WILLOW CREEK WIND FARM

Sound Modeling Assessment

Ørsted Onshore North America, LLC

Document No.:10263277-HOU-R-01
Issue: B**, Status:** Final
Date: 16 November 2020

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Project name:	Willow Creek Wind Farm	DNV GL Energy USA, Inc.
Report title:	Sound Modeling Assessment	Renewables Advisory
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Date of issue:	16 November 2020	
Document No.:	10263277-HOU-R-01	
Issue:	B	
Status:	Final	

Task and objective: Sound Assessment of the Willow Creek Wind Farm located in Butte County, South Dakota.

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Keywords:
Sound modeling, South Dakota

Issue	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	4 November 2020	Draft	A. Nercessian	J. Puggioni	G. Constantin
B	16 November 2020	Final	A. Nercessian	J. Puggioni	G. Constantin

Table of contents

Appendices

List of tables

List of figures

EXECUTIVE SUMMARY

DNV GL Energy USA, Inc. ("DNV GL") has conducted a sound modelling assessment for the Willow Creek Wind Farm (the "Project") located in Butte County, South Dakota. The purpose of this assessment is to demonstrate compliance with the Public Utilities Commission's (PUC) stipulation regarding acoustic impact from wind turbines, which states:

> *Applicant shall submit a report to the Commission… [showing that the] modeled, incremental noise attributable to any WTG at any residence, business, or public building does not exceed 50 dBA.*

The Project layout consists of 5 GE 2.3-116 and 33 GE 2.78-127 wind turbines and one substation, for a total project capacity of approximately 103 MW.

Three (3) potentially inhabited receptors within one mile (1.6 km) of a turbine have been included in this report. Only receptors within one mile have been assessed because impacts due to the Project would not be expected to be significant beyond this point.

The sound pressure level (SPL) at each noise receptor for the aggregate of all wind turbine generators (WTG) and the associated transformer for the Project was calculated based on the ISO 9613-2 method.

The highest modeled sound level was 48.3 dBA. This occurs at a participating receptor location. All receptors are compliant with the PUC's stipulation regarding acoustic impact.

1 INTRODUCTION

Ørsted Onshore North America, LLC ("Ørsted" or the "Customer") requested that DNV GL Energy USA, Inc. ("DNV GL") perform a sound modeling assessment for the Willow Creek Wind Farm (the "Project") located in Butte County, South Dakota.

The Project layout considered for the sound assessment consists of 5 GE 2.3-116 and 33 GE 2.78-127 wind turbine generators (WTGs) with a hub height of 80 m and 89 m respectively. One main step-up transformer is also included within the project substation.

The objective of this assessment is to predict the cumulative sound levels generated by the Project's WTGs, transformers and the neighboring project at all receptors within 1 mile of a Project turbine or transformer, using the ISO 9613-2 sound propagation model [1] and to confirm that the Project complies with local sound regulations.

2 ENVIRONMENTAL SOUND BACKGROUND

Sound levels are expressed in the decibel unit and are quantified on a logarithmic scale to account for the large range of acoustic pressures to which the human ear is exposed. A decibel (dB) is used to quantify sound levels relative to a 0 dB reference. The reference level of 0 dB is defined as a sound pressure level of 20 micropascals (μPa), which is the typical lower threshold of hearing for humans.

Sound levels can be presented both in broadband (sound energy summed across the entire audible frequency spectrum) and in octave band spectra (audible frequency spectrum divided into bands). Frequency is expressed in the Hertz unit (Hz), measuring the cycles per second of the sound pressure waves. The audible range of humans spans from 20 to 20,000 Hz. Since the human ear does not perceive every frequency with equal loudness, spectrally varying sounds are often adjusted with a weighting filter. The A-weighting filter is applied to closely approximate the human ear's response to sound. This scale is commonly used in environmental and industrial sound. Sound expressed in the A-weighted scale is denoted dBA. This is used as the weighting in this report.

