analysis provided as Appendix M to the Application prepared by you or under your supervision and control?

A. Yes.

Q. What was the purpose of the shadow flicker modeling and analysis discussed in the Shadow Flicker Analysis?

A. The purpose of the Shadow Flicker Analysis was to estimate the potential annual frequency of shadow flicker associated with the operation of the Project turbines and to assess compliance with the shadow flicker requirements of the Sweetland's Development Agreement with Hand County.

Q. Were the same turbine model, turbine layout, and sensitive receptor data used for the Shadow Flicker Analysis as were used for the acoustic analysis?

A. Yes.

Q. Could you provide an overview of the methodology used in conducting the shadow flicker modeling?

A. The modeling was conducted using WindPRO, which is software commonly used to assess potential wind turbine shadow flicker levels. Two different modeling scenarios were used: a "worst-case" scenario and an "expected" scenario. In addition to the proposed Project layout, turbine dimensions, and receptor data

[5] This citation comes from the following reference on the Danish Wind Industry Association website: http://xn--drmstrre-64ad.dk/wp content/wind/miller/windpower%20web/en/tour/env/shadow/index.htm.

provided by the Applicant, the following inputs were used for the "worst-case" scenario:

- Greenhouse Mode: Each receptor was assumed to have glass on all sides of the building in all directions ("greenhouse" mode), which yields conservative results.
- Terrain: The terrain height contour elevations for the area modeled were generated from elevation information derived from the U.S. Geological Survey's NED. A conservative "bare earth" modeling approach was used, which excludes obstacles (i.e., buildings and vegetation) from the analysis. When accounted for in the shadow flicker calculations, such obstacles may significantly mitigate or eliminate the flicker effect depending on their size, type, and location.
- Constant Sunshine and Operation: The sun was assumed to always be shining during daylight hours and the wind turbine was assumed to always be operating.

For the "expected" scenario, the worst-case model was further refined by incorporating site-specific sunshine probabilities and yearly wind turbine operational estimates:

- Sunshine Probabilities: Monthly sunshine probability values were obtained from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information publicly available historical dataset for Huron, South Dakota.
- Operational Estimates: The number of operational hours for each of the 16 wind direction sectors was provided by the Applicant. These hours per wind direction sector were used by WindPRO to estimate the "wind direction" and "operation time" reduction factors. Based on this dataset, the wind turbines would operate 90 percent of the year due to cut-in and cut-out specifications of the proposed unit.

The values produced by the “expected” shadow flicker refinement are presented in the Shadow Flicker Analysis.

Q. Could you summarize the results of the shadow flicker modeling?

A. Modeling was completed for the GE 2.82-127 turbine model with either an 89- or 114-meter hub height.[6] Although up to 71 turbines are expected to be installed, modeling was conducted at all 86 potential turbine locations of the proposed configuration to ensure that any location selected has been considered in the shadow flicker analysis and represented in the results of such analysis. The model included a total of 41 occupied receptors.

Utilizing the conservative modeling parameters and expected shadow flicker values, the shadow flicker modeling results indicate the maximum expected annual flicker at a non-participating receptor is 9 hours, 16 minutes. The maximum expected annual flicker at a receptor with pending participation is 14 hours, 49 minutes.

While the modeling indicates that four residences in Hand County could experience annual shadow flicker levels above 30 hours per year, all four residences are participants and it is Epsilon’s understanding that Sweetland will obtain written waivers for these residences in accordance with the Hand County Development Agreement for the Project. Therefore, the Project meets the requirements with respect to shadow flicker in the Development Agreement.

Since the modeling treated homes as all-glass houses and assumed no vegetation or other existing structures, the modeled levels are likely higher than actual levels would be.

[6] A total of 64 primary and 9 alternate turbines are proposed to have a hub height of 114 meters and a total of 7 primary and 6 alternate turbines are proposed to have a hub height of 89 meters.

Q. Based on the results of the shadow flicker analysis set forth in the Study, will the Project comply with the requirements of the Development Agreement between the Applicant and Hand County?

A. Yes.

VII. CONCLUSION

Q. Does this conclude your direct testimony?

A. Yes.

Dated this 6th day of March, 2019.

Robert D. O'Neal

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Robert O’Neal

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