A sound source has a certain sound power level rating which describes the amount of sound energy per unit of time. This is a basic measure of how much acoustical energy it can produce and is independent of its surroundings. Sound pressure is created as sound energy flows away from the source. The measured sound pressure level (SPL) at a given point depends not only on the power rating of the source and the distance between the source and the measurement point (geometric divergence), but also on the amount of sound energy absorbed by environmental elements between the source and the measurement point (attenuation). Sound attenuation factors include meteorological conditions such as wind direction, temperature, and humidity; sound interaction with the ground; atmospheric absorption; terrain effects; diffraction of sound around objects and topographical features; and foliage.

3 APPLICABLE REGULATIONS

The Willow Creek Wind Farm is located entirely in Butte County, South Dakota. The local Public Utilities Commission (PUC) has a permit condition[1] applicable to the Project that states:

> *Within 90 days of the Project's completion, Applicant shall submit a report to the Commission that provides the following information:*

a) As-built location of structures and facilities, including drawings clearly showing compliance with setbacks required by state and local governments and that the modeled, incremental noise attributable to any WTG at any residence, business or public building does not exceed 50 dBA (unless Applicant retains written consent from the property owner to lesser distance or greater noise levels).

This report will verify the sound levels at residences and compare them to the 50 dBA limit to determine project compliance.

[1] Wind Energy Facility Permit-Settlement Stipulation. Exhibit A-Amended Permit Conditions #27-a. Signed Nov 16, 2015

4 DESCRIPTION OF THE WIND PROJECT SITE

4.1 Site description

The proposed wind project is situated in relatively simple terrain, consisting of flat farmland and mild ridges and valleys, with wind turbine base elevations ranging from approximately 2985 feet to 3117 feet above sea level. The ground cover on and near the site is primarily composed of farmland or open fields. Very few structures or dwellings are found in and around the Project site.

The site is in Butte County, South Dakota, immediately northwest of US Highway 212, and 12 miles northeast of the town of Newell.

4.2 Wind farm layout

The Project consists of 5 GE 2.3-116 and 33 GE 2.78-127 wind turbine generators (WTGs) with a hub height of 80 m and 89 m respectively.

The coordinates of each turbine and transformer are presented in Appendix A. The turbine layout and substation location were provided by the Customer [2] [3].

No alternate turbine locations were included in the analysis.

4.3 Neighboring wind farms

There are no neighboring wind farms near the Project.

4.4 Receptor locations

DNV GL identified 3 noise receptors within one mile of a Project turbine based on a desktop review and information provided by the Customer [4]. One of the 3 receptors is a project participant. Coordinates of each receptor center point are presented in Appendix B. DNV GL has not confirmed that these receptors are inhabited.

All receptors have been conservatively modeled at a height of 4.5 m above ground level, representing 2-story structures.

5 SOUND ASSESSMENT

5.1 Description of the sound sources

5.1.1 Project turbines

The sources of sound considered in this analysis are the Project WTGs and substation transformer. Sound associated with other sources in the vicinity of the Project, such as construction activities, have not been considered.

Broadband and octave band sound power levels for the GE 2.78-127 and GE 2.3-116 wind turbines were contained in the manufacturer documentation provided by the Customer [5]. The maximum sound power level is 110.0 dBA and 107.5 dBA for the 2.78 MW and 2.3 MW turbines respectively, occurring at a hub height wind speed of 10 m/s. The hub heights are 89 m and 80 m for the 2.78 MW and 2.3 MW turbines respectively.

Table 5-1 shows the octave band sound power levels associated with the turbine used in this analysis.

Table 5-1 GE 2.78-127 and GE 2.3-116 acoustic emission summary [dBA]

Frequency [Hz]	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Broadband**
GE 2.78-127	82.8	92.6	98.0	100.6	104.2	105.5	102.1	94.1	76.0	110.0
GE 2.3-116	78.7	88.7	95.1	99.9	102.9	102.1	97.7	89.2	68.4	107.5

5.1.2 Project transformer

There is one transformer planned at the Project substation rated at 110 MVA with a voltage of 120 kV on the HV side.

A broadband sound power level of 108 dBA was estimated for a 110 MVA, 120 kV utility scale transformer according to IEEE standard C57.12.90-2006 [6], based on an audible sound level of 85 dBA [7] and assumed physical dimensions of a transformer with a similar capacity.

A typical transformer octave band distribution [8] was used. The octave band sound power levels of the transformer are shown in Table 5-2.

Table 5-2 Transformer acoustic emission summary [dBA]

Frequency [Hz]	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Broadband**
110 MVA transformer	65.2	84.4	96.5	99.0	104.4	101.6	97.8	92.6	83.5	108.0

5.2 Assessment methodology

The sound pressure level at each receptor for the aggregate of all wind turbine generators and transformers associated with the Willow Creek Wind Farm plus the neighboring project was calculated using CadnaA acoustic modeling software based on the ISO 9613-2 method [1]. The simulation was performed using the maximum sound power level of the turbines and the maximum sound power level of the transformer. The Project turbines were modeled as point sources with a height of 80 m and 89 m (see Section 5.1). A point source with a height of approximately 16 ft (5 m) above ground level (agl) was used for the substation transformer. The receptors were modelled as points at a height of approximately 15 feet (4.5 m) agl representing 2 story structures.

The ISO 9613 standard provides a prediction of the equivalent continuous SPL at a distance from one or more point sources. The method consists of octave-band algorithms (i.e., with nominal mid band frequencies from 31.5 Hz to 8 kHz) for calculating the attenuation of the emitted sound. The algorithm takes into account the following physical effects:

- Geometrical divergence – attenuation due to spherical spreading from the sound source
- Atmospheric absorption – attenuation due to absorption by the atmosphere
- Ground absorption – attenuation due to the acoustical properties of the ground

The ISO 9613-2 standard calculates attenuation "under meteorological conditions favorable to propagation from sources of sound emission." These meteorological conditions are for "downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night". In other words, though a physical impracticality, the ISO 9613-2 standard treats every receptor as being downwind from every source of sound emission (in this case, transformers and turbines).

The ISO 9613-2 standard accounts for ground effect by assigning a numerical coefficient (G) with a value ranging from 0 to 1. A value of G = 0 represents hard ground (paving, water, ice, concrete, tamped ground, and other ground surfaces with a low porosity), while a G = 1 value represents porous ground (ground covered by grass, trees, or other vegetation, and other ground surfaces suitable for the growth of vegetation such as farming land). Though the ground use on and around the site is farming, a mixed (semi-reflective) global ground factor of G = 0.5 was used in this assessment.

Additionally, temperature, barometric pressure, and humidity parameters were selected to represent typical local annual averages, and topographical information to accurately represent terrain in three-dimensions was included in this assessment.

Specifically, the ISO 9613-2 parameters were set as follows:

- Ambient air temperature: 50º F (10º C)
- Ambient barometric pressure: 101.32 kPa
- Humidity: 70%
- Overall ground factor: 0.5
- Topography included

Additional attenuation from foliage was not considered in this assessment, implying that lower sound levels are expected in areas where there is foliage present in the line of sight between any turbine and a sound receptor. Similarly, because the model assumes every receptor is downwind of every sound source at all times, lower sound levels are expected at times when a receptor is upwind of any sound source.

6 RESULTS

Detailed maps illustrating predicted SPL at receptors located in the vicinity of the Project are presented in Figure 6-1**.**

The predicted cumulative sound levels at each of the 3 receptors located within 1 mile of the Project WTGs are presented in Appendix B.

For each receptor, the following information is provided:

- ID
- Coordinates in UTM projection and NAD83 Datum
- Closest wind turbine
- Distance to the closest wind turbine
- Sound pressure levels (SPL) in dBA at the receptor location

The highest result at the modeled receptors throughout the Project area is 48.3 dBA.

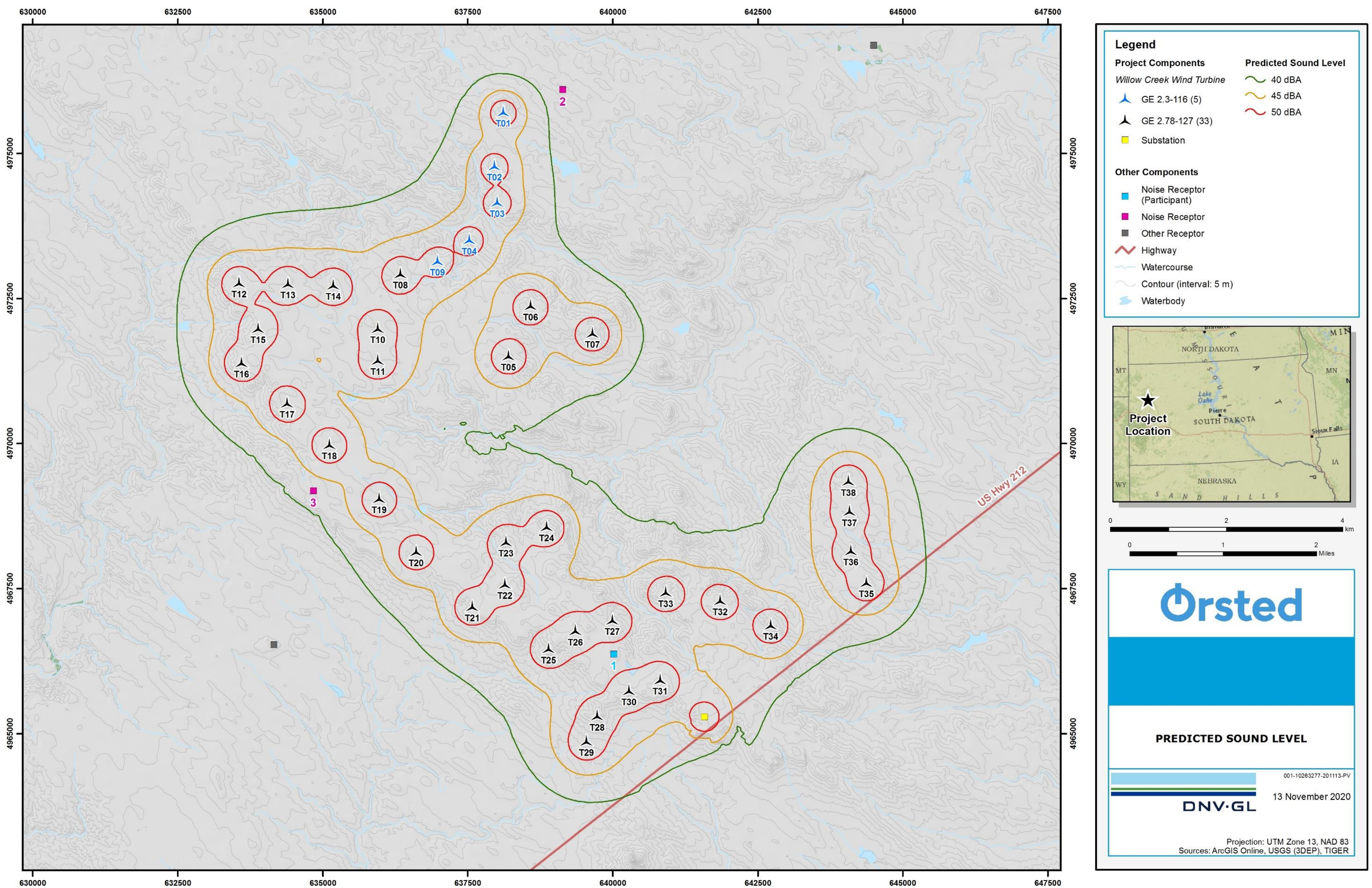

Figure 6-1 Modeled sound levels at Willow Creek Wind Project

7 CONCLUSION

DNV GL has conducted an analysis to determine the maximum predicted sound levels at sound receptors in the vicinity of the Willow Creek Wind Farm in Butte County, South Dakota.

This analysis includes 5 GE 2.3-116 and 33 GE 2.78-127 wind turbines, for a total project capacity of approximately 103 MW, and one substation transformer.

Results are presented for sound receptors within 1 mile of a sound source. Modeled cumulative sound pressure levels range from 36.4 dBA to 48.3 dBA. The highest modeled sound level occurs at a participating receptor location.

All three receptors within one mile of a Project turbine do not exceed 50 dBA of incremental acoustic contribution attributable to the Project and are therefore compliant with the PUC’s stipulation regarding acoustic impact.

8 REFERENCES

[1] International Organization for Standardization. ISO 9613-2: Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation. 15 December 1996.

[2] *WillowCreek_As-Built.kmz*, provided by Customer on October 22, 2020

[3] *WCW-SS0-E-EL0-P01-01.pdf* and *WILLOW_CREEK_COLLECTION_ASBUILT.kmz*, provided by Customer on October 19, 2020.

[4] *Willow Creek Data Request 1_Figure A.pdf,* provided by Customer on October 19, 2020

[5] *2.2 - Noise_Emission_NO_2.3-DFIG-116-xxHz_1-2MW_EN_r01.pdf* and *Noise_Emission-NO_2.x-DFIG-127-60Hz_1-2MW_EN_r02.pdf*

[6] C57.12.90-2006 IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

[7] WCW - MPT Technical Data Sheet.pdf.

[8] Handbook of Acoustics. Edited by Malcolm J. Crocker. John Wiley & Sons. 1998.

APPENDIX A – WTG AND TRANSFORMER COORDINATES

Turbine ID	UTM Zone 13, NAD 83 Datum	
	Easting [m]	**Northing [m]**
T1*	638114	4975695
T2*	637958	4974766
T3*	638009	4974140
T4*	637525	4973493
T5	638203	4971494
T6	638582	4972358
T7	639649	4971882
T8	636340	4972907
T9*	636980	4973128
T10	635947	4971964
T11	635947	4971419
T12	633554	4972751
T13	634402	4972736
T14	635183	4972711
T15	633887	4971964
T16	633599	4971373
T17	634387	4970677
T18	635114	4969965
T19	635974	4969035
T20	636610	4968121
T21	637577	4967170
T22	638141	4967556
T23	638159	4968286
T24	638861	4968550
T25	638893	4966444
T26	639354	4966754
T27	639997	4966937
T28	639730	4965287
T29	639544	4964849
T30	640278	4965724
T31	640821	4965909
T32	641850	4967277
T33	640915	4967417
T34	642726	4966851
T35	644375	4967586
T36	644106	4968135
T37	644084	4968813
T38	644066	4969333
sub	641583	4965288

Note: Turbines T1, T2, T3, T4 and T9 are GE 2.3-116 turbines at 80 m hub height. All other locations use the GE 2.78-127 turbine with 89 m hub height.

APPENDIX B – RECEPTOR LOCATIONS AND ASSOCIATED SOUND LEVELS

Receptor ID	UTM Coordinates Zone 13, NAD 83 Datum		Nearest Turbine [ID]	Distance to Nearest Turbine [feet]	SPL at Receptor [dBA]
	Easting [m]	Northing [m]			
1	640019	4966369	T27	1865	48.3[2]
2	639138	4976100	T1	3615	36.4
3	634841	4969186	T18	2707	42.5

[2] This is a participant receptor

